



FULL PAPER VOLUME

UNIVERSITY OF VOCATIONAL TECHNOLOGY, SRI LANKA

INTERNATIONAL RESEARCH SYMPOSIUM 2023

"Emerging Technologies and Skills for Resilient Industries"



INTERNATIONAL RESEARCH SYMPOSIUM -2023 (IRS2023-UoVT)

Emerging Technologies and Skills for Resilient Industries



**UNIVERSITY OF VOCATIONAL TECHNOLOGY
SRI LANKA**

FULL PAPER VOLUME

INTERNATIONAL RESEARCH SYMPOSIUM -2023 (IRS2023-UoVT)

DISCLAIMER

ISSN 2602-8778: © University of Vocational Technology

The papers published in these proceedings reflect the opinion of the respective authors. Information contained in these proceedings has been obtained by the editors from sources believed to be reliable. Authors of specific papers are responsible for the accuracy of the text and technical data. Neither the publisher nor the editors guarantee the accuracy or completeness of any information published herein, and neither the publisher nor the editors shall be responsible for any errors, omissions, or damages arising out of use of this information. Trademarks are used with no warranty of free usability.

All rights reserved. No part of this publication, including the cover design, may be reproduced, stored or transmitted in any form or by any means, whether electrical, chemical, mechanical, optical, recording or photocopying, without prior permission of the publisher.

LIST OF REVIEWERS

Senior Prof. K.K.D.S. Ranaweera	University of Sri Jayewardenepura, Sri Lanka
Prof Dulani Meedeniya	University of Moratuwa, Sri Lanka
Prof. Chandana Gamage	University of Vocational Technology, Sri Lanka
Prof. Chandana Jayalath	University of Vocational Technology, Sri Lanka
Prof. Malini Munasinghe	University of Colombo, Sri Lanka
Prof. Priyanga Gunarathne	University of Pittsburgh, USA
Prof. R.L.W. Koggalage	University of Vocational Technology, Sri Lanka
Prof. Mahinsasa Narayana	University of Moratuwa, Sri Lanka
Prof. Thusitha Gunawardana	Prof. Thusitha Gunawardana
Dr. Jayantha Wannisinghe	University of Colombo, Sri Lanka
Dr. Shashinie M. Thenabadu	University of Colombo, Sri Lanka
Dr. Prasanna Illankoon	University of Moratuwa, Sri Lanka
Dr. Sudarma Harischandra	National Institute of Education, Sri Lanka
Dr. Nisansa de Silva	University of Moratuwa, Sri Lanka
Dr. Thanuja Ramachandra	University of Moratuwa, Sri Lanka
Dr. Adeesha Wijayasiri	University of Moratuwa, Sri Lanka
Dr. (Eng.) Lalith Liyanage	Ministry of Education, Sri Lanka
Dr. A.S.K. Warahena	University of Vocational Technology, Sri Lanka
Dr. R.S.M. Samarasekara	University of Sri Jayewardenepura
Dr. Chamila Dias	The Open University of Sri Lanka
Dr. Debashree De	University of Essex, UK
Dr. Chathuri Senanayake	University of Sri Jayewardenepura
Dr Dileepa Fernando	Nanyang Technological University, Singapore
Dr. L.W.S. Kularatne	University of Vocational Technology, Sri Lanka
Dr. S.A.N. Danushka	University of Vocational Technology, Sri Lanka

Dr.Pasan Maduranga	General Sir John Kotelawala Defence University, Sri Lanka
Dr.T.S.L.W. Gunawardhana	University of Ruhuna, Sri Lanka
Dr. R. M. P. S. Bandara	General Sir John Kotelawala Defence University, Sri Lanka
Dr. Senesh Dissanaiké Bandara	University of Sri Jayewardenepura, Sri Lanka
Dr. G.T.Wasantha Sriyani	University of Ruhuna, Sri Lanka
Dr. Rumesh Liyanage	University of Sri Jayewardenepura, Sri Lanka
Dr.Monica Carvalheira	NOVA School of Science and Technology, University of Lisbon
Dr. D.D. D. Suraweera	University of Vocational Technology, Sri Lanka
Dr. Sanjeewa Sondarangallage	University of Vocational Technology, Sri Lanka
Dr. Kasun Nandapala	University of Vocational Technology, Sri Lanka
Dr. Jayalal Wettasinghe	University of Vocational Technology, Sri Lanka
Dr. Sumith Gopura	University of Moratuwa, Sri Lanka
Dr. U.A.S.K. Edirisinghe	University of Vocational Technology, Sri Lanka
Dr. J.A.E.C. Jayawardena	University of Vocational Technology, Sri Lanka
Dr. Budditha Hettige	General Sir John Kotelawala Defence University, Sri Lanka
Dr. Gayan Priyadarshana	University of Sri Jayewardenepura, Sri Lanka
Dr. B.L. Sanjaya Thilakarathne	University of Colombo, Sri Lanka
Dr.Gamunu Samarakoon	University of South-Eastern Norway
Dr. Kaushalya Wijayasekara	University of Sri Jayewardenepura, Sri Lanka
Dr. Dulani Somendrika	University of Sri Jayewardenepura, Sri Lanka
Dr. M. Munasinghe	La Trobe University, Australia
Dr. Ruwan Abeysekara	ESOFT Metro Campus, Sri Lanka
Dr.Nilanthi Wijewardhana	National Institute of Post-Harvest Management, Sri Lanka
Dr.Mafasiya Fairoz	University of Ruhuna, Sri Lanka

Dr. S.D.T.Maduwanthi	Sri Lanka Tea Board, Sri Lanka
Ms. C.A.K Dissanayake	Rajarata University of Sri Lanka
Mr. W.M.C.B.Wasala	National Institute of Post-Harvest Management, Sri Lanka
Ms Sachini Herath	Simon Fraser University, Canada
Mr. S. P.Yohan Weerasinghe	NERD Center ,Sri Lanka
Ms. L.B Kalugampitiya	Wayamba University of Sri Lanka
Ms. Kanthi Jayaweera	University of Vocational Technology, Sri Lanka
Ms. K.G. Alahapperuma	University of Vocational Technology, Sri Lanka
Ms. Madhavi Perera	University of Vocational Technology, Sri Lanka
Mr. H.A. Gayan Madushanka	University of Vocational Technology, Sri Lanka
Ms. A. A. Gunawardana	University of Vocational Technology, Sri Lanka
Ms. Indrachapa Gunasekera	University of Vocational Technology, Sri Lanka
Ms. J A M B Karunarathna	University of Vocational Technology, Sri Lanka
Ms. L. H. D. L. Ranasuriya	University of Vocational Technology, Sri Lanka
Mr. T D Deneagama	University of Vocational Technology, Sri Lanka
Ms. M.Thenabadu	University of Vocational Technology, Sri Lanka
Ms. A. A. S.U. Gunarathna	University of Vocational Technology, Sri Lanka

SYMPOSIUM ORGANIZING COMMITTEE

Symposium Chair

- Mr. H.A. Seneviratne, Senior Lecturer, Faculty of ICT, University of Vocational Technology

Advisory Committee

- Prof. C. Mahesh Edirisighe , Vice Chancellor, UoVT
- Dr. L.W.S. Kularatne ,Dean – Faculty of Education ,Former Chair –IRS-2022
- Prof. Chandana Jayalath ,Dean- Faculty of Industrial Technology ,Former Chair –IRS-2021
- Dr. D.D.D. Suraweera Senior Lecturer ,Former Dean ,Chair IRS 2017

Programme Committee

Prof. Chandana Gamage- Programme Chair

Prof. Chandana Jayalath

Dr. Sunil Kularathna

Dr. D.D.D. Suraweera

Dr. Jayalal Weththasinghe

Dr. Sanjeewa Sondarangallage

Prof. R.L.W. Koggalage

Dr. Kamal Edirisinghe

Dr. (Ms.) Erandya Jayawardena

Dr. Kasun Nandapala

Dr. S.A.N Dhanushka

Ms. J. A. M. Buddhima Karunarathna

Ms. Methmini Rathnapala

Ms. Indrachapa Gunasekera

Mr. Gayan Madushanka

Ms. Pramodi Somarathna

Ms. L. H. D. L. Ranasuriya

Ms. A. A. Gunawardana

Ms. L.A.M.H.P Udayakumari

Mr. P.Uruthiran

Organizing Committee Members

- Ms. Malkanthi Thenabadu (Secretary)
- Ms.Methmini Ratnapala (Co-Secretary)
- Ms.W.A.I.M. Gunasekara Co-Secretary)
- Dr. Kamal Edirisinghe (Dean, Faculty of Industrial Technology)
- Dr. L.W.S. Kularatne (Dean, Faculty of Education)
- Ms. T.K. Malwatta (Dean, Faculty of Information and Technology)
- Dr. Jayalal Wettasinghe (Dean, Faculty of Engineering Technology)
- Dr. M.P.K.C. Nandapala (Director AAQA)
- Ms. S.R.M.P Seneviratne (Head, Department of Quantity Surveying)
- Mr. Dilantha Rathnayake (Head, Department of Film and Television Production Technology)
- Dr. Erandya Jayawardena (Head, Department of Agriculture & Food Technology)
- Ms. U . Sivachelvi(Head, Department of Management Studies)
- Mr. Tharinda Denagama (Head, Department of Construction Technology)
- Mr. Dilshan Ganegoda (Head, Department of Electrical & Electronics Technology)
- Ms. Gayanthi Alahapperuma (Head, Department of Mechanical & Manufacturing Technology)
- Ms. G M S R G Manawadu (Actg Head, Department of Building Services Technology)
- Ms. L.H.D.L. Ranasuriya (Head, Department of Language Studies)
- Ms. Y.S. Manathunga (Head, Department of Education and Training)
- Mr. P.Uruthiran (Head, Department of Software Technology)
- Mr. R.M.C.A.B. Rathnayaka (Actg. Head, Department of Network Technology)
- Dr. D. D. D. Suraweera (Senior Lecturer, Faculty of Engineering Technology)
- Ms. J.K. Kanthi- Senior Lecturer, Department of Electrical & Electronics Technology
- Ms. J.A.M.B Karunaratna- Senior Lecturer, Department of Language Studies
- Ms. G.W.G Upamalika- Senior Assistant Librarian
- Mr. R.D.P.I.Priyadarshana -(System Administrator)
- Mr. M.G. Dharmasiri-(Senior Assistant Registrar- Admin/UoVT)
- Ms. W.P.G.C Pramila- (Assistant Registrar- Faculties)
- Mr. R.D. Nishantha-Assistant Bursar

- Mr. G.W. Banduwardena- Assistant Bursar (Supplies)

CMT coordinators

Mr. H.A. Seneviratne

Ms. M. Thenabadu

IT Support

Mr. R.D.P.I. Priyadarshana

Mr. L. A. U. P. Pushpakumara

Mr. R. C. G. Vidanapathirana

Mr. C. Weerasinghe

Media & Publication

Mr. Dilantha Rathnayake

Mr. Gayan Madushanka

Mr. T. C Jayamuthuge

MS. Suranji Dharmapala

MESSAGE OF THE HON MINISTER OF EDUCATION



Greetings to the esteemed participants, scholars, and innovators gathered for the University of Vocational Technology's International Research Symposium 2023 and Collaborative Initiatives in Sri Lanka's Technical and Vocational Education and Training (TVET) Landscape.

In our pursuit of educational excellence, the University of Vocational Technology (UoVT) has been an unparalleled beacon of transformative change. Envisioned through the parliamentary Act No. 31 of 2008, UoVT has been steadfast in its commitment to nurturing excellence in Technical and Vocational Education. Its pioneering initiatives and unwavering dedication have set the stage for a paradigm shift in Sri Lanka's educational landscape.

The IRS 2023 stands as a testament to UoVT's unwavering commitment to innovation, collaboration, and sustainable development. The symposium, themed "Emerging Technologies and Skills for Resilient Industries," serves as a converging point for visionaries, educators, practitioners, and students to deliberate on key themes crucial for our evolving industries and educational platforms.

The outlined themes of IRS23 encompass a diverse array of areas imperative for resilience and innovation across industries, technological advancements, and educational platforms. From fostering sustainable practices in various industries to harnessing innovative pedagogies for transformative educational platforms, each theme addresses contemporary challenges and sets the course for transformative growth.

Moreover, the parallel events meticulously curated alongside IRS23 further amplify the symposium's impact. From the Committee of Vice-Chancellors and Directors meeting to the Leadership and Management of TVET Institute program, these events not only complement the grandeur of IRS23 but also signify our collective dedication to fortifying TVET excellence and fostering industry-academia collaborations.

The collaborative workshops and seminars planned during this symposium are invaluable incubators for innovation and sustainable practices within the TVET landscape. The initiatives, such as the Waste Management and Sustainability Development workshop in collaboration with the TESS EU project, highlight our commitment to nurturing environmentally-conscious practices and fostering industry partnerships.

I commend the University of Vocational Technology for its relentless pursuit of excellence, innovation, and sustainable development in the TVET sector. Together, let us continue to chart new pathways, foster collaborations, and propel Sri Lanka towards a future defined by resilience, innovation, and educational excellence.

Hon (Dr.) Susil Premajayantha
Minister of Education, Sri Lanka

MESSAGE OF THE SECRETARY TO THE MINISTRY OF EDUCATION



Greetings to all gathered for the University of Vocational Technology's International Research Symposium 2023 and Collaborative Initiatives in Sri Lanka's Technical and Vocational Education and Training (TVET) sector.

I commend the University of Vocational Technology (UoVT) for spearheading transformative initiatives within Sri Lanka's education sector. The IRS 2023, themed "Emerging Technologies and Skills for Resilient Industries," unites minds to deliberate on pivotal aspects shaping our industries and educational framework.

These discussions encompass resilient industries, sustainable practices, technological innovations, and transformative educational pedagogies, crucial for our nation's progress. The aligned parallel events, including the CVCD meeting, Leadership and Management of TVET Institute program, and the Industry Seminar, serve as catalysts for refining strategies and forging collaborations.

I am particularly enthused by UoVT's collaborative initiatives, notably the Waste Management and Sustainability Development workshop with the TESS EU project. This reflects our dedication to cultivating environmentally-conscious practices and facilitating knowledge exchange among industry leaders, researchers, policymakers, and students.

I commend UoVT's dedication and strides in advancing the TVET landscape in Sri Lanka. Let us continue nurturing an environment where innovation, collaboration, and educational excellence thrive, propelling our nation towards resilience and sustainable growth.

Mr. M. N. Ranasinghe
Secretary to the Ministry of Education, Sri Lanka

MESSAGE OF THE VICE CHANCELLOR



Technical and Vocational Education and Training (TVET) serves as a cornerstone in a nation's knowledge creation through education and research. The TVET sector, being instrumental in generating crucial knowledge and innovative solutions, guides policy agendas and aids in achieving national development goals. Recognizing the importance of empowering its youth to address challenges, Sri Lanka, as a developing country, places a high priority on enhancing the novelty, relevance, and quality of research and innovation within its TVET sector.

In pursuit of this objective, the University of Vocational Technology has actively participated in numerous national and international projects spanning diverse disciplines. Upcoming projects slated for implementation in the coming year focus on critical areas such as education, agriculture, health, food, renewable energy, engineering, information and communication technology, and waste management. The overarching goal is to cultivate a high-quality workforce by enhancing skills and capacities within the TVET sector, among youth, and among entrepreneurs.

As a premier institution in the TVET sector, the Vocational University of Technology plays a pivotal role, in offering students the opportunity to pursue degrees in technology. The university's purview encompasses student training, trainer development, curriculum design, quality assurance, and accreditation. This empowerment positions us to address the human resource needs of emerging industries through the creation of innovative training materials and courses.

The 7th International Research Symposium (IRS 2023) signifies a crucial juncture as we elevate the TVET sector and position the University as a model for the next wave of paradigm shifts in teaching and learning practices, aligning with both local and international expectations. The conference will delve into future trends and practices within Industrial Technology and the TVET sector.

In my role as the Vice-Chancellor of Vocational Technology University, I extend my appreciation to the IRS 2023 organizing team for their dedication and tireless efforts in orchestrating such a high-profile event. The success of the 2023 International Research Symposium hinges on the quality of the research presented. I extend heartfelt congratulations and best wishes to all the authors and researchers who have contributed to this endeavor.

Professor C. Mahesh Edirisinghe
Vice Chancellor
University of Vocational Technology

MESSAGE OF THE SYMPOSIUM CHAIR



I extend a warm welcome and heartfelt greeting to all of you as the Chair of the symposium. This event holds great significance for the University of Vocational Technology (UoVT) Sri Lanka, signifying a monumental step toward fostering a robust research culture within the University and the TVET sector.

I am thrilled to share that the response to our call for submissions has exceeded expectations. The dedication and enthusiasm displayed by all authors in their submissions are truly commendable. In our commitment to nurturing a dynamic research culture, we have given special emphasis to advancements in engineering, industries, education, ICT, vocational training, and waste management sectors. Recognizing the pivotal role of emerging scholars, we have also focused on contributions from students who represent the future generation of researchers.

After careful deliberation and rigorous evaluation, a selection of outstanding submissions has been chosen to be part of the symposium proceedings. These contributions epitomize the forefront of research in engineering technology, industrial technology, education technology, ICT, TVET, and waste management and sustainability. We are excited to provide a platform for these ideas to be shared and discussed. Beyond being an event, this symposium serves as a catalyst for positive change. It marks the beginning of a journey toward creating a lasting impact on sustainable technology practices, not only in Sri Lanka but globally. We envision this event as a steppingstone to fostering collaboration, innovation, and a deeper understanding of challenges and opportunities in the realm of sustainability.

To all our authors, I extend heartfelt congratulations on your achievements in the field of research. Your dedication and hard work have brought us to this moment, and we eagerly anticipate the discussions and insights that will emerge during the symposium. As we approach the UoVT International Research Symposium 2023, we eagerly anticipate the vibrant exchange of ideas, the forging of new partnerships, and the collective pursuit of knowledge. Together, we can make a difference in the world of sustainable technology development.

We wish each and every one of you the best of luck as you present your research and engage in the stimulating conversations that lie ahead. May this symposium be the beginning of an exciting journey into a future filled with groundbreaking research and positive change?

Helawikum Athauda Seneviratne
Symposium Chair
UoVT International Symposium 2023

MESSAGE OF THE KEYNOTE SPEAKER



Digital transformation of society, news media and families

Digital transformation affects society and culture in complex and interrelated ways as digital technologies dramatically change the ways in which individuals, companies and governments interact among and with one another. New media technology and artificial intelligence are changing working life and business models. Theories of 'surveillance capitalism', 'attention economy' and 'social acceleration' describe how media technology changes society. Global media platforms such as Meta/Facebook and Tik Tok's collect data from users 'likes', 'dislikes', views etc, while artificial intelligence replaces journalists and teachers, media content is more easily disseminated globally, and everything seems to go faster and faster in our modern society. Children, families and societies are affected worldwide.

Eiri Elvestad is professor of media sociology at USN. She has extensive experience with research into the role of media in society, with a particular interest in news media use, the spread of misinformation and democracy. Lately, she has done research on digital parenting and children's rights in a digital world. In this lecture, she will discuss how global media platforms and social media change the spread of information in society and intervene in family life.

The lecture is based on recent research on the opportunities and dangers of children's digital lives, and how digital media change the parental role. Elvestad argues that raising and protecting children today requires knowledge of how parents and children use social media as well as global media platforms' algorithms and datafication. Parents across the world worry a lot about their children's media use. 'Sharenting' is an example of a phenomenon that shows how children's digital lives and security also depend on their parents' use of social media. Elvestad also argues for the need for more research, and more comparative studies that include non-Western countries. Despite global platforms, she further points out that the way social media is used and regulated varies across countries.

Professor Eiri Elvestad
Vice Dean for Research & Development
University of South-Eastern Norway Delegation

MESSAGE OF THE PROGRAM COMMITTEE CHAIR



The 2023 International Research Symposium of the University of Vocational Technology is the seventh iteration of the flagship platform to disseminate the groundbreaking research done in the areas of industrial technology, education technology, engineering technology, and information technology at the university as well as by partner institutions both locally and overseas.

The annual research symposium is part of a series of activities that include training workshops and research outcome dissemination events conducted by the university leveraging its unique position as the highest education institute in Sri Lanka for the tertiary and vocational education sector bringing together educators, industry practitioners, and technology researchers.

The International Research Symposium originated from the Annual Research Symposium of the university and gained broader participation of local experts as well as international contributors gradually elevating its stature. The International Research Symposium was held for the first time in 2017 under the Conference Program Committee Chairmanship of Dr Dimuthusiri Suraweera and continued under the able guidance of Prof Kanchana Perera (2018), Prof KKDS Ranaweera (2019), Prof Chandana Jayalath (2021), and Dr Sunil Kularatne (2022).

This year, the conference received a total of 123 research papers with 77 accepted as full papers for oral presentation and a further 32 papers accepted for poster presentations. Every submitted paper was reviewed by at least two subject area specialists in a double-blind review process to improve the quality of the research dissemination as well as to provide useful feedback to the researchers for further improving and extending their research work.

The 2023 International Research Symposium has eight tracks covering areas of importance to the Sri Lankan economy, technology, and environment with a particular emphasis on sustainability, resilience and innovation. These themes are of great importance to Sri Lanka as it emerges from the pandemic and sovereign debt induced economic crisis as well as climate change driven challenges to food security and disaster preparedness.

As the primary higher education centre leading research, technology development, and training of experts for the TVET sector, the University of Vocational Technology places great emphasis on this flagship symposium to highlight the achievements of researchers and provide a broad platform to disseminate research outcomes for practical implementations and adaptation to existing technologies.

On behalf of the Program Committee, I wish to acknowledge the extraordinary effort volunteered by the members of the research paper review committee from local universities, industries, public sector organizations, and overseas universities. The value added by the review committee members to the continued development and upliftment of the International Research Symposium is immeasurable. The program committee gratefully acknowledges the leadership and guidance provided to it by the Vice Chancellor, Prof Mahesh Edirisinghe, the General Chair of the Symposium, Mr Athauda Seneviratne, and the Symposium Secretary, Ms Malkanthi Thenabadu.

I wish to thank all contributing researchers, reviewers, presenters and participants of the 2023 International Research Symposium of the University of Vocational Technology for the continuing support to ensure the success of the event.

Prof Chandana Gamage
Chairman, Program Committee
University of Vocational Technology

**INTERNATIONAL RESEARCH SYMPOSIUM -2023
(IRS2023-UoVT)**

University of Vocational Technology

CONFERENCE PROCEEDINGS

Partners and Sponsors of IRS23



Erasmus+
CBHE Capacity Building in
Higher Education



Skills for Inclusive Growth



Table of Contents

TECHNICAL SESSION: Waste treatment, Waste management and circular economy for sustainable industries **1**

Sustainable Solid Waste Management Practices in Sri Lanka: A Case of Moratuwa Municipality	2
--	---

T.R. Vidanapathirane, Chamara Kuruppu, U Sivachelvy., B.M.T.D. Jayasekara., R. Shanmugapriya and K.G.N.P. Rajapaksha

Circular Entrepreneurship for Shared Value Creation: Case Study from Southern province Sri Lanka	8
--	---

F.Mafasiya Fairoz, T.S.L.W Gunawardana, G.T.W Sriyani, M.W. Indrani, K.G.P.V. Gunarathne

Household Waste Management Practices in Sri Lanka	14
---	----

D. D. D Suraweera, K.G Alahapperuma

Upcycling to Preserve Intergenerational Equity: The Project of Green Life Generation	19
--	----

Chamara Kuruppu, Savandie Abeyratne, Daniel N Subramaniam

Reviewing the Biogas Generation Technologies and Identifying the Potential Applications in Local Concept	23
--	----

M.A.S.M.Dissanayake, H.N.W.Gunasekara, A.S.K. Warahena

Recycling of Blended Fiber Fabrics for Sustainable Textile Industry: Short Review of Methods and Processes	30
--	----

M.H.M.T.Rathnapala

Integration of Skill Development and Waste Management for Waste to Wealth	35
---	----

R.K. Panigrahi, P. Patnaik

Value Chain Development for Municipal Solid Waste Management in Sri Lanka: An Integrated Approach for Sustainable Urban Development	42
---	----

G.T.W. Sriyani, T.S.L.W. Gunawardana, F. Mafasiya Fairoz, K.G.P.V. Gunarathne, M.W.Indrani

Determinants of Households' Pro-Environmental Behavior on Solid Waste Management: Towards Circular Economy in Sri Lanka	48
---	----

W.A.D.S. Wijesekara, T.S.L.W. Gunawardana., G.T.W. Sriyani, M.W. Indrani, M.B.F. Mafasiya, K.G.P.V. Gunarathne

Enhancing the sustainability of Sri Lankan waste-to-energy plants: a circular economy approach 54

Debashree De, Chamara Jayanath Kuruppu Gowindage

Stakeholder Analysis in Pursuit of Developing Curriculum for a Master's Degree in Waste Management and Circular Economy 62

D. Ambalangodage, A.J. Fernando, K. D. Gunawardana, A.H.G.K. Karunaratne, G.C.J. Kuruppu, R. C. Peiris

Study on the Effect of Turmeric in Water Treatment as a Case Study for Nagoda and Thawalama Rural Water Supply Schemes in Galle District 69

K.K.G.M Peumini, T.D Denagama

TECHNICAL SESSION: Advances in Agriculture and Food Technology innovations 76

Utilization of Cinnamon (*Cinnamomum verum*) to Suppress the Glycaemic Impact of Wheat Bread 77

U.S. Wijewardhana, M.A. Jayasinghe, I. Wijesekara, K.K.D.S. Ranaweera

Development of green pepper (*Piper nigrum*) and garlic (*Allium sativum*) based sauce and evaluation of color degradation during the storage 80

M.L.P. Thathsarani, S.N.C.M. Dias, U.A.S.K. Edirisighe, Y.N. Amarathunga

Electrically Assisted Membrane Separation Processes and Its Application in Food Industry Innovations 85

H.M.T.M.Ranasinghe, W.G.D.A.M.Watagodapitiya, I.S.Faaris, J.D.K.V.Juliange, T.A Warahena

Production of a Nutritional Composite Powder Mixture Using Selected Grains 88

D.M.M.M Premarathna, U.A.S.K Edirisinghe, Malkanthi Thenabadu

The goodness of Chlorophyll enriched Food, and beyond with Cactus and Hathawariya (Shathavari) – Nutritional advancements with Nature and Technology 94

B.M.D.S.Piyasena, W.M.D.C.Wijekoon, K.B.R.G.Jayathilaka, A.S.K.Warahena

Development of Artichoke (*Goepperia allouia*) and Sweet Potato (*Ipomoea batatas*) Based Instant Cream Soup 99

P.U.A.Senanayake, M. Thenabadu

Microbiology Quality Evaluation of Selected Cow Milk Products Collected from Small Scale Farmers in the Ratmalana Area, Sri Lanka	103
<i>M.G.N.C.B. Meegahakotuwa</i>	
Investigation of The Medicinal Plant, Aporosa Lindleyana (Wight) Baill. For Their Biochemical Composition and Proximate Analysis	107
<i>S.S.I. Jayarathne, E.M.C.K. Ekanayake</i>	
Assessment of Knowledge of Pregnant Mothers on Maternal Nutrition and Associated Factors: Udubaddawa Divisional Secretariat, Kurunegala, Sri Lanka	110
<i>A.D.M.P. Dissanayake, M.Thenabadu</i>	
Detecting the Diseases of Potato Based on Leaves Using SVM and XG-Boost Classifiers	115
<i>Anushka Parajuli, Bidur Devkota, Pratikshya Shrestha, Ashok R. Parajuli</i>	
Exploring a Versatile Carboxymethyl Cellulose Coating for Enhancing Passion Fruit Quality and Shelf Life	119
<i>A.D.M.P. Dissanayake, Erandya Jayawardene,, Kamal Edirisinghe</i>	
Introducing A Natural Nutrient Enriched Organic Solid Baby Food To The Sri Lankan Market	123
<i>L.N.Weerakkody, H.G.L.L.Padmasiri, J.A.E.C. Jayawardena</i>	
Development and Sensory Quality Evaluation of Rice Bran Oil Incorporated Ice Cream as a Functional Food	127
<i>I.G.V.V. Gilsinghe, Erandya Jayawardene, Malkanthi Thenabadu</i>	
Biodegradable Nursery Containers; a Sustainable Solution for Plant Growth	132
<i>S.L.T. Kumarasingha, C.J. Abeywickrama, U.A.S.K. Edirisinghe</i>	
Identification of Pathogen Causing Tomato Canker Symptoms: a Sustainable Solution for Healthy Tomato Cultivation	137
<i>S.L.T. Kumarasingha</i>	
A Comprehensive Review of Production Methods, Nutritional Properties, Applications, and Future Perspectives of Single Cell Protein Technology	140
<i>K.P.S.W. Karunarathna, D.M.M.M Premarathna, Malkanthi Thenabadu</i>	

Review of 3D Food Printing Techniques: Advancements, Challenges, and Future Perspective 149

D.M.M.M. Premarathna, K.K.D.S. Ranaweera

TECHNICAL SESSION: Advancements in Manufacturing Technology and Emerging role of Mechatronics 154

Automated Rice and Grain Cooker: Design and Development of a Smart Kitchen Appliance 155

Sondarngallage D.A.Sanjeewa, H.G.R.Lakshan, P.I.Madushanka, C.M.S.Madushan and H.M.R.G.Herath

Mould Coating to Improve the Surface Finish of the Cast Iron Products 160

K.G. Alahapperuma and N.I. L. Aththanayakea

Change of Technical Properties of Polyvinyl Chloride Products in Outdoor Environment 165

K.G. Alahapperuma, A.M.P.B. Samarasekara and S. Weragoda

A Role of IOT in Industrial Data Monitoring: A Review 170

B.N.Ekanayake, D.G.S.A.Munasinghe, K.O.Kotalawala, Sondarngallage D.A.Sanjeewa

Sustainable Product Recovery: A Review on Remanufacturability Potential of Worn-out Journal Bearings Used in Locomotive Engines 179

M.R.P.P. Wijesiri, H.N.W. Gunasekara

IOT Based Real-Time Portable Weather Data Collecting Station 185

R L W Koggalage, W M A Sampath, H G A Sampath, K Y R Amaradewa

Design and Development of Electrically Operated Wheelchair 190

K.G.Sasindu Gimhana, K.G. Chamith.Gayanjana, G.R.Y. Priyankara Senevirathna, M.I.T.D. Damith Wijesinghe, Jayalal Wettasinghe

Design and Development of an Efficient Portable Seed Sowing Machine 194

P.U.L.Pushpasiri, D.T.Ganegoda, K.G.B.Amaranatha

Development of Semi-Automatic Ergonomic Smart Table 199

K.A.D.H. Kumarasinghe, R.G.D.B. Dissanayake, L. Mallikarachchi, S.P.A.R.S. Jayathilake

Smart LP Gas Cylinder Carrier and Safe Regulator	203
<i>H.W.C. Madhubashana, H.K. Wannigama, M.W.P.I.S. Thalangama and J.K. Kanthi</i>	

TECHNICAL SESSION: Emerging trends in ICT and media technology for resilient industries 209

Ensuring Resilient Software-Defined Networking Infrastructure against Advanced Persistent Threats	210
<i>W.U.Chamodya</i>	

Aspect Based Sentiment Analysis on Nepali Language Tweets related to COVID-19	221
<i>B. Parajuli, B. Devkota and S. Tamrakar</i>	

E-Commerce Website for Astrology Services: Bridging Tradition with Technology	228
<i>S.Y.Randimal, Janith Wijekoon, Kosala Kasthuriarachchi and Helawikum Seneviratne</i>	

Catalyzing Data Efficiency: A Process Support System for Colombo Consumer Price Index (CCPI)	235
<i>G.H.K.N.Peeris, N.S.R.Pathirana, K.M.N.Madhubhashini and H.A.Seneviratne</i>	

Rich Computer Network Infrastructure for the University of Vocational Technology (UoVT)	244
<i>H.K.S.H.Premadasa, V.B.Godagama, H.P.A.I.Pathirana</i>	

Conceptualizing the "Quality Teledrama" as the future of Sri Lankan Teledrama Art and Cultural Industry for 2023-2032, fifth decade	252
<i>Senesh Dissanaike Bandara</i>	

Customer Relationship Management Methods for Freelance Audio-Video Content Creators in Sri Lanka	259
<i>R.A.C. Chathuranga, R.R.M.D.P.Rathnayake</i>	

Exploring Narrative Subjects for Contemporary Sri Lankan Cinema	266
<i>R.A.C. Chathuranga, K.P.S.P. Kariyawasam, W.V.D. Fernando, T.M.C. Buddika, M.S. Niroshana and H.A. Gayan Madushanka</i>	

Challenges in Budgeting for Freelance Video Editors in Sri Lanka	272
<i>W.V.D. Fernando</i>	

Use of Access Control Systems in Government Organizations in Sri Lanka 279
H.M.M.S Doratiyawa, and D.M.L.M Dissanayake

The Factors Effecting Number of Runs Gain in Sri Lanka Vs India One Day International Matches and Forecasting 283
P. H. S. S. Wijayarathna

Selection of Optimum Image Compression Technique for Mobile Communication 289
W.L.S. Wickramaarachchi, W.S.P. Fernando and M.K.A.J. Maldeniya

Gap analysis of the standard propagation model with LTE band 38 in the suburban region 295
L.P.S.S Dissanayake

Developing a Conceptual Framework for ICT Integration in the Sri Lankan Agricultural Sector 300
P.A.M.L. Pannala

TECHNICAL SESSION: TVET and Resilient Industries: Industrial management practices, and Hospitality 303

Application of Creative Tourism Performs in Sri Lankan Ramayana Tourism to Achieve Creative Economic Development 304
U.A.D. Premarathna, R.S.S.W Archchi

Empowering Middle Age (6–11) Children in Marginalized Communities: A Personality Development Project at Ashoka Primary School, Delgoda, Biyagama, Sri Lanka 312
R. M. T. G. Udula Rathnayake, J. D. A. Kumara

The Socio-cultural factors affecting the Vocational Education Stream students to become an entrepreneur 319
R.R.P.W.R.M.D.S Galagoda, Thanuja Vidanapathirane

Analyzing the Adequacy of Soft Skills for Employability of TVET Diploma and Certificate Holders 327
I. S. Samarasekara, K.A.S.I. Gajaweera, Jayalal Wettasinghe

Factors Affecting on the Small Businesses during the COVID-19 Pandemic Period with Special Reference to Mahipalagoda Grama Niladari Division 331
M.P.I.N Madushanka and P.S.Y Gamage

TECHNICAL SESSION: Innovative Pedagogies and developments in Language studies

336

Strategies Used by ESL Teachers Engaged in Emergency Remote Teaching to Overcome the Challenges in Using Activities for Developing Speaking Skills at the Secondary Level Grades of Government Schools in Sri Lanka 337

M.N.R Wijenayake, L.W.S Kularatne

Use of a Selected Neuro-Linguistic Programming Technique to Improve Public Speaking Skills in English among English as a Second Language Learners 342

K.G.D.M.Gunawardan, J.A.M. B. Karunarathna

Assurance of Test Authenticity: Power of Table of Specification (TOS) 349

S.A.N. Danushka, P.S.Y. Gamage

Challenges Faced in Understanding Subject Content Due to the Change of Medium of Instructions from L1 to L2: A Case Study Based on a Technical College in Sri Lanka 353

L.H.S. Piyumika, A.A. Gunawardana

Strategies of Developing Speaking through Experiences of Teachers- A Narrative Inquiry 353

P.K.D.T. Sachithra, L.H.D.L. Ranasuriya

Effectiveness of E-learning in Two “Type 1AB” Schools in Kandy Educational Zone 364

W.M.S.P Wickramasinghe

Challenges Faced During Speaking Activities – A Survey Carried Among the Mechatronics Students of UoVT 369

S. Usenthini and L.H.D.L.Ranasuriya

Psychological Factors Affecting Speaking in English Among Lower Secondary Level ESL Learners 374

K.A.S.C.K. Kasthuriarachchi, Y.S. Manathunge

Implementation of School-Based Management: School Leadership Challenges and Opportunities Faced by School Principals 382

Raveenthiran Vivekanantharasa, K.T.P.C. Somarathna

The Impediments to the Progression of Oral Competence of English as a Second Language of Grade 13 Students of the National Schools In Sri Lanka 386

D.M.A.N Alwis, G.J.S.Wijesekara

Applying Bloom's Digital Taxonomy for the University Education 393

Nipuni Kariyawasam, Sudath Liyanage

TECHNICAL SESSION: Sustainable construction practices and built environment, for sustainable future

401

Investigation of the Effectiveness on Strength of the Alluvial Deposit Mix with Rice Husk Ash for Soil Stabilization of Back Filling 402

D.P. Ileperuma, T.D. Dengama

Determination of Effective Area of a Salinity Barrier to control Saltwater Intrusion to Paddy lands in Weligama, Matara 408

R.M.T. Chathurika, T.D. Denagama

Commuter preference analysis for the proposed light rail transit service from Malabe to the Colombo Fort 413

V. P. Gunawardhane, P. S. Gunawardhane, G.H.C.S. Amarasooriya, S.S. Wanniarachchi

Optimising Technical Properties of Concrete Bricks with Waste Steel Powder 418

K.G. Alahapperuma, K.A.H.H. Rasanjana

Economic Analysis of an Inverter and Non-Inverter Type Split Unit Air- Conditioners for Hotel Buildings in Coastal Belt of Sri Lanka (Case Study) 422

A.N. Fernando, W.C.C. Sumathirathn

Investigation of Acceptability of Offshore Sand for the Construction Industry in Sri Lanka 426

D.M.N.Niranjaya, A. A. S. U. Gunarathna

Surge Protection Device Monitoring System 433

R.I Udayanga , A.R.H.M Rajapaksha , K.M.P.P Kumara and P.M Perera

Crack Investigation And Proposing Remedies: A Case Study In “Jeewaka Hostel, Borella 436

Kasun Nandapala, G.H.S.Jayangani

Identifying Issues Related to Domestic Plumbing, Corrective and Preventive Measures: A Case Study 443

K.A.D.S. Karunarathna, Kasun Nandapala

Impact of Unexpected Rapid Price Fluctuations on Medium-Scale Building Construction Projects in Sri Lanka: A Case Study 448

R.M.T.K. Ranasinghe, Kasun Nandapala

TECHNICAL SESSION: Energy management and quantity surveying best practices for resilient industries 449

Mitigation of Financial Risks Involved in the Budget Performance of Building Construction Projects 450

K.H.S.U. Thilakarathna, S.R.M.P Seneviratne

The impact of challenges of current economic crisis on the performance of Sri Lankan building construction projects 459

G.A.S.Gunathilaka, U.Sivachelvy and S.R.M.P.Seneviratne

A Review of Emission Filtering and Controlling Systems Applicable for Fossil Fuel-Based Electricity Generators 469

I.M.D.W.Hasakelum, A.M.S.Amandani and S.V.R. Gamage

Guidelines to improve supply characteristics of Solar PV system components to improve sustainable supply chain practice 477

P. A. D. Madushan, S. R. M. P. Seneviratne

A Study on Lighting Technologies Used in Homes in Sri Lanka and its Impact on the Energy Demand of the Country 484

R.M.K.S.K Ranaweera, W.M.C.A Weerasekara, N K L K Pathum and P.M Perera

Energy management for the sustainability of Sri Lanka: Transition through green energy, Challenges & Future Prospects 487

D.S.B.Ratnayake

Analysing the Impact of Behavioral Changes on Residential Building Energy Consumption : A Case study of Raddolugama National Housing Scheme	491
<i>J.T Lakmal, K.A.D.R.S. Rathnasekara, J. M. S. L. S. Ranasinghe, G.M.S.R.G.Manawadu</i>	
Development of a solar photovoltaic system with single-axis tracking	495
<i>R L W Koggalage, W M A Sampath, H G A Sampath, K Y R Amaradewa</i>	
Design and Development of Foot Step Power Generation System	500
<i>H.G.E.Chandramal, W.M.R.P Bandara, W.L Shyamalee and M.Barathy</i>	
Improving the Viability Assessment Process of Unsolicited Development Projects in Sri Lanka	503
<i>L.P.S.P.K. Loku Pathirage, Roshani Palliyaguru</i>	
The Adoptability of the Construction Industry Security of Payment Acts Enforced in Developed Countries to the Sri Lankan Construction Industry	511
<i>A.K.J.M.Priyanatha and R.Palliyaguru</i>	

Waste Treatment, Waste Management and Circular Economy for Sustainable Industries

Sustainable Solid Waste Management Practices in Sri Lanka: A Case of Moratuwa Municipality

Vidanapathirane T.R.
Department of Management Studies
University of Vocational Technology
Sri Lanka
thanuja.vidanapathirane@uovt.ac.lk

Chamara Kuruppu
USN School of Business
University of South-Eastern Norway
Norway

Sivachelvy U.
Department of Management Studies
University of Vocational Technology
Sri Lanka
sivachelvy@uovt.ac.lk

Jayasekara B.M.T.D
Department of Management Studies
University of Vocational Technology
Sri Lanka
bmtjayasekara@uovt.ac.lk

Shanmugapriya R.
Waste Management Authority
Western Province Battaramulla
Sri Lanka
prym@yahoo.com

Rajapaksha K.G.N.P
Department of Management Studies
University of Vocational Technology
Sri Lanka
Pushpa.rajapaksha@uovt.ac.lk

Abstract- *Sustainable practices in solid waste management play a crucial role in establishing a viable waste management system. The volume of solid waste has emerged as a serious environmental concern in Sri Lanka and the prevailing system struggles to dispose municipal solid waste as per the Sustainable Development Goals. Our study explores how Moratuwa Municipality has established sustainable solid waste management practices. The findings of the study elucidate that cooperating among a range of actors has enabled it to overcome the socio-cultural aspect of waste management and to generate additional revenue to the municipal budget. Similarly, this study demonstrates that officers like public health officers could play a leading role in fostering sustainable waste management practices at Municipalities.*

Keywords:- *Municipal Council, Municipal Solid Waste, Waste Segregation, Sustainable Waste Management Practice.*

I. INTRODUCTION

The volume of waste generation increases along with the growth of population, increasing urbanization and economic development amongst others (Vidanaarachchi, Yuen and Pilapitiya, 2006). Managing Municipal Solid Waste (MMSW) is a challenging task for developed countries as well. Municipalities in developing countries often fail to manage their solid waste (Guerrero, Maas and Hogland, 2013). There is no exception in the context of Sri Lanka. The government has historically ignored the problem of solid waste. As elucidated by Vidanaarachchi et al. (2006), the country's Ministry of Environment developed a "National strategy for Solid Waste Management" in the year 1999. Nearly 80% of households in the Southern Province of Sri Lanka are

likely to burn waste. In the end, the acuteness of MSWM has been witnessed by the country in 2017 as a result of "Meethotamulla Municipal Solid Waste Dump Disaster".

Waste refers to anything that its owner intends to dispose, as it has reached the end of its useful life. The term municipal solid waste is normally assumed to include all forms of waste generated in a community, except waste generated by municipal services, treatment plants and industrial and agricultural processes (Tehnobanoglous and Kreith, 2002). The main sources of Municipal Waste in Sri Lanka are residences, markets and commercial institutions (Kularathne, 2015). In Sri Lanka, Municipal Council, Urban Council and Pradeshiya Saba governed under the purview of Ministry of Local Government and Provincial Council are responsible for collecting, transporting and disposing solid waste. Provisions to manage waste are made available under the sections 129, 130 and 131 of the Municipal Council Ordinance; sections 118, 119 and 120 of the Urban Council Ordinance; and sections 93 and 94 of the Pradeshiya Sabha Act. Our study explores how Moratuwa Municipal Council attempts to address the challenge of managing its solid waste which is a requirement under the Sustainable Development Goal 11 and 12.

II. LITERATURE REVIEW

Solid Waste Management (SWM) is a crucial aspect of the social system (Rahardyan et al. (2004). In the early civilization, solid waste management concerns were at their most basic level, as everyone took care of waste by dumping at the back of a cave (Wilson, 1977). Due to urbanization, and changes in the lifestyle and dietary

habits, the volume of waste is currently growing quickly and altering its composition (Poopor et al., 2004; Ogbonna, 2007; Agdag, 2008). The rapid rise of population in the absence of a sound waste management system is a primary factor that contributes to the problem of solid waste. While solid waste generation is unavoidable and is a consequence of human behavior (Khan et al., 2022), global solid waste generation is likely to be increased by threefold in the dawn of 2100 (Minelgaite and Liobikiene, 2019). Our inability to manage such waste efficiently undermines well-being of humans and environmental health (Khan et al., 2022)

SWM is concerned with tasks related to the generation, collection, transport, and disposal of solid waste in an ecologically friendly manner while implementing concepts of economy, energy efficiency, and conservation (Cader, 2001). The stakeholders such as the national government (Shekdar, 2009); municipal authorities; city corporations; non-governmental organizations (NGO's); households (Sujauddin et al., 2008); private contractors; Ministries of Health; Environment, Economy, and Finance (Geng et al., 2009) and recycling companies (Tai et al., 2011) are interested in managing waste. Nevertheless, some difficulties associated with waste collection and disposal practices were recognized in the literature. Among them, improper bin collection system, poor scheduling of waste collection routes, availability of few vehicles for waste collection and badly maintained road system are notable (Guerrero et al., 2013).

MSWM Practices and Regulations.

Tchobanoglous and Kreith (2002) emphasize that Municipalities and residents employ a variety of methodologies, regulations, and practices to limit garbage's harmful repercussions and locate valuable recyclables. To him, waste management is organized into six organizational functions: waste generation, waste handling at source, collection, transportation, processing and transformation, and disposal (Tchobanoglous and Kreith, 2002). Open dumping is a widely used practice for MSW disposal nevertheless this practice poses significant environmental and health due to toxic and greenhouse gases (GHGs) emissions through direct combustion and/or decay of wastes (Yash et al., 2019). Literature suggests that integrated solid waste management (ISWM) consists of different methods such as, incineration, composting, anaerobic digestions, refuse-derived fuel, material recovery facility, and sanitary landfilling, is much needed (Khan et al., 2022).

2.1 Sustainable Development Goals and waste management

The subject of SWM is well embedded in many SDGs. (Mahajan.R. 2020S) WM acts as an essential prerequisite

for the attainment of 17 broad sustainable development goals (SDGs) in 2030 in developing countries. It contributes towards the progress of a wide range of SDG targets either implicitly or explicitly. It paves way for executing SDG 6: Clean Water and Sanitation, SDG 3: Good health and Well-being, SDG 11: Sustainable cities and communities, SDG 12: Responsible consumption and production SDG13: Climate change and, in particular and other SDGs in general. According to the UN-Environment Programme (1972-2022), SDG- Indicator 11.16.1. Represents the Proportion of municipal solid waste collected and managed in controlled facilities out of total municipal solid waste generated by cities.

Target 11.6: By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management. The indicator measures the progress of the performance of a city's municipal solid waste (MSW) management. It aims to determine the proportion of municipal solid waste regularly collected and treated in a city. It quantifies:

- I. The total MSW generated in the city (tones/day)
- II. The total MSW collected in the city (tones/day)
- III. Proportion of population with access to basic MSW collection services in the city (%)
- IV. The total MSW managed in controlled facilities in the city (tones/day)
- V. MSW composition

2.2 Factors influencing the elements of the waste management System

Scholars have argued that there are some factors influencing a waste management system. According to Sujauddin et al. (2008), the generation of waste is influenced by family size, their education level, and monthly income. Household attitudes related to the separation of waste are affected by the active support and investment of a real estate company, community residential committees' involvement for public participation (Zhuang et al., 2008), and fee for collection service risks based on the waste volume or weight (Scheinberg, 2011). Gender, peer influence, land size, location of household, and membership of environmental organizations explain household waste utilization and separation behavior (Ekere et al., 2009).

III. METHOD AND MATERIALS

Firstly, a detailed Literature survey was carried out to internalize the holistic picture of the existing practices of municipal solid waste management and the issues and challenges associated with solid waste. The study relies upon single case study approach, as our study aims to explore how Moratuwa Municipal Council attempts to

address the challenge of managing its solid waste within its administrative area. As elucidated by Yin (2003), case study is an empirical inquiry that explores contemporary phenomenon in its real-life context. This study is predominantly a qualitative study. The Purposive sampling technique was used to collect data from key informants such as Commissioner of the Municipal Council, public health inspectors (4 PHIs), waste collectors (07) at the municipality, and 10 residents live in the administrative area of Moratuwa Municipal Council. In addition, field observations also were carried, including a visit to the Material Recovery Facility (MRF) at the municipality and the Karadiyana waste treatment facility.

Semi-structured interviews were conducted. Interview recordings were transcribed, coded and themes were generated. The interview data was analyzed and summarized using theme-based content analysis method. Codes were generated using Excel. "Coding reduces lots of data into small chunks of meaning". (Moir Maguire & Brid Delahunt 2017) Open coding was used to avoid pre-set coding. The theme-based content analysis followed Braun & Clarke's (2006) six-phase framework for thematic analysis which comprised with 6 (six) steps namely, Becoming familiar with the data, Generating initial codes Searching for themes, Review themes, Define themes and Write-up. There were 4 themes generated following 12 codes and the themes were then elaborated and explained. The Study further relied on secondary data collected from Action plans of MMC, Websites, Annual reports/Action plans of the Waste management authority, central Environment Authority, Presentations, Relevant ordinances, and Progress reports and action plans of Karadiyana Waste Treatment Center.

IV. ANALYSIS AND FINDINGS

This section presents the analysis and findings of the interviews conducted focusing on current solid waste management practices adopted by Moratuwa Municipality. The interview findings concluded that Moratuwa Municipality is performing a unique waste collection and segregation mechanism at point of waste generation and maintaining a high Resource recovery percentage compared to other MCs. The most interesting find is that this municipality recovers 97% of its resource and recycle them and only 3% is disposed to open dump site at the Karadiyana waste treatment facility.

Data gathered through interviews, observation and documents envisages the following six areas: SWM process, Sustainable SWM practices, Segregation at collection points and Collection frequency, MRF unit support, NGO involvement, Social awareness, Informal waste collectors, and challenges and issues (Institutional support, peoples' attitudes, Financial constraints,

Hindrance for institutional entrepreneurship by co-workers due to political influence, Population)

IV.1 Solid waste management process at Moratuwa Municipality

As revealed by Vidanaarachchi et al. (2006), officers such as medical officer of health, health inspectors in the municipalities and urban councils are particularly involved in waste management in Sri Lanka. This is no exception in the context of Moratuwa Municipality. Collecting and disposing of waste is one of the main functions handled by the Public Health Department of the municipality under the supervision of the CPHI (Chief Public Health Inspector). In the Moratuwa Municipality, there are 9 PHIs including CPHI. The total volume of waste generation in the municipality is approximately 126 MT/Day and daily waste collection is about 96 MT, which is 76% of the Total waste. 18-25% of the municipal budget is allocated to solid waste collection

The municipality's administrative area is divided into five waste collection zones and its 9 PHIs are deployed in these zones, including supporting staff such as supervisors sub supervisors and laborers. It also revealed that the total bio-degradable waste collected by MC is 66 MT per day approximately while the total non-biodegradable waste collection is around 15-25 MT. Findings highlighted that nearly 1 MT ton of bio-degradable waste is composted by this municipality while the rest 60-65 MT is transported direct to Mihisaru Compost yard at Karadiyana established under the Waste Management Authority for final disposal. It also revealed that 15-25 MT of non-biodegradable waste is collected and transferred to its MRF, whereas 10 MT of such waste is collected by informal collectors.

IV.2 Sustainable Solid Waste management procedure and practices

Sustainable MSW management requires a rich understanding of waste streams, material balance, and flow along with the proper knowledge and willingness of the stakeholders (Vidanaarachchi et al. 2006). In Sri Lanka Technical Guideline on Municipal Solid Waste Management has been established by Central Environmental Authority precisely articulating the general, operational, and Legal requirements of Municipal Solid waste Collection, Transportation, Establishing MRF, Incineration, Composting, Biogas and Land filling Facility that are the main phases of waste chain. Moratuwa MC has attempted to follow the guidelines at different stages of the WM process based on available resources. The involvement of its PHIs in managing waste has enabled to implement several methods in the stage of collection, segregation, and disposal of waste. Similarly, this municipality has increased the collection

frequency, while introducing more segregation at the source of origin. In addition, further segregation at the collecting truck, and again segregation is at its MRF. The composting programs of the municipality require such segregation of waste. Therefore, its administration has launched awareness programmes to motivate the residents to segregate waste at the point of origin and to confirm that waste is sorted again at the truck, which leads to bring clean and segregated waste to final dumping site - karadiyana. Following sections represent the WM practices that the MC used to Manage Solid waste effectively.

IV.2.1 *Waste collection frequency and segregation at source of generation.*

Moratuwa Municipality collects waste from households, commercial entities, institutions, and industries. Household waste is collected at certain frequencies based on the category of waste while Commercial/Industry/intitutional waste is collected when there is a request from them. Based on the volume of waste, commercial places and industries are charged for collecting their waste. Domestic waste is collected five days a week. Bio-degradable waste is collected for two days, and non-biodegradable waste is collected another 2 days of the week. Residents are made aware to segregate non-biodegradable waste basically into three types, namely polythene, plastic bottles and paper. However, the municipal workers segregate waste again while being transported to the MRF. As the municipality maintains a very systematic segregation and collection system, its workers never hesitate to reject dirty waste such as lunch sheets and shopping bags. Every month, 1st 2nd, and 3rd Sunday, the municipality collects reusable waste such as glass bottles, fabric, shoes, leather bags, etc. Such items are made available at the “Sathi pola” where people can buy them at a very low price.

IV.2.2 *Material Recovery Facility (MRF) as a step to sustainable waste management*

Wastage was not segregated and mixed wastage was collected before establishing MRF at the municipality. During 2015-2016, though the public was advised to segregate domestic waste. Although it was separated into 3 categories, it was delivered to Karadiyana as mixed waste. This Municipal Council paid an enormous amount of money to deliver its waste. Karadiyana waste site could not bear the volume of waste delivered by municipalities. Therefore, the management of this waste dump rejected accepting waste from the municipality. Accordingly, the municipal administration was forced to establish its MRF. Because of the MRF at this municipality, it could avoid paying around 2 000 000 LKR to Karadiyana Landfill. At

present, 15 - 25 MT of non-biodegradable waste is daily transferred to the MRF. Primarily segregated waste is re-sorted into 42 categories and bailed at the MRF and could sell to recyclers. In addition, our results demonstrated that although most Municipalities operate an MRF, it causes an unclean and dirty atmosphere in the surrounding area. Being situated in the center of the town where most public institutions and commercial entities are located, this municipality maintains a very clean environment, especially around the municipality. Therefore, this municipality receives no complaint about gathering of flies, and mosquitos and emitting bad air due to the MRF in contrast to other municipalities in the country.

IV.2.3 *High Resource Recovery Efficiency as an approach to Sustainability*

It is necessary to use effective alternative treatment methods to avoid biodegradable ending up in landfill (Kamaruddin et al., 2015). Recovery of waste is an example of diverting waste from being landfilled. This method usually represents biological, physical, and thermal, including energy recovery (He et al., 2008). Moratuwa Municipality has developed a unique waste collection system made of segregating waste as per the types of waste and efficient disposal practices. All kinds of waste that are treated as a resource. In other words, all degradable wastes are composted; recyclables wastes are forwarded to recycling companies through its MRF while non-recyclable waste is diverted to the Waste-To-Energy Plant. The MRF facility accepts only less dirty waste from households and commercial places. Waste such as paper/cardboard, plastic containers, polythene wrappers and metals are collected on the day of collecting recyclable waste. This became a practice because of continuous community awareness campaigns.

Any waste management system is influenced by the aspects such as technical, financial, environmental, socio-cultural, institutional and legal (Gurrero et al., 2013). It had been difficult to change social attitudes at initial stages. However, now people got used to separate their waste as instructed. The collected recyclable waste is further segregated manually by the workers into 42 categories such as PET bottles, PP cans, PP containers, HIPS (yoghurt) caps, Cardboard, Paper, New Paper, LDPE wrappers & bags, etc. During further segregation process at the MRF, recyclable waste is separated based on the type of material; for example, a PET bottle is separated from plastic waste and their lids are separately collected and stored. All the separated materials are sent to the respective recycling companies. The non-recyclable laminated polythene packing materials are delivered to the Waste-to-Energy Plant located at Kerawalapitiya or to the Cement Kline of INSEE cement factory as a fuel subsidiary. Totally a small

volume of non-recyclables such as wooden offcuts, soil mixed waste, sanitary waste and slaughterhouse waste are sent to the landfilling site at Karadiyana. In June and July 2023, this municipality delivered respectively 123.20 MT and 125.56 MT to Karadiyana. In the end, the municipality has recovered 97% of resources.

IV.2.4 *Composting and re-using*

In 2008, the government initiated a programme, namely “Pilisaru”, which aimed to lay foundation for 110 composting plants around the island (Bekchanov and Mirzabaev, 2018). The daily open market in this municipality sells essentials such as vegetables, fruits, fish, coconut etc. A large amount of organic waste is generated by this market. To upcycle such waste, a composting plant under the “Pilisaru” project has been established and maintained by this Municipal Council nearby the market. This composting plant, operated by the Chief PHI, a project officer and workers, could produce 12.5 tonnes compost and each 1 kg is sold at 10.00 Rupees. It has enabled to attain a viable solution for reducing waste amount transferred for open dumping while generating revenues to the municipal budget. Similarly, the concept of reusing is also promoted by this municipality. For this purpose, a Sunday service is offered to collect reusable items such as shoes, bags, clothes etc. Such waste is made available at “Parisara Pola” where people can purchase at a very low cost. However, it was revealed that most of the items are taken and used by the labours of MC before sending “Parisara Pola”. This system also helped to reduce the amount of waste for open dumping.

IV.3 *Informal waste collectors*

Highly active informal sectors for waste collection, in the low- and middle-income countries, make it more difficult to regulate and implement a new efficient and standardized waste treatment system (Wilson et al., 2012b). Our findings show that 10 MT of non-biodegradable waste is collected by informal waste collectors. Informal waste collectors at this municipality play a significant role in the waste management chain. As there is no proper mechanism to integrate them into the waste management chain, they contribute to generating another challenge to the municipality. They tend to dump unrecyclable or sellable waste at roadsides or bare lands.

V. CONCLUSION AND RECOMMENDATION

Our study explores how Moratuwa Municipal Council attempts to address the challenge of managing its solid waste which is a requirement under the Sustainable Development Goal 11 and 12. Our findings contribute to the literature dealing with municipal solid waste management. The socio-cultural aspect of waste

management is considered as one of the major challenges for developing countries to build a sustainable waste management practice (Guerrero and Hogland, 2013). As demonstrated by this study, collective efforts by stakeholders such as the municipal administration, its ordinary employees and residents have enabled to mitigate the negative consequences from a two main aspect of waste management, namely socio-cultural. The municipality has nurtured the habit of segregation of waste at its origin and reusing or recycling such waste that could generate additional income to the municipal budget. In addition, its waste management practices help to reduce the cost of disposing waste, as biodegradable waste is properly segregated before delivering to the waste disposal site that composts such waste. To foster good waste management habits within its administrative area, the PHIs have played a main role, which contradicts with the findings of Vidanaarachchi et al. (2006). Based on their study, the involvements of PHIs instead of engineers exacerbate the problem of solid waste management in Sri Lanka.

Poor sorting and increasing complexity of the product’s composition limit sustainable resource recovery operations in a sustainable solid waste management system (Singh et al., 2014). The literature envisages that MSW generation is affected by different factors, such as population; socioeconomic development index (HDI) income level (GNI per capita) (Wilson, 2007; Wilson et al., 2012b); and climate of the region (World Bank, 2012). Generally, the greater the economic prosperity, the greater the amount of waste produced. Sri Lanka generates 7000 Tons of waste per day and only less than 50% is systematically collected and treated by Local authorities and the remaining continue to be informally dumped on roadsides or barren lands creating an adverse impact to the ecological system. The current study concludes that an integrated approach to streamline all parties in waste chain and specially the community awareness on responsible consumption and disposal patterns should be encouraged. Community awareness on prevention, Minimization, Reduce, and reuse should be expanded as in Moratuwa municipality. And similar approach will enable to attain the SDG 11: Make cities and human settlements inclusive, safe, resilient and sustainable, and SDG 12: Ensure sustainable consumption and production patterns.

The industries should apply more circular economy strategies at all stages of the product life cycle, and Local Authorities must promote innovative culture promoting institutional entrepreneurship and Organization Citizenship behavior to propose to sustainable solutions for regional waste generation. Similarly, politicians and celebrities can play an exemplary role by simply changing the attitudes of people and moving society to embrace

sustainable waste management practices. We urge scholars to explore how other municipalities in Sri Lanka cooperate with various actors to propagate sustainable waste management habits and practices. Similarly, it is important to explore why biogas production in Sri Lanka has not been successful, albeit the history of biogas generation in Sri Lanka traceable as far as back to the late 1960s (Vidanaarachchi et al., 2006). The countries like Norway and Sweden have been successful in using biofuel to drive vehicles belong to the municipality.

Acknowledgment: This paper is part of Techno-Economic-Societal Sustainable Development Training in Sri Lanka (TESS) Project, No: 609925-EPP-1-2019-1-NO-EPPKA2-CBHE-JP, which is co-funded by the European Commission under its ERASMUS+ CBHE programme

VI. REFERENCES

- Agdag, O.N., (2008), "Comparison of old and new municipal solid waste management systems in Denizli, Turkey", *Waste Management*, 29, 456-464.
- Cader, A.A., (2001), "A public perception study on garbage and related issues in Sri Lanka" [online]. Centre for policy alternatives, media unit. Available from: <http://www.cpalanka.org/page.php> [Accessed 20 July 2023].
- Damghani, A.M., Savartpour, G., Zand, E. and Deihimfard, R., (2007), "Municipal solid waste management in Tehran: Current practices, opportunities and challenges", *Waste management*, 28, 929-934.
- Ekere, W., Mugisha, J., Drake, L., (2009). Factors influencing waste separation and utilization among households in the Lake Victoria crescent, Uganda. *Journal of Waste Management* 29, 3047-3051.
- Geng, Y.; Zhu, Q.; Doberstein, B.; Fujita, T. Implementing China's circular economy concept at the regional level: A review of progress in Dalian, China. *Waste Manag.* 2009, 29, 996-1002.
- Jagdeep Singh, Rafael Laurenti, Rajib Sinha, & Björn Frostell. (2014). Progress and challenges to the global waste management system. *Waste Management & Research*, 32(9), 800-812.
- Khalil, N.; Khan, M. (2009). A case of a municipal solid waste management system for a medium-sized Indian city, Aligarh. *Manag. Environ. Qual. Int. J.*, 20, 121-141
- Kularatne, R.K. Case study on municipal solid waste management in Vavuniya Township: Practices, issues and viable management options. *J. Mater. Cycles Waste Manag.* 2015, 17, 51-62
- Kum, V., Sharp, A. and Harnpornchai, N., (2004), "Improving the solid waste management in Phnom Penh city: a strategic approach", *Waste management*, 25, 101-109.
- Lalitha, R., & Fernando, S. (2019). Solid waste management of local governments in the Western Province of Sri Lanka: An implementation analysis. *Waste Management*, 84, 194-203.
- Rahardyan, B., Matsuto, T., Kakuta, Y. and Tanaka, N., (2004), "Resident concerns and attitudes towards solid waste management facilities", *Waste management*, 24 (5), 2-14.
- Saja, A.M.A.; Zimar, A.M.Z.; Junaideen, S.M. (2021) Municipal Solid Waste Management Practices and Challenges in the Southeastern Coastal Cities of Sri Lanka. *Sustainability*, 13, 4556.
- Scheinberg A, Wilson DC and Rodic L (2010) *Solid Waste Management in the World's Cities: Water and Sanitation in the World's Cities 2010*. London, UK: Earthscan For Un-Habitat.
- Shekdar, A.V. (2009) Sustainable solid waste management: An integrated approach for Asian countries. *Waste Manag.*, 29, 1438-1448.
- Sujauddin, M., Huda, M.S., Rafiqul Hoque, A.T.M., 2008. Household solid waste characteristics and management in Chittagong, Bangladesh. *Journal of Waste Management* 28, 1688-1695.
- Tai, J., Zhang, W., Che, Y., Feng, D., (2011). Municipal solid waste source-separated collection in China: a comparative analysis. *Journal of Waste Management* 31, 1673-1682.
- Tchnobanoglous, G. & Kreith, F. (2002). *Handbook of Solid Waste Management*, 2nd edition, McGraw-Hill Handbooks.
- Vidanaarachchi, C.K.; Yuen, S.T.; Pilapitiya, S. (2006). Municipal solid waste management in the Southern Province of Sri Lanka: Problems, issues and challenges. *Waste Manag.*, 26, 920-930.
- Wilson D.C, Rodic L, Scheinberg A, Velis C.A and Alabaster G (2012b) Comparative analysis of solid waste management in 20 cities. *Waste Management & Research* 30: 237-254.
- Wilson, D.G., (1977), "Hand book of solid waste management" 1st Ed. New York: Van Nostrand Reinhold Company.
- Yash Pujara, Pankaj Pathak, Archana Sharma, & Janki Govani. (2019). Review on Indian Municipal Solid Waste Management practices for reduction of environmental impacts to achieve sustainable development goals. *Journal of Environmental Management*, 248
- Yin, K. (2003), *Case study research: Design and methods*, 3rd edition, SAGE publications, London
- Zhuang, Y., Wu, S.W., Wang, Y.L., Wu, W.Z., Chen, Y.X., (2008). Source separation of household waste: a case study in China. *Journal of Waste Management* 28, 2022-2030.

Circular Entrepreneurship for Shared Value Creation: Case Study from Southern Province Sri Lanka

F Mafasiya Fairoz
Department of Management and Entrepreneurship
mafasiyaf@gmail.com

M.W. Indrani
Department of Accountancy
University of Ruhuna, Sri Lanka
induwithana@ymail.com

T.S.L.W. Gunawardana
Department of Business Management
tslw2013@gmail.com

K.G.P.V. Gunarathne
Department of Accountancy
University of Ruhuna, Sri Lanka
gunarathnavijitha@gmail.com

G.T.W. Sriyani
Department of Management and Entrepreneurship
wsriyanigt@gmail.com

Abstract—Economies are facing numerous social, and environmental challenges due to the absence of proper waste management. Circular entrepreneurship plays an important role in identifying and exploiting new business opportunities to create innovations from waste which is paramount to enhancing resource efficiency and reducing negative environmental impact. Therefore, circular entrepreneurship is imperative in achieving sustainable development goals. In this milieu, this study explores how circular entrepreneurs create innovation from wastes which leads to shared value creation through business start-ups in southern Sri Lanka, and recognizes the challenges they face during the start-up stage. The Multiple case study method was applied and data were collected from three circular entrepreneurs by conducting in-depth interviews. The findings of the study reveal that these circular entrepreneurs introduce innovations by using waste with the motivation of reusing it to reduce resource wastage and negative environmental impact. Their knowledge and experience, creativity, cross-sector collaboration, networking, and learning induce them to make business start-ups in this sector. Further, they are facing several challenges during the start-up stage such as lack of access to finance, high electricity costs, finding partners, technical faults in the machinery, having licenses from multiple authorities which delay the process, and inadequate support from the government. This study provides insights to the practitioners and policy-makers in Sri Lanka to facilitate circular entrepreneurs to successfully exploit circular business opportunities that impact the triple bottom line and achieve sustainable development goals.

Keywords: *Circular Entrepreneurship, Waste Management, Shared Value Creation, Sri Lanka*

I. INTRODUCTION

Waste is currently known as a valuable resource and the application of circular economy practices for waste management would help to achieve sustainable development goals. In the business community, sustainability is coined as “the triple bottom line”, expressing that industry has to expand the traditional economic aspects to incorporate environmental and social dimensions to create a more “sustainable business” (Elkington, 1997). Even though there are many business opportunities available in the upcycling of waste, the community is unaware to convert these into value addition and innovations (Leal et al., 2019) which ultimately contributes to shared value creation (economic, social, and environmental values) through circular entrepreneurship. Circular entrepreneurship focuses on reusing, recycling, refurbishing, remanufacturing, or upcycling wastes through circular closed-loop processes when compared with the linear economic model (Henry and Hekkert, 2020) which ultimately goes for landfilling and creates many environmental issues for the economy. Creative use of waste in the production process provides many benefits such as extending the lifetime of materials and products, increasing material efficiency, reducing energy consumption, and generating economic opportunities for local communities (Sung et al., 2019).

Urbanization, population growth, overconsumption, lack of awareness, malpractices by industries, etc. create the problem of waste management which has been continued for many years in Sri Lanka and came to be known well after the collapse of the Meethotamulla waste disposal site in 2017 which

created severe environmental issues and death of lives. Subsequently, the economic downturn in Sri Lanka resulting from the COVID-19 pandemic created many issues for society while burdening the livelihood of people. Therefore, it is imperative that both profit maximization and minimizing resource utilization through circular entrepreneurship in all sectors of the economy (Gunasekara, 2021). Proposing circular business models plays a worthy impact in the Sri Lankan economy to ensure food security, good health, provide job opportunities, empower youth and MSMEs, and reduce cost and environmental pollution. Even though circular entrepreneurship is an emerging research area around the world, there is still a lacuna of research on the value creation done from circular business models in Sri Lanka (Jayasinghe et al., 2020) as well as scarce research in management insights (Donner et al., 2020). Thus, this study aims to explore three circular business models in the agro-waste sector by analyzing the process of circular entrepreneurship and shared value creation in terms of economic, social, and environmental aspects of sustainability in the context of southern Sri Lanka. Moreover, this paper reveals the challenges facing circular entrepreneurs in the process of value creation.

II. LITERATURE REVIEW

2.1 Circular Economy (CE)

CE model appeals across various academic disciplines as well as among practitioners and communities around the world. Where CE is an emerging field of scholarship with an increasingly coherent set of shared beliefs and concepts, with the participation of multiple actors (Kirchherr et al., 2023 and Suchek et al., 2022). The transition to a CE means a systemic change that aims to reduce the impacts of the linear economy construct long-term resilience and establish economic and business opportunities in addition to returning environmental and social benefits (Ellen MacArthur Foundation, 2015). Geissdoerfer et al. (2017) conceptualized the CE as, “*a regenerative system in which resource input and waste, emission, and energy leakage are minimized by slowing, closing, and narrowing material and energy loops. This can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling*”. CE is an alternative model to the linear economy which is mainly based on “take-make-dispose” with a lack of concern for the natural environment and society (Sauvé et al., 2016). Thus, the CE model proposed to utilize materials, and products over time through slowing, closing, and narrowing production cycles (Bocken et al., 2016). CE adopts the “life cycle thinking” approach which

expands the traditional focus on manufacturing processes to incorporate various aspects associated with a product over its entire life cycle. The main goal of life cycle thinking is to reduce resource use and emissions from/to the environment as well as to improve social performance in various stages of a product's life. One of the main goals of CE is to transform waste into a resource and waste management emerges as a subsector of CE (Merli et al., 2018).

2.2 Circular Entrepreneurship and Shared Value Creation

Circular Entrepreneurship is “*the processes of formation and exploitation of opportunities, using both commercial and ecological logics to address environmental challenges with the aim of closing, slowing, and narrowing the loop of resources and regenerating/reconstituting natural capital*” (Zucchella & Urban, 2019). Circular entrepreneurs are crucial to any economy, they identify creative ways to reuse and recycle waste while inducing consumer awareness and promoting green products (Veleva & Bodkin, 2018). According to Gandhi and Raina (2018), Social entrepreneurship stands out among the several sorts of entrepreneurial pathways because of its value proposition. Sinthupundaja et al. (2020) stated that “*social entrepreneurship can be represented as a transitional vehicle that serves for creating shared value among an entrepreneur, society, and the environment*”. Social entrepreneurs not only offer benefits to society that commercial enterprises do not, but also pursue financial objectives with limited resources and support, by generating profits, social enterprises hope to attain economic benefits while achieving their mission (Shin, 2018). Further, social entrepreneurs “*benefits for society, local people and the local community, to resolve social problems around local communities such as enhancing community health and safety and uplifting the well-being of local people*” and at the same time circular entrepreneurs create environmental value as “*the betterment of the natural environment. It also refers to resolving environmental problems around global communities, such as reducing waste and pollution*” (Sinthupundaja et al., 2020).

Donner et al., (2020) identified six types of circular business models in the agro-waste sector such as biogas plant, upcycling entrepreneurship, environmental biorefinery, agricultural cooperative, agro park, and support structure. Drawn a sample of 39 case studies from 15 countries, the study revealed that these models differ in their way of value creation, but strongly depend on partnerships and their capacity

to respond to changing external conditions. Suchek et al., (2022) reviewed the literature on entrepreneurship and circular economy and developed a framework for circular entrepreneurship including antecedents, consequences, and support ecosystem for circular entrepreneurship, and emphasized the need for new studies to deepen the understanding of circular entrepreneurship in different contexts. A study by Donner and Radic (2021) conducted an empirical study in the olive waste sector based on 41 cases drawn from 12 Mediterranean Countries. It explored that innovative business models such as olive waste valorization, and bioenergy production have emerged and still olive biomass is under-valorized. Through the application of a qualitative case study approach, Jayasinghe et al., (2020) conducted a SWOT analysis by investigating three upcycling eco-enterprises in Sri Lanka as well as the challenges facing them in sustaining growth and scale-up. Findings revealed that limited access to funds, lack of business and marketing skills, and access to suitable markets are major challenges faced by eco-enterprises.

III. METHODOLOGY

This study applied the qualitative multiple case study method. The case study method is defined as "*an empirical inquiry that investigates a contemporary phenomenon in depth and within its real-life context, especially when the boundaries between phenomenon and context are not evident*" (Yin, 2014). We selected the case study method to the contemporary nature of the phenomenon under investigation and to gain an in-depth, contextual understanding (Yin, 2014) because this research attempts to explore how circular startups create shared value. Three case studies were selected from the southern province by using the purposive sampling technique which is fit into the current study. Three cases were first identified through a focus group discussion held with circular entrepreneurs. Then these three cases were identified as successful circular entrepreneurship models because they are pertinent examples to generate insights into the phenomenon of our research with the best practices of circular economy models (Ünal et al., 2019). In-depth interviews were conducted via the online Zoom platform with selected circular entrepreneurs through an interview guide to reveal the process of circular entrepreneurship, shared value creation as well the challenges faced by them during the start-up stage. Probing also took place following the interviews to have an in-depth understanding of the phenomena and circular entrepreneurs explained their journey as a story of their life in a very insightful discussion. Interviews lasted about one to one and a half hours until the data became saturated and interviews were

recorded with the permission of the respondents. Subsequently, transcribed interviews to critically review and analyze the cases with their narratives.

IV. FINDINGS AND DISCUSSION

This section presents three empirical case analyses by emphasizing the circular entrepreneurship process and shared value creation. Further, the study presents the challenges faced by them during the start-up stage.

4.1 Case 1

A rice mill owner in Tissamaharama seized a business opportunity of producing eco-pellets from rice husks in the year 2011. He thought that since many people in that area were doing paddy farms as their main livelihood activity and also many rice mills were located in the area, which created tons of rice husks like mountains and no use of these for other purposes and just burning and landfilling threats to the environment. Then he searched the alternative ways to reuse these husks because it is a big issue for the community. Since he had already exported rice to India, he had a good network there. Through that company, he visited Vietnam, Thailand, and China to study technological know-how. He set up a factory in 2012 with 06 employees to produce eco-pallettes from rice husks which could be used as a burning material for factories and households instead of gas and other energies. He purchased two machines from China to operate the production process which cost about Rs. 14,000,000. Then, he could develop a good supply chain in the area to provide raw materials without interruption which benefited to earn income for a large number of suppliers and their employees. Usually, 1200 kg of rice husk is needed to produce 1000 Kg of pallets with the capacity of producing 1600 Kg of pallets per day by two machines. First, he exported the product to an Indian company and then some other companies established in Industrial zones and cement factories in Sri Lanka. Next, due to the scarcity of gas in the market after Covid 19, there was a high demand for this product.

Concerning the availability of abundant waste rice husks and well-developed supply chain to the factory he had an idea of generating electricity through this waste in the year 2017. Then he registered with the Central Environmental Authority (CEA) to get permission because he thought to supply the electricity to the Ceylon Electricity Board (CEB). Then it was required to get a license from several authorities such as CEA, Water supply and drainage board, Forest department, Coast conservation department, and local government authority. It takes about 02 years to obtain licenses from these authorities. Afterward, he got

permission from CEB and signed the agreement in February 2023 to supply electricity for 20 years. The factory can supply 2.5 MV to CEB and 0.5 MV for personal use per day which consumes about 50 tons of rice husk. He says that *“we would be able to supply electricity for about 35,000 households out of this 03MV. As per the initial estimation it requires about Rs. 75 million, but due to the inflation and rising the Dollar value currently it needs about Rs. 160 Million to launch the project”*.

One of the major challenges that he is facing in initiating this project is the financial issue. Though he has already been talking with several banks, they did not agree to provide a higher amount of loan and then he talked with a China Bank. Though it agreed to provide a loan, they ask for collateral for the total amount of the loan and he has no such properties to keep as collateral since the value of the project is rather higher. Therefore, currently, he is searching for partners to invest in the project and talked with several parties in foreign countries as well, they have positive signs in investing in the project and hopefully launch the project shortly. He says that after several years he had faced the challenge of finding the market since the Indian company stopped orders in 2016 because of the price and it could find other alternatives rather than this pallet. Then he contacted with Jaffna cement factory as well as an allied company of Unilever located in Aagarapathana to find the market and it was successful. However, these companies demand the product from time to time as per their requirements so they cannot sell these continuously. Further, the rising electricity bills create a high cost of maintaining the factory and challenging to keep the cost low. Moreover, operating machines also created some issues like because our rice husk is harder than in China which consumes more electricity, and the breakdown of bearings leads to frequent repairs. The main challenges for launching an electricity generation project are finding finance and obtaining a license from multiple authorities which was very difficult and time-consuming since there is no mechanism in Sri Lanka to get these licenses through one request in one stage and multiple requests need to be done and not favorable mindset is developed to support entrepreneurs as well as for this kind of important projects.

4.2 Case 2

A university undergraduate living in Amabalantota who produces healthy food and drinks from the waste of banana trees. As usual, after harvesting the banana, the tree is cut since it produces bananas only at once.

Therefore, abundant banana trees are cut by banana farmers during harvesting and many banana farmers are available in the Hambantota district, especially for commercial purposes. He was thinking of making some value additions from these wastes and generating an idea of producing food from them. Banana belly/stem is well known as a healthy food among the villages but it has not yet been seized for industrial application and the opportunity of reusing and upcycling banana belly into a rich source of nutritious food and drinks such as flour, cordial, and wine. Further, since he is an undergraduate in the field of food science at the University of Vocational Technology, he was able to gain knowledge and skills in this field. Especially during the period of Covid 19 with the vacation and free time, students were assigned to do a project and submit a report. Accordingly, he was inspired to exploit this opportunity to make value additions from banana belly in the year 2021 because of his creative thinking the intrinsic motivation to introduce a commercially viable product from waste rather than just doing something to fulfill the requirement of the university. Then he identified the ranges of products that could be produced through banana belly for example; freezing, dehydrating, chutney, etc., and the suitable raw material such as the correct types of banana trees with rich fiber since some types of banana belly are not suitable to make the products. Accordingly, according to the experiments and guidelines given by the Ministry of Agriculture he chose *“Ash plantain, Puwalu, and Ambull”* as are most suitable and then studied the costs, the food preservation and dehydration technology, convenience, time duration, etc., and selected this option. Next, he bought a dehydration machine and a blender which cost about Rs. 100,000 with the support of his parents. Next, he started the process of making flour from banana belly and did experiments in making juice and wine as well. He obtained quality certifications from ITI. This flour contains a rich source of nutrition with more fibre which could be added for preparing any food like porridge, roti, cake, biscuits, and other bakery items that have a good taste as well. He introduced the products in the exhibition to aware the community. As he says *“I introduced my products to the ProFood ProPack exhibition held at BMICH 2023. The product was launched through the Ministry of Agriculture. Many people who are health-conscious for example who are going to fitness centers bought many packs since it improves easy digestion and this helped me to identify another group of the target market for my products. I got contacts to export this product. This product won third place in the University category as well in the competition of “Sahasak Nimawum” organized by the Sri Lanka*

Inventors Commission. I am thinking of marketing the product through the supermarkets based on the supply". Moreover, he has applied for GMP certification and ordered to design of suitable machines to extract fibre from banana trees without any waste. Cross-sector collaboration and stakeholder management are also important to continue the process.

One of the major challenges that he is facing today is the financial problem. He talked with several banks with the coordination of the Ministry of Agriculture, but they asked collateral to approve loans since the business is at the start-up stage.

4.3 Case 3

She was inspired to start self-employment by running a restaurant. Meanwhile, she got to know about a training program on making value-added products from bamboo organized by the National Craft Council in 2018 and attended the workshop since she was very eager and interested to learn such things. She was also able to get the training on value additions which could be produced from eakle during this workshop. Even though she got training on both materials, she selected Eakle since they are abundantly available and obtained free of charge without incurring any transport costs. Then she started the business and produced many types of eakle products such as bags, baskets, etc. and she could provide some job opportunities to women in her village and empower them to support their livelihood. Moreover, she was willing to share her knowledge with women and attended different training programs organized by National Craft Council, and other community-based organizations as a resource person. She expressed; *"I made contact with some hotels in Hikkaduwa to sell my products. The product is durable as far as wood and its eco-friendly. One of the major challenges that I am facing is finding skilled employees to finish the final outlook of the product"*.

Findings suggest that circular entrepreneurship contributes to shared value creation. Thus, this study validates the results of previous studies indicating the value of circular entrepreneurship for sustainability (Dantas et al., 2022; Cullen et al., 2021, Jayasinghe et al., 2020).

V. CONCLUSION AND RECOMMENDATIONS

The study explored the circular entrepreneurship models by studying three cases of circular entrepreneurs located in southern Sri Lanka. Circular entrepreneurs identified the opportunity through wastes that are abundantly sourced continuously from their areas and produce value-added products such as pallets & electricity generation through rice husks, food and beverages from banana belly, and, crafts from eakle. These circular entrepreneurs contribute to shared value creation by providing job opportunities, income generation, support for livelihood, developing supply chain, skills & training, cross-sector collaboration, empowering women, and contributing to generating energy, and reducing environmental pollution. The challenges facing them during the start-up stage could be mentioned as high electricity costs, lack of access to finance, finding partners, technical faults in the machinery, having licenses from multiple authorities that delay the process, and inadequate support from the government. This study provides insights to the practitioners and policymakers in Sri Lanka to facilitate circular entrepreneurs to successfully exploit circular business opportunities that impact triple bottom lines and achieve sustainable development goals.

There are some limitations in our study since the research is based only on three cases in southern Sri Lanka and applied a qualitative approach which restricts the possibility of generalizing the results. Future research may explore how circular entrepreneurs create shared values by drawing a large sample of different industries in diverse economic contexts.

ACKNOWLEDGMENT

This paper is part of the Techno-Economic-Societal Sustainable Development Training in Sri Lanka (TESS) Project: 609925-EPP-1-2019-1-NO-EPPKA2-CBHE-JP, which is co-funded by the European Commission under its ERASMUS+ CBHE programme.

VI. REFERENCES

- Bocken, N. M. P., Schuit, C. S. C., & Kraaijenhagen, C. (2018). Experimenting with a circular business model: Lessons from eight cases. *Environmental Innovation and Societal Transitions*, 28, 79–95. <https://doi.org/10.1016/j.eist.2018.02.001>.
- Cullen, U. A., and De Angelis, R. (2021). Circular entrepreneurship: A business model perspective. *Resources, Conservation and Recycling*, 168(6–7):105300. DOI:10.1016/j.resconrec.2020.105300.

- Dantas, R.M.; Ilyas, A.; Martins, J.M.; Rita, J.X. (2022). Circular Entrepreneurship in Emerging Markets through the Lens of Sustainability. *J. Open Innov. Technol. Mark. Complex.* 8, 211. <https://doi.org/10.3390/joitmc8040211>.
- Donner, M., Gohie, R., and de Vries, H. (2020). A new circular business model typology for creating value from agro-waste. *Science of the Total Environment*, 716. pp. 1-11. <https://doi.org/10.1016/j.scitotenv.2020.137065>
- Donner, M.; Radić, I. (2021). Innovative Circular Business Models in the Olive Oil Sector for Sustainable Mediterranean Agrifood Systems. *Sustainability*, 13, 2588. <https://doi.org/10.3390/su13052588>
- Ellen MacArthur Foundation. (2015). Towards a Circular Economy: Business rationale for an accelerated transition. <https://www.ellenmacarthurfoundation.org/publications/towards-a-circular-economy-business-rationale-for-an-accelerated-transition>.
- Henry M, Bauwens T, Hekkert M, Kirchherr J (2020). A typology of circular start-ups: analysis of 128 circular business models. *Journal of Cleaner Production*, 245:118528.
- Jayasinghe R, Liyanage N., Baillie C (2020). Sustainable waste management through eco-entrepreneurship: an empirical study of waste upcycling eco-enterprises in Sri Lanka. *Journal of Material Cycles and Waste Management*, 23(5):1–9. <https://doi.org/10.1007/s10163-020-01140-0>
- Leal Filho, W., Ellams, D., Han, S., Tyler, D., Boiten, V.J., Paço, A., Moora, H., and Balogun, A.L., (2019). A review of the socio-economic advantages of textile recycling. *Journal of Cleaner Production*, Vol. 21, PP 10-20, <https://doi.org/10.1016/j.jclepro.2019.01.210>.
- Merli, R., Preziosi, M., & Acampora, A. (2018). How do scholars approach the circular economy? A systematic literature review. *Journal of Cleaner Production*, 178, 703–722. <https://doi.org/10.1016/j.jclepro.2017.12.112>
- Suchek, N. Ferreira, J.J., & Fernandes, P.O. (2022). A review of entrepreneurship and circular economy research: State of the art and future directions. *Business Strategy and the Environment*, pp.1-28. DOI: 10.1002/bse.3020.
- Sauvé, S., Bernard, S., & Sloan, P. (2016). Environmental sciences, sustainable development, and circular economy: Alternative concepts for trans-disciplinary research. *Environmental Development*, 17, 48–56. <https://doi.org/10.1016/j.envdev.2015.09.002>
- Sung K, Cooper T, Kettley S (2019) Factors influencing upcycling for UK makers. *Sustainability*, 11(3):870.
- Unal, E., Urbinati, A., Chiaroni, D., & Manzini, R. (2019). Value creation in circular business models: The case of a US small medium enterprise in the building sector. *Resources, Conservation & Recycling*, 146, 291-307.
- Veleva, V., & Bodkin, G. (2018). Corporate-entrepreneur collaborations to advance a circular economy. *Journal of Cleaner Production*, 188, 20–37. <https://doi.org/10.1016/j.jclepro.2018.03.196>.
- Yin, R. (2014). *Case study research design and methods* (5th Editio). Thousand Oaks, CA: Sage.

Household Waste Management Practices in Sri Lanka

D.D.D Suraweera

*Department of Department of Electrical and Electronics
Technology,
University of Vocational Technology,
Rathmalana, Sri Lanka
dddsuraweera@uovt.ac.lk*

K.G Alahapperuma

*Department of Mechanical and Manufacturing Technology,
University of Vocational Technology,
Rathmalana, Sri Lanka
kgalahapperuma@uovt.ac.lk*

Abstract - Proper disposal of domestic waste is a concern in every society. The purpose of this study was to identify how households dispose of different categories of waste to find out any deviation from standard practices. The study analysed responses from 143 technology stream undergraduates to determine how different varieties of garbage are disposed of from their houses. Even though the majority dispose of waste after separating into different types, and environmentally friendly practices are used for disposing of biodegradable waste, burning of plastics, rubber and other allied waste materials was identified as the most significant concern. Additionally, very low responses were received for the questions related to the disposal of electronics or e-waste. Hence, the study findings show a great need for identifying or making aware of proper waste disposal methods.

Keywords - *biodegradable waste, electronic waste, household waste disposal, non-bio-degradable waste*

1. INTRODUCTION

Managing household waste is a complex process because its poor implementation could lead to harmful and unintended consequences to humans, other living beings, and, in general, to the environment. In achieving sustainable development, countries struggle to cope with the increased solid waste and its environmental impact. The domestic sector is one of the leading producers of the biodegradable category.

Numerous attempts have been undertaken in Sri Lanka to educate the public on proper waste disposal methods. According to the World Bank report on 'What a waste 2.0 - Global snapshot of solid waste management to 2050', an average Sri Lankan produces 0.34 kilograms of waste per day [19].

Domestic solid waste management has become a complex issue if waste is not disposed of after separating into different varieties at the disposal point. In Sri Lanka, Urban Councils, Municipal councils, and Pradeshiya Sabhas are the mandated bodies to collect and dispose of domestic waste in an environment-friendly and sustainable manner. The said councils conduct awareness programmes highlighting the importance of separating waste at home before dispatching or handing it to the authorities for disposal.

Further, individuals have stepped into a collection of metal, glass, paper, and electronic waste, which they conduct as a business. These people play a vital role in collecting and disposing of waste varieties.

Many studies have been conducted on the management of solid waste. However, a critical link of this whole process of solid waste management is the proper disposal at the generation site, i.e. houses. Therefore, people have a very casual approach to play with. Many people don't have any awareness or understanding of the consequences of the wrong waste disposal. Keeping this in mind, this study intended to identify practices used by households in disposing of their waste.

II. REVIEW OF LITERATURE

Since solid waste management is a global issue, several studies have been conducted in different regions and societies. However, apparent success in managing solid waste isn't easily attained due to the complex nature of the problem. Findings of several past studies on the disposal of solid waste in general, as well as studies on the disposal of specific categories of solid waste, are summarised below.

Solid wastes such as non-recyclable packaging, textiles and plastics encompass non-biodegradable materials generated from households. The management of solid waste possesses challenges in terms of collection, separation and disposal. Research conducted by Bensusan and the group in 2018 emphasised the need for adequate waste management infrastructure, public awareness campaigns and recycling initiatives to reduce the environmental impact of solid waste [14].

Managing solid waste is also crucial for maintaining environmental sustainability and public health. Several studies have focused on strategies to improve solid waste management practices, including waste reduction, recycling and proper disposal methods. The survey conducted by Wilson and his group in 2019 explored the significant role of the informal sector in solid waste management in developing countries. It examines the contributions of informal waste pickers to recycling and reducing waste, highlighting the potential for sustainable waste management through integration with formal systems [9].

In 2022, Charles and his group conducted a study among specific communities in Bo Southern Sierra Leone to investigate the participation and knowledge of households on waste management. As per the revealed results, knowledge of the domestic sector on solid waste disposal is very low, and 42% of the respondents are used to burning waste as the disposal method, causing a risk of disease outbreak [1].

In the final report, “Data Collection Survey on Solid Waste Management in the democratic socialist republic of Sri Lanka”, submitted by the Japan International Cooperation Agency (JICA) in 2016, the requirements of ten leading local authorities of the country for solid waste management have been summarised. Condition of provision of proper transportation facilities and human resources, update the waste collection system with appropriate rules, improve the functioning of the existing compost plant, improve material recovery systems, establish a new sanitary system while enhancing the current disposal sites, establish subsidies for solid waste management from central government and, introduce facilities of intermediate treatment of waste for extending the service time of disposal sites are among the suggested points in the report.[4].

The technical guidelines on solid waste management in Sri Lanka provide comprehensive guidelines on solid waste management to be considered by any entity, including local authorities. However, these guidelines are aimed at covering municipal solid wastes only. Therefore, guidelines for managing hazardous and sewerage waste aren't covered here [5].

In a study undertaken in Urban Malawi, a questionnaire survey was used for randomly chosen 200 houses in a populated region to collect factors that influence household waste disposal practices—as per the results, choosing relatively good waste disposal practices, such as composting and using private services for the waste collection practised by female-headed households. Based on the results, a six-month waste management plan was arranged for the community. To transfer families from a throwaway behaviour to better waste disposing methods, community-based waste management programmes targeting male-headed houses proved effective [6].

A study was undertaken by Hubaybah et al. to investigate the effectiveness of training on household waste disposal methods. As per the results of this study, the provision of training on household waste management has resulted in a substantial improvement in attitudes, knowledge and actions of housewives towards reducing the rate of disposing of house garbage into the river nearby [7].

Food waste is a significant component of domestic waste, contributing to environmental pollution and economic losses. Improper disposal of food waste leads to the emission of greenhouse gases and the depletion of natural resources [11]. Several studies (Gustavsson et al. in 2019 and Parfitt et al. in 2010) highlight the importance of reducing food waste through source reduction strategies, such as improved meal planning, composting and donation programmes [11, 12, 13].

A review study by Smith and Guptha in 2018 examined the various factors influencing household food waste

behaviour, such as consumer attitudes, behaviour and socio-economic factors. It also discusses the effectiveness of interventions and strategies to reduce food waste at the household level [8].

Plastic waste has gathered increasing attention due to its persistence in the environment and detrimental effects on wildlife. Significant environmental challenges arose due to the long lifespan of plastic waste and its adverse impact on ecosystems.

Numerous studies (Hopewell et al. in 2019 and Rochman et al. in 2013) explored solutions for plastic waste management, such as recycling technologies, extended producer responsibility and public awareness campaigns [15,16]. The study conducted by Geyer et al. in 2019 provides a comprehensive analysis of the production, consumption and ultimate fate of all plastics made. It highlights the urgent need for effective plastic waste management strategies and calls for collaborative efforts to reduce plastic waste generation [17].

Furthermore, according to certain researchers (Ghisellini and Ulgiati in 2020, Kaza in 2018, etc.), innovative approaches like biodegradable plastics and circular economy models offer promising alternatives to traditional plastic waste management practices [18, 19].

Recently, in 2023, Kankanamge conducted research among university students to evaluate the Sri Lankan young consumers' practices on electronic waste management. As per the revealed results, most respondents used to store the discarded e-waste in their homes, and they weren't aware of the available schemes for e-waste management. Stockpiling of e-waste is also a common domestic problem. The study emphasised the education requirement on proper e-waste management among the general public, especially university students [3].

The increase in electronic devices has led to a surge in e-waste. E-waste management faces unique challenges due to hazardous substances and the need for specialised recycling facilities. Previous research conducted by Julander et al. in 2014 emphasises the importance of implementing proper collection and recycling systems, as well as promoting sustainable design principles to reduce the environmental and health risks associated with e-waste [20].

Balde and his group's study, conducted in 2017, also examined various aspects of e-waste management, including recycling methods, policy frameworks, and the environmental and health impacts of improper disposal. The report of this study provides a comprehensive overview of the global e-waste problem, including the quantities, flows and resources associated with e-waste. It emphasises the importance of sound e-waste management practices and the potential for resource recovery through recycling [10].

Glass waste, which is generated primarily from containers and packaging, is highly recyclable and has a lower environmental impact compared to other types of garbage. Research by Ghinea et al. in 2019 emphasises the benefits of recycling glass, including energy savings and reduced greenhouse gas emissions. However, existing challenges regarding collection and processing efficiency

highlight the need for improved infrastructure and consumer participation [21].

III. METHODOLOGY

The study was undertaken as a descriptive survey. An online questionnaire in a Google form was administered to a sample of 200 undergraduates of Bachelor of Technology degree courses at the University of Vocational Technology. The sample was selected through cluster sampling. However, only 143 undergraduates have responded. Simple descriptive data analysis methods were used to analyse the data.

IV. RESULTS

According to the responses, 46.9% of respondents dispose of waste after separating it into degradable and non-biodegradable varieties, while 37.1% indicate that they sometimes dispose of it after separation. Out of the other respondents, 9.1% of them rarely separate waste, whereas 7% do never separate waste before disposing. These responses are shown in the Fig. 1.

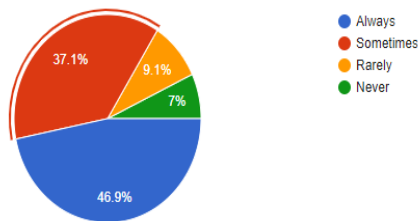


Fig. 1. Percentage of responses received for the alternative answers to the question, “Do you dispose of waste after separating into bio-degradable and non-biodegradable varieties ?”

Out of all responses, 49% of respondents dispose of biodegradable waste by dumping it into a pit in their land, whereas 39.2% of them make compost, which is a good trend. These responses are shown in the Fig. 2.

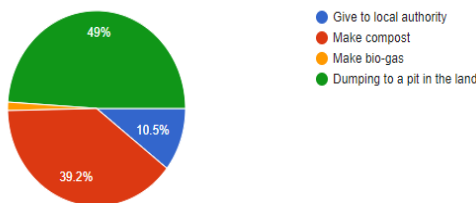


Fig. 2. Percentage of responses received for the alternative answers to the question, “How do you dispose of biodegradable solid waste (kitchen waste) ?”

When disposing of non-biodegradable waste, only 18.9% of respondents separate it into different categories of materials such as plastic, glass, rubber, metals, etc. In comparison, the majority of 37.1% of respondents separate

this waste, sometimes only. While 20.3% of respondents rarely separate non-biodegradable waste, 23.8% never dispose of it as mixed waste. These responses are shown in the Fig. 3.

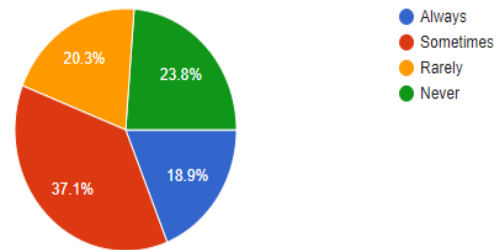


Fig. 3. Percentage of responses received for the alternative answers to the question, “Do you dispose of waste as a mixed waste without grouping it into different materials (such as plastic, glass, rubber-metal, etc.) ?”

When considering the disposal of plastic waste, 57.3% of the respondents indicate that they burn polythene and other types of plastic waste. Of all the respondents, 21% handed over their waste to the relevant local authorities, while 16.1% handed over waste plastic to the waste collectors. The responses to this question are shown in Fig. 4.

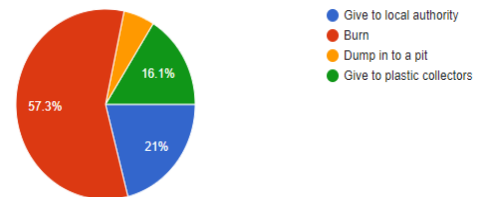


Fig. 4. Percentage of responses received for the alternative answers to the question, “How do you dispose of polythene and other plastic waste (bags, lunch sheets, yoghurt cups, etc.) ?”

Similarly, 35.7% of respondents burn packing material such as rigifoam (expanded polystyrene), whereas 36.3% hand over such waste to their local authority. While 19.6% of respondents don't express a particular disposal method for this category of waste, 20% of them dispose of it by handing it over to waste collectors. These responses are shown in the Fig. 5.

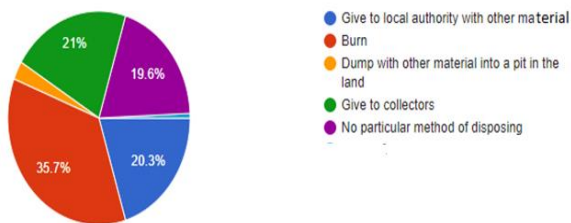


Fig. 5. Percentage of responses received for the alternative answers to the question, “How do you dispose of packing material like rigid foam?”

Regarding glass and other ceramic waste, a large majority (37.8%) dispose of it by giving it to waste collectors. At the same time, 24.5% and 17.5% of respondents dispose of such waste by dumping it in a pit and landfilling, respectively. Further, 17.5% of respondents hand over such waste to their local authorities. Responses to this question are shown in the Fig. 6.

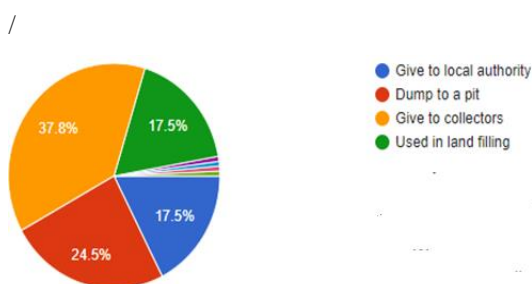


Fig.6. Percentage of responses received for the alternative answers to the question, “How do you dispose of glass and ceramic waste ?”

Burning is the primary disposal method for rubber-based waste, practised by 37.1% of respondents, whereas 30.8% hand over their waste to collectors. Another 6.8% of respondents handed over it to local authorities. Further, 15.4% of them dump their waste rubber into a pit in their land. Percentages of these responses are shown in the Fig. 7.

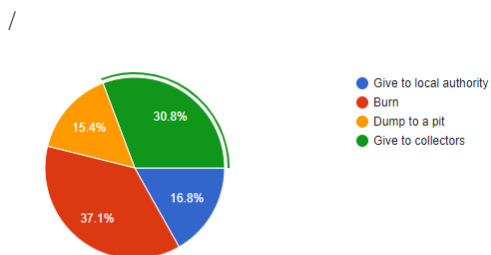


Fig.7. Percentage of responses received for the alternative answers to the question, “How do you dispose of rubbery waste (like carpets, tires, slippers, etc.)?”

In the case of hazardous waste, the identification of waste by type is at a satisfactory level, as indicated in Table 1.

TABLE 1. PERCENTAGE OF RESPONDENTS WHO HAVE SELECTED EACH CATEGORY OF WASTE AS HAZARDOUS

Category of Material/Waste	Percentage of Respondents Who Have Selected This Category of Waste as Hazardous
	79.0
Burned CFL bulbs	79.7
Burned tube lights	79.0
Used watch batteries	75.5
Used torch batteries	76.2
Used car batteries	88.1
Mobile phone parts such as batteries, displays, etc.	85.3
Used phone chargers	51.7
Used mobile phones	65.7
Used television parts	66.4
Used face masks	28.7
Used earphones	40.6
Used paint brushes	23.8
Used paint cans	42.0
Damaged thermometers which have mercury	83.2
Used switches and plugs	39.2
Leftover paint	40.6
Polythene and related waste such as wrapping and shopping bags, etc.	46.2
Rigifoam (expanded polystyrene)	45.5
Used cooking oil	24.5
Detergents (soap, dishwasher liquids, toilet bowl cleaning liquid etc.)	33.6
Mosquito coils and coil ash	41.3
Pesticides	57.3
Weedy sides	55.2
Inorganic fertiliser	52.4

However, when considering the disposal of e-waste, out of 143 respondents, only six have responded to the related question, leaving an undetected situation. According to the responses received, they dispose of e-waste by handing it over to waste collectors or returning it to the sellers when buying a new electronic device. Due to a low number of respondents, actual disposal practices of e-waste aren't reflected.

Regarding metallic waste, most received responses indicate that most respondents hand over their metallic waste to waste collectors or relevant local authorities. Percentages of accepted answers for the disposal way are shown in Fig. 8.

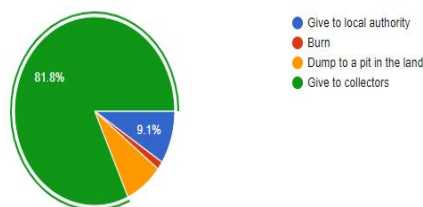


Fig.8. Percentage of responses received for the alternative answers to the question, "How do you dispose of metallic waste?"

Concerning the large majority of received responses, most respondents are used to handing over their metallic waste to waste collectors or related local authorities.

V. DISCUSSION

Municipalities and individual waste collectors play a more significant role in collecting domestic waste. As per the study's findings, before disposal, a large majority of people separate waste into different groups of materials, which implies a favourable trend for environmental protection. In the case of e-waste, most respondents don't dispose of it in an environmentally harmful way. A considerable proportion of respondents used to keep e-waste generated by discarded electronic devices with themselves for a significant time until buying a new appliance, rather than disposing of it straight away. As revealed by Kankanamge's study, even though the respondents are educated young adults, they aren't aware of proper discarding methods of e-waste [3]. Alternatively, according to the received responses, burning plastics, rubber and other allied materials is practiced by many respondents, which is highly harmful to the environment. One of the most effective ways to manage plastic waste in households is the reduction of generation, as suggested by Geyer et al. in 2019 [17]. Finally, there is a scope for inculcating environmentally friendly waste disposal methods, which can be achieved through awareness and training programmes, as agreed by past studies [6,7,14].

VI. CONCLUSION

For the disposal of domestic waste, environmentally friendly practices are adopted by the households, in the case of biodegradable waste. However, the approach of the majority of people towards the disposal of plastic, rubber and other allied waste can't be accepted, as it harms the environment. Further, the majority of them are not very sure about the proper waste disposal methods.

VII. RECOMMENDATION

Proper waste disposal methods can be achieved by implementing well-organised education and training or awareness programmes targeting the domestic sector. Therefore, it is suggested to incorporate domestic waste disposal as an integral component of all educational programmes, especially in tertiary and higher education.

REFERENCES

E. Charles, A. H. Koroma, Y. K. Kawa and J. P. Kaisam, "Assessment of knowledge and participation on households solid domestic waste management in some selected communities in Bo Southern Sierra Leone", *International Journal of Environmental Chemistry*, Volume 8, Issue 1, 2022

- [2] C. Ghinea and M. Gavrilescu, "Solid Waste Management for Circular Economy: Challenges and Opportunities in Romania – The Case Study of Iasi County: Texts and Studies in the History of Philosophy", In book: *Infinity in Early Modern Philosophy*, pp. 25-60.
- [3] C. E. Kankanamge, "Consumer behaviour in the use and disposal of personal electronics: a case study of university students in Sri Lanka", *Circular Economy and Sustainability*, volume 3, pp. 407–424, 2023
- [4] Final Report, Data collection survey on solid waste management in the democratic socialist republic of Sri Lanka, Japan International Cooperation Agency (JICA), p.256, 2016.
- [5] Technical guidelines on solid waste management in Sri Lanka, Hazardous Waste Management Unit, Pollution Control Division, Central Environmental Authority, Sri Lanka, n. d.
- [6] P. K. Kalonde, A. C. Austin, T. Mandevu, P. J. Banda, A. Banda, M. C. Stanton and M. Zhou, "Determinants of household waste disposal practices and implications for practical community interventions: Lessons from Lilongwe", n.d. <https://ssrn.com/abstract=4151604>
- [7] Investigation on waste management training effectiveness on community behaviour in household waste to reduce the waste number into the river in Penawar Village, Kerinci Regency.
- [8] Smith, M. and Gupta A, "Understanding household food waste behaviour: A review of the literature", *Waste Management*, vol.77, pp.200-213, 2018, doi:10.1016/j.wasman.2018.04.027
- [9] Wilson, D. C., Velis, C., and Cheeseman, C "Role of informal sector recycling in waste management in developing countries". *Habitat International*, vol.94, 101978. doi:10.1016/j.habitatint.2019.101978
- [10] C. P. Baldé, V. Forti, V. Gray, R. Kuehr and P. Stegmann, "The global e-waste monitor 2017: Quantities, flows, and resources", United Nations University, International Telecommunication Union & International Solid Waste Association, 2017.
- [11] F. G. Smith, M. Miroso, and S. Skeaff, "A mixed-methods study of retail food waste in New Zealand", *Food Policy*, vol.92, 101845, 2020.
- [12] J. Gustavsson, C. Cederberg, U. Sonesson, R. V. Otterdijk and A. Meybeck, "Global food losses and food waste", *Biotechnology Save Food Congress*, Dusseldorf, May 2011.
- [13] J. Parfitt, M. Barthel, and S. Macnaughton, "Food waste within food supply chains: quantification and potential for change to 2050", *Philosophical Transactions of the Royal Society B: Biological Sciences*, vol.365, issue 1554, pp. 3065-3081, September 2010 <https://doi.org/10.1098/rstb.2010.0126>
- [14] N. R. Bensusan, D. C. Wilson, and S. R. Smith, "Uncontrolled burning of solid waste by households in Mexico is a significant contributor to climate change in the country", *Environmental Research*, vol.163, pp.280-288.
- [15] J. Hopewell, R. Dvorak, and E. Kosior, "Plastics recycling: challenges and opportunities", *Philosophical Transactions of the Royal Society B: Biological Sciences*, vol.364, issue.1526, pp. 2115-2126, 2009.
- [16] C. M. Rochman, M. A. Browne, B. S. Halpern, B. T. Hentschel, E. Hoh, H. K. Karapanagioti, ... & R. C. Thompson, "Classify plastic waste as hazardous" *Nature*, vol.494, issue: 7436, pp.169-171,
- [17] R. Geyer, I. R. Jambeck and K. L. Law "Production, use and fate of all plastics ever made", *Science Advances*, vol. 3, Issue. 7, e1700782, 2019. doi:10.1126/sciadv.1700782
- [18] P. Ghisellini, and S. Ulgiati, "Circular economy transition in Italy, Achievements, perspectives and constraints", *Journal of Cleaner Production*, vol. 243, issue.118360, 2020.
- [19] Kaza S, Yao L, P. B. Tata and F. V. Woerden, "What A Waste 2.0: A Global Snapshot of Solid Waste Management to 2050", (Urban Development Series, Washington, DC: World, 2018. <https://doi.org/10.1596/978-1-4648-1329-0>.
- [20] A. Julander, L. Lundgren, L. Skare, M. Grandér, B. Palm, M. Vahter, and C. Lidén, "Formal recycling of e-waste leads to increased exposure to toxic metals: an occupational exposure study from Sweden", *Environment International*, vol.73, pp. 243-251, 2014.

Upcycling to Preserve Intergenerational Equity: The Project of Green Life Generation

Chamara Kuruppu,
USN School of Business,
University of South-Eastern Norway
Norway
chamara.kuruppu@usn.no

Savandie Abeyratne
Green Life Generation
Kandy, Sri Lanka
greenlifegene@gmail.com

Daniel N Subramaniam,
Department of Civil Engineering
University of Jaffna
Sri Lanka, daniel@eng.jfn.ac.lk

Abstract: Unsustainable waste management practices undermine well-being of both present and future generations. Our study demonstrates how upcycling efforts by a woman contribute to preserving intergenerational equity. The forms of cultural, economic and social capital help to sustain her business. She keeps transforming one form of capital to another form of capital during crisis. Similarly, a new form of currency, namely “BinCoin” is introduced to foster a grassroots circular economy. Her upcycling initiatives are in line with some of the sustainable development goals.

Keywords: *Upcycling, Waste, Intergenerational Equity & Forms of Capital*

INTRODUCTION

The global community produces nearly 2 billion tonnes of solid waste annually while the unsafe waste disposal rate is 33% (World Bank, 2018). In general, waste refers to any substance or item that its owner intends to dispose, and the owner finds no benefits or value having that item or substance in possession. Waste could entail a twofold challenge namely, negative impacts on human health and the environment, and loss of finite and valuable resources (Van Ewijk and Stegemann, 2020).

Any environment unfriendly waste disposal practice could negatively influence the well-being of both present generation and future generations. Such a scenario is unfair and environmentally unsustainable, as the latter group has no opportunity to oppose any decision made by the former group. This means that we should not prioritise our well-being at the cost of future generations’ well-being. Therefore, the present generation should make its efforts and commitment to preserve intergenerational equity – the right of future generations to reap the benefits of natural resources without a substantial deduction of their availability (Lamberton, 2000). Drawing on upcycling and forms of capital, this study explores how a Sri Lankan woman makes efforts to conserve intergenerational equity by upcycling waste.

The remainder of the paper is divided into four sections. The second section elucidates a frame of reference consists of upcycling and forms of capital, whilst the third section explains the research approach. The fourth section elaborates and analyses the study’s findings. The final section discusses findings and makes conclusions. In addition, directions for further studies are also provided.

FRAME OF REFERENCE

A Perspective on Upcycling

The earth is viewed as a closed and circular system while its assimilative capacity is limited (Geissdoerfer et al., 2017). Nevertheless, business enterprises often adopt a linear economic approach (Neumeyer et al., 2020) – promoting the behaviour of extracting resources, producing products, consuming and disposing – that multiplies the volume of waste accumulated over time. The term waste is controversial, as for a particular item or substance to be treated as waste, a boundary has to be defined. And that item or substance can only then be identified as waste within that boundary. Nevertheless, it can well be a resource outside the boundary. Such potentials have often been overlooked in traditional production and consumption cycles.

Scholars elucidate the importance of using waste as a resource to minimise its negative consequences (Van Ewijk and Stegemann, 2020). In other words, the circular economy (CE) is the pathway for enterprises to operate their business activities with the environmental consciousness (Coronac et al., 2019). Upcycling of waste simply refers to extending the usage of the life span of a product beyond the boundaries that defined it as waste while using as a resource for the production of consumption outside the initial boundaries (Zambrano et al., 2021; Zhang et al., 2022; Zhou et al., 2021). Upcycling as part of the CE plays a significant role in reducing waste and minimising its negative consequences. Upcycling is a process that repurposes waste that the owner wish to dispose (Singh et al., 2019). In this process, discarded products or materials are used to drive a product with higher quality or value (Bridgens et al., 2018; Zhang et al., 2021). In other words, upcycling enables to upgrade waste materials’ quality and value (Korley et al., 2021).

Forms of Capital

A stream of research discusses the forms of capital necessary to overcome challenges (Kuruppu et al., 2016). Capital can take the form of economic, social, cultural or symbolic. According to Bourdieu (1986a, 1986b, 1990), economic capital takes the form of money and property right that is easily convertible to cash. Cultural capital refers to a range of knowledge that remains in a person’s body and mind. Similarly, historical and cultural artifacts, and formal education and competence are also part of cultural capital. Social capital represents a network of relationships that its members could mobilise based on the necessity. Symbolic

capital is the embedded status of prestige, celebrity, consecration, or honour in the social strata. One form of capital can be converted to another and such a possibility is essential for the reproduction and accumulation of capital (Bourdieu, 1986b, 1990; Kuruppu et al., 2016).

DATA COLLECTION

This study adopts autoethnography approach. Autoethnography is a qualitative research method (Wall, 2006). Butz and Besio (2009) reveal that autoethnographic personal narratives could be derived from a range of viewpoints such as academics' efforts to critically reflect on their experience about a phenomenon, researchers' reflection about their field work, marginalised groups' reflection about their representation in a specific context, indigenous ethnographies and other forms of inside member research.

Autoethnography can be articulated by scholars with interdisciplinary background (Hayano, 1979). Scholars, representing three disciplines, cooperated in the process of writing this article. A female author in this manuscript propagates upcycling of paper and wood offcuts in her hometown - Kandy. As elaborated by Duncan (2004), participant observation, reflective writing, interviewing, and collecting documents and other artifacts should be used to triangulate personal narratives. In addition to the female scholar's personal narratives, a semi-structured interview conducted by two male scholars, newspaper articles, YouTube videos, and interview in magazine about Green Life Generation (GLG) are used to write this paper.

UPCYCLING INITIATIVES BY GREEN LIFE GENERATION

The findings of the study are presented in this section. Section one elaborates the company's background and its products. Section two delineates what has been done during the recent Covid-19 pandemic crisis.

Inspiration for founding the company

GLG is a profit-oriented organisation which encompasses its own research and development wing to help the company evolve into an ecosystem. Its founder had completed her master education in England. The trajectory of founding this company is the Meethotamulla waste dump disaster in 2017. However, the company's name was determined in 2016. The inspiration for this name was her research on painful experience of unskilled female domestic migrant worker in the Middle East. She thought of generating employment opportunities for them, whilst addressing the challenge of managing solid waste. Her thinking has been transpired by her attendance in some of the business bridge sessions at her university. In these sessions, participants were requested to think of a social problem. She reckoned managing waste as a problem in Sri Lanka and waste could be used to make some valuable products. GLG makes innovation and evolution to conserve the environment by the adoption of zero environmental footprint of its business and research activities.

In the late 2016, GLG's founder and her husband were in Sri Lanka to collect data for her studies. She was devastated by the news of waste dump collapse and the loss of life in April 2017. She and her husband discussed what part could they play to dignify the society that merely dependent on the waste dump as responsible citizens. They decided to establish a small and medium enterprise to offer part-time employment

opportunities at least for 6 vulnerable females, in their very locality in Kandy District. A project, namely "I am Upcycled" was initiated to produce marketable products out of cement bags, cardboard cartons, strings and wood offcuts. GLG aims to propagate innovations and skills enhancing opportunities for vulnerable females.

As her husband did not work in Sri Lanka, she proposed him to look for materials littered in a nearby housing construction site to produce something valuable (add value to the otherwise waste material). Having observed that cement packages and wood offcuts were consistently available, they decided to make some souvenirs out of offcuts and obtained the permission to pick such waste up. She and her husband had designed some souvenirs to sell to tourists visiting the country. Initially, they employed 6 women as part-time employees. The reason not to offer fulltime employment was their responsibility to take care of children after the school. Each employee was to be paid 100 Rupees per hour.

She possesses a local and international network of friends, as she has been educated at an international school in Kandy and her stay in England for 15 years. Her friends and relatives had given her cash gifts when she got married. Collection of such gifts from that occasion was the initial capital of GLG. Their souvenir products were attractive and could be sold through Laksala as well. Friends – who saw their souvenir made of wooden waste – were impressed by the "I am Upcycled" project. A friend of the family promised to donate 100 Euro every month to help her business, as it contributes to protecting the planet. Similarly, her parents give money to meet some of her expenses. In addition, she invested the cash award received from her university. She won the first place in the competition on policy brief for the doctoral students in 2018 and 2019, and the second place in 2020.

As the demand for the wooden souvenirs increased, they started thinking of producing wrappers for their products. At this juncture, the possibility of producing wrappers out of cement packages was considered, as one of the employed girls and her mother could make bags. The company produces a range of giftbags, giftboxes, gift wrappers, stationaries and items for decorating ceremonies. Sometimes, their employees bring materials that could potentially be used in the production process.

The founder of GLG and her husband promote their products through Facebook. A cosmetic enterprise contacted the company to purchase its bags made of used cement packages. Similarly, her friends and relatives order their decorations and wrapping products for festivals. The business grew to a level that it is not necessary to approach business entities to sell its products. The customers place their orders through emails or over the phone. Unexpectedly, this situation changed in 2019. Next section demonstrates how the company survived during the deep pandemic and then economic crisis period.

Changing the approach for employment

The founder of GLG borrowed around 250 000 Rupees from her friends to invest in the business, as the company had promising market potentials. In 2019, the country was considered not safe for tourists because of the Easter Sunday attack. The demand for its souvenirs suddenly dwindled. Similarly, some entities that bought the company's product

were out of business. Fortunately, her friends do not expect any interest or money back on a specific date. Though the demand for its packaging products remained unstable, the company could not generate income to pay the salary for its 16 staff members. As such, GLG was coerced to make a very painful decision to lay off some of its employees. At this point, the management considered the efficiency of each employee before terminating the employment of staff members who could not produce high quality products.

The Covid-19 pandemic situation and economic crisis made it challenging to obtain waste materials. Therefore, GLG aimed to provide some services, as the purchasing power of citizens had declined. Since the restriction for movement had been lifted, it was decided to open its boutique which could be used to sell its products and second-hand clothes. Used clothes were available free of charge from friends and relatives of GLG's owners. The intention of opening the shop was to offer the employment opportunity for 2 vulnerable females.

The boutique is situated in front of a school. GLG made it a space available for mothers waiting for their children. Similarly, they were invited to exchange waste such as cardboard, papers and plastic packages for the used clothes. This exchange system motivated the company to introduce a currency, namely "BinCoin" that can be exchanged for waste. The members of BinCoin exchange system could use their coins to purchase goods or services. At present, there are around 400 members. The company now offers a daycare service for its BinCoin members. In addition, there is a cafe for its members to buy foods and drink. School children are also members of the new ecosystem. They tend to buy snacks and stationaries. It is interesting to witness that the BinCoins have created a grassroots exchange system and the employment opportunities for 24 vulnerable females.

The company now aspires to promote alternative education by using its infrastructure system consisting of waste collection point, BinCoin system and upcycling methods to demonstrate how a grassroots system of circular economy could function. The company offers a guided tour package that the visitors could choose within the range of half-day to three-day tour. The tour package includes a backpack and a notebook made of waste items. The guided tour of the company focuses the visitors' attention on 16Rs instead of famous 3Rs. Recovery, Record, Responsibility, Research, Regulate, Reuse, Reduce, Refuse and Recycle are few of them to name. A group of 60 French tourists have made reservation to learn about its 16Rs in September 2023. They have managed to get this order through their social network.

DISCUSSION AND CONCLUSIONS

It is important to adopt environment friendly waste management practices, as unsustainable waste disposal practices endanger biodiversity, quality of air and water, degrading soil, and depleting resources amongst others that could undermine the ability of preserving intergenerational equity. The founder of GLG makes initiatives to upcycle waste such as wood offcuts, cement packages and cardboard cartons and to offer decent employment opportunities for vulnerable and marginalised females while fostering a grassroots circular economy. Therefore, her efforts particularly contribute to attaining some of the SDGs. Among them, SDG – 1 and SDG – 2: enabling vulnerable females to meet the cost of living,

SDG – 5: empowering women, SDG – 11: making human settlements resilient and sustainable, and SDG – 12: ensuring sustainable production and consumption behaviour are notable.

She has initially used her education and European exposure which is cultural capital and her savings that represent economic capital (Bourdieu, 1986a, 1986b, 1990) to establish the company. Similarly, she draws on the family's cultural capital to design products and market them through Facebook. In addition, her competence of writing policy reports has enabled to win the competition at the university and to receive additional funding for the business. Social capital made of her school and family friends plays a significant role in generating sales income and additional funds (Bourdieu, 1986a, 1986b, 1990) to invest in the company during the Covid-19 pandemic. In this way, she uses one form of capital to access another form type of capital in the process of managing her business (Bourdieu, 1986b, 1990; Kuruppu et al., 2016).

The United Nations' agenda for sustainable development underlines the importance of making authentic efforts to assure the sustainable existence of people and planet. Our study envisages how GLG endeavours to introduce a new type of currency, namely "BinCoin". Such innovations could play a significant role in the process of fostering a grassroots circular economy. We urge scholars to explore how entrepreneurs attempt to foster a grassroots circular economy by introducing a new form of currency in other contexts and what kinds of challenges could encounter when making such initiatives. Similarly, it is important to research how entrepreneurs capitalise various forms of capital and transform them one form to another at the different stages of business growth.

ACKNOWLEDGMENT

This paper is part of Techno-Economic-Societal Sustainable Development Training in Sri Lanka (TESS) Project: 609925-EPP-1-2019-1-NO-EPPKA2-CBHE-JP, which is co-funded by the European Commission under its ERASMUS+ CBHE programme.

LIST OF REFERENCES

- Bourdieu, P. (1986a). *Distinction: A social critique of the judgement of taste*. Great Britain: Routledge.
- Bourdieu, P. (1986b). The forms of capital. In J. G. Richardson (Ed.), *Handbook of theory and research for the sociology of education* (pp. 241–258). Westport: Greenwood Press.
- Bourdieu, P. (1990). *In other words: Essays towards a reflexive sociology*. Cambridge: Polity Press.
- Bridgens, B., Powell, M., Farmer, G., Walsh, C., Reed, E., Royapoor, M., Gosling, P., Hall, J. & Heidrich, O. (2018). Creative upcycling: Reconnecting people, materials and place through making. *Journal of Cleaner Production*, 189, 145-154.
- Butz, D. & Besio, K. (2009). Autoethnography, *Geography Compass*, 3/5, 1660-1674.
- Coronac, B., Dhen, L., Reike, D., Carreon, J. R. & Worrell, E. (2019). Towards sustainable development through the circular economy – a review and critical assessment on our circularity metrics. *Resources, Conservation and Recycling*, 151, 1-15.
- Duncan, M. (2004). Autoethnography: Critical appreciation of an emerging art. *International Journal of Qualitative Methods*, 3, 28-39.
- Hayano, D. M. (1979). Auto-ethnography: Paradigms, problems and prospects. *Human Organization*, 38, 99-104.

- Korley, L. T. J., Eppsc, T. H., Helms, B. A. & Ryan, A. J. (2021). Toward polymer upcycling – Adding value and tackling circularity. *Science*, 373, 66-69.
- Kuruppu, C., Adhikari, P., Gunarathne, V., Ambalangodage, D., Perera, P. & Karunaratne, C. (2016). Participatory budgeting in a Sri Lankan urban council: A practice of power and domination. *Critical Perspectives on Accounting*, 41, 1-17.
- Lamberton, G. (2000). Accounting for sustainable development - A case study of city farm. *Critical Perspectives on Accounting*, 11, 583-605.
- Neumeyer, X., Ashton, W.S. & Dentchev, N. (2020). Addressing resource and waste management challenges imposed by COVID-19: An entrepreneurship perspective. *Resources, Conservation and Recycling*, 162, 1-3.
- Singh, J., Sung, K., Cooper, T., West, K. & Mont, O. (2019). Challenges and opportunities for scaling up upcycling business – The case of textile and wood upcycling businesses in the UK. *Resources, Conservation & Recycling*, 150, 1-15.
- Van Ewijk, S. & Stegemann, J.A. (2020). Recognising waste use potential to achieve a circular economy. *Waste Management*, 105, 1-7.
- Wall, S. (2006). An autoethnography on learning about autoethnography. *International Journal of Qualitative Methods*, 5, 146-160.
- World Bank (2018). *What a waste 2.0: A global snapshot of solid waste management to 2050*. Washington: World Bank.
- Zambrano, F., Marquez, R., Jameel, H., Venditti, R. & Gonzalez, R. (2021). Upcycling strategies for old corrugated containerboard to attain high-performance tissue paper: A viable answer to the packaging waste generation dilemma. *Resources, Conservation & Recycling*, 175, 1-13.
- Zhang, F., Wang, F., Wei, X., Yang, Y., Xu S., Deng, D. and Wang, Y. (2022). From trash to treasure: Chemical recycling and upcycling of commodity plastic waste to fuels, high-valued chemicals and advanced materials. *Journal of Energy Chemistry*, 69, 369-388.
- Zhang, X., Shao, X., Jeong, E. & Olson, E. (2021). I am worth more than you think I am: Investigating the effects of upcycling on event attendees' recycling intention. *International Journal of Hospitality Management*, 94, 1-14.
- Zhou, Y., Zhang, Y. & Li, X. (2021). Upcycling of paper waste for high-performance lithium-sulfur batteries. *Material Today Energy*, 19, 1-11.

Reviewing the Biogas Generation Technologies and Identifying the Potential Applications in Local Context

M.A.S.M. Dissanayake
Department of Mechanical &
Manufacturing Technology
University of Vocational Technology
Sri Lanka
shashini726madushani@gmail.com

H.N.W. Gunasekara
Department of Mechanical and
Manufacturing Technology
University of Vocational Technology
Sri Lanka
hasith.gunasekara@uovt.ac.lk

A.S.K. Warahena
Department of Mechanical &
Manufacturing Technology
University of Vocational Technology
Sri Lanka
aruna.warahena@gmail.com

Abstract—The issue of Waste Management has garnered considerable attention from various authorities, coupled with the significant challenge of non-renewable energy depletion. Consequently, there is a pressing need to adopt an eco-friendly alternative energy source to mitigate these problems. In this regard, ‘Biogas Technology’ emerges as an effective solution, offering a more stable and efficient renewable energy source with the potential to maintain a pollution-free environment. Biogas proves to be competitive, economically viable, and generally sustainable, benefiting from the abundant supply of inexpensive feedstocks. Its versatility is evident in a wide range of applications, including heating, power generation, fuel production, and serving as raw materials for further processing and the sustainable production of chemicals such as H₂O, CO₂, and biofuel. This review paper provides a comprehensive overview of biogas generation, design, and operation, exploring operational parameters, the biogas production potential of organic matter, as well as highlighting the benefits, applications, and upgrading technologies associated with biogas.

Keywords—*Biogas Technology, non-renewable energy source, sustainable, eco-friendly, alternative source*

I. INTRODUCTION

The depletion of non-renewable energy sources and the global waste management challenge stand out as significant issues on a global scale. The escalating global population has led to an imbalance between energy demands and the available supply. Traditional energy resources like oil, coal, and natural gas, which have been regularly utilized, are diminishing, and their combustion releases greenhouse gases contributing to climate change. Notably, petroleum alone meets 38.1% of energy demands [8], leading to an increasing scarcity of fuel, surging fuel prices, and adverse economic impacts. Consequently, there is a predominant research focus on finding efficient and environmentally friendly alternatives to address the drawbacks of these depleting and harmful non-renewable energy sources. In this context, the development of ‘Biogas’ technology emerges as a highly favorable alternative energy source for daily human activities. It represents a promising solution to meet current and future

energy demands sustainably and ensures environmental well-being.

Conversely, the issue of waste management is a crucial facet of contemporary society, with the volumes of waste generated often linked to income levels and rates of urbanization. With the global population anticipated to reach 9.7 billion by 2050, there is an ongoing surge in the demand for food, water, and energy. In 2016, an estimated 2.01 billion tonnes of municipal solid waste were generated, and projections indicate a rise to 3.40 billion tonnes by 2050 [13]. Developing countries are expected to experience a more than threefold increase in the total quantity of waste generated by 2050 [13]. The persistent escalation in solid waste production poses hazardous challenges for both human well-being and the environment. Addressing these challenges entails the enhancement and implementation of biogas technology, utilizing waste in a manner that ensures a more sustainable future.

In simple terms, Biogas is a flammable gas primarily composed of Methane (CH₄) and Carbon Dioxide (CO₂), generated by bacteria breaking down organic material in the absence of oxygen. The production of biogas yields numerous benefits, including renewability, eco-friendliness, cleanliness, and green attributes. It helps mitigate greenhouse effects, offers a cost-effective solution, diminishes reliance on fossil fuels, contributes to the reduction of global warming, and produces high-quality enriched fertilizer, enhancing soil fertility. Furthermore, as a smokeless domestic fuel, biogas decreases the occurrence of eye and lung diseases. The proposition of biogas as an alternative for meeting energy demands stems from its multifaceted advantages. This research is centered on studying and advancing biogas as an economical and sustainable alternative energy source, aiming to alleviate environmental pollution, enhance the quality of life, promote the use of superior organic fertilizers over chemical ones, and contribute to the improvement of people's literacy.

II. AIM AND OBJECTIVES

○ Aim

To be able to manage the food waste that accumulates daily and finally to prove that biogas technology is a very valuable process for humans as well as the environment to the extent that there is no such thing as waste. Also, to pave the way for further expansion of biogas technology.

○ Objectives

- To study biogas yield and its efficiency to fulfill the requirement of the household and commercial.
- To achieve a very successful & better-quality flame & upgrading the gas for thermal applications.
- To find solutions for problems faced arise during and after yield of the biogas.

III. METHODOLOGY

A comprehensive assessment of the advantages, drawbacks, applications, and upgrading processes outlined in existing literature is crucial for gaining a thorough understanding of the future prospects of biogas adoption. The analysis of literature, extraction of pertinent cases, and their reinterpretation offer valuable insights from diverse theoretical and practical perspectives. To achieve this, the review follows specific steps. Initially, the identification of the topic is based on various research endeavors. Thematic coding is then employed to extract pertinent information from research articles, focusing on themes such as biogas production for sustainability, types of digester design, operational parameters of biogas plant, and biogas production potential of organic matter. Subsequently, the benefits and disadvantages of biogas, its applications, and upgrading technologies are identified. Finally, the coded literature is synthesized to produce meaningful information that aligns with the objectives of this review paper.

IV. LITERATURE REVIEW

With population growth and elevated living standards, the challenges associated with energy shortages are increasingly prevalent at both local and global levels. The escalating demand for fossil fuels, driven by heightened consumption levels, stands as a significant contemporary issue affecting the global population. Consequently, there is a pressing need to explore alternative forms of energy generation to diversify the current energy matrix, which currently relies on fossil fuels for 90% of its composition worldwide. In this context, 'Biogas,' as a renewable energy resource, emerges as one of the most efficient and effective solutions [1]. Numerous studies [1-6] have delved into the production and diverse applications of biogas. By the close of 2019, the global biogas plant capacity reached approximately 19.5GW, signifying a substantial increase in capacity [1]. Factors such as energy scarcity, soaring fossil fuel prices, ready access to biomass feedstock, and concerns related to emissions and global warming appear to have played pivotal roles in driving this growth.

○ Biogas Production

The typical composition of biogas ranges from 50-70% ethane (CH_4) and 25-50% Carbon Dioxide (CO_2), dependent on the substrate introduced to the digester. Additionally, trace amounts of Hydrogen (H_2), Nitrogen (N_2), Hydrogen Sulfide H_2S , and Ammonia (NH_3) may be present [4]. The production of biogas involves the anaerobic digestion of various organic materials, including agricultural waste, household and municipal waste, plant material, manure or dung, human and animal feces, sewage, garden (green) waste, and food waste. Anaerobic digestion is a complex process encompassing chemical and biological transformations that organic matter undergoes to yield biogas.

Microbial action in the digester is responsible for biogas production. The organic matter undergoes rapid digestion upon being processed and introduced into a reactor through a gradual fermentation process. In this process, microorganisms utilize organic materials such as proteins, carbohydrates, and lipids as nutrition, leading to the production of gases, predominantly in the form of CH_4 and CO_2 .

○ Benefits of Biogas Technology

In addition, there are more benefits of biogas production. Those are,

- The improvement of farming in rural communities, which enhances the economy of a community through job creation.
 - Waste reduction using organic agricultural waste and municipal solid waste for an increased energy production.
 - The improvement of the environment quality through CO_2 emission reduction.
 - The combination of the disposal of organic waste with the formation of valuable energy 'Methane (CH_4)' by biogas.
- One of the primary benefits of biogas, particularly when considered from economic and environmental perspectives, is the reduction of greenhouse gas emissions (GHG) [5]. In a study assessing the environmental and economic advantages of a biogas combined heat and power plant, the system's performance was evaluated using the GHG abatement cost methodology over its life cycle. The focus of the study was to identify key drivers for achieving competitive GHG reductions. Agricultural waste served as the energy crop substrate in this context. The examined plant demonstrated the production of 4.5MWh of electricity and 1.7MWh of thermal energy annually. The findings highlighted that the cost of GHG abatement could be significantly lowered through the efficient utilization of thermal energy [5].

○ Biogas Digester Design

A biogas digester is a living system and must have suitable conditions for the growth of anaerobic bacteria that produce methane. So, it reveals that choosing a right biogas digester is very important in constructing a biogas plant. As well as anaerobic digestion system designs range widely, primarily due to different feedstock types and applications in specific environment [7-9] [11].

The examination of a research paper focused on the design and application of common biogas digesters underscores the critical significance of selecting an appropriate digester in practical situations during the design phase. It is emphasized

that making informed decisions at this stage is vital. Factors such as the nature of solid materials to be digested, geological conditions, digester shape, yield, and the accessibility of construction materials should be thoroughly assessed before initiating the design process [7].

Accordingly, it has been discussed how biogas digesters can be divided under two main types.

Industrial bio digester: This biodigesters are mainly used in developed countries to release pressure at landfills for anaerobic digestion of municipal solid waste (MSW). Thus, the biogas produced is mainly used for the production of electricity.

Domestic bio digester: This biodigesters are most popular among developing countries because of its ability to generate biogas on a small scale at the household level. The gas generated is used as a fuel to reduce the use of biomass as fuel. So,

- (i) Fixed dome digester
- (ii) Floating dome digester
- (iii) Plastic bag digester
- (iv) Plug flow digester/ Inclined digester have become popular as domestic biogas digesters used for small scale biogas production [7][9].

Among these, fixed dome digesters are widely favored for their durability, despite being relatively expensive. These digesters are typically installed underground. While digesters of sizes 4, 6, 8, and 10 cubic meters are popular for small families, their costliness makes them more commonly utilized at the institutional level [7] [9-10]. On the economical side, floating plastic dome and plastic bag digesters stand out. The plastic bag digester is particularly cost-effective but requires careful handling due to its delicate nature, resulting in a shorter lifespan. Another economical choice is the plug flow or inclined digester, which is simple and cost-effective to install and operate. However, it is not as efficient or consistent as the completely mixed design [7].

Apart from this, bio digesters designs can be classified according to the type of feeding, according to temperature and heating [7][8].

Under, depending on type of feeding they are classified as,

- 1) *Batch Type Digester:* Batch type biogas plants are recommended for situations where acquiring daily supplies of raw waste materials proves challenging. In this system, a batch-loaded digester is filled to its capacity, sealed, and provided with sufficient retention time within the digester. Once the digestion process is complete, the residue is emptied, and the digester is refilled for subsequent cycles.
- 2) *Continuous Digester:* Here, fresh organic material continuously enters the tank, and an approximately equal amount of digested material is removed in an ongoing process. Various stages of digestion exist throughout this process to attain balance.

Next, based on temperature, fermentation process is categorized into,

- (i) *Psychrophilic digestion:* Occurs at ambient temperatures between -15° and 10°C
- (ii) *Mesophilic digestion:* Occurs at ambient temperatures between 20° and 45°C

- (iii) *Thermophilic digestion:* At elevated temperatures up to 70°C

o *Operational Parameters of Biogas Plants*

Biogas primarily consists of CH₄ and CO₂, with the proportion of CH₄ influenced by the type of feedstock used in the biogas plant. Various operational conditions also significantly impact the potential for biogas production. Therefore, optimizing the design of a biogas plant is crucial to achieving optimal biogas production with minimal costs, considering specific requirements and potential.

To ensure stable and efficient biogas production, several design considerations and operational parameters must be considered. Monitoring various operating parameters, such as temperature, pH value, retention time, organic loading rate (OLR), chemical oxygen demand (COD), biochemical oxygen demand (BOD), among others, allows for adaptation to unexpected conditions.

Research reviews have underscored those decisions regarding biogas plant design, operation, and monitoring conditions hinge on numerous factors, including temperature range, pH value, OLR, feedstock, COD, BOD, and biogas quality. It's important to note that the optimal range of operational parameters may vary from one biogas plant to another [12].

o *Biogas Production Potential of Organic Matter*

Food waste is the organic material having the high calorific value and nutritional value for microorganisms and therefore can increase the efficiency of methane production by several orders of magnitude. It means higher efficiency and size of the reactor and cost of biogas production is reduced. Accordingly, most easily degradable organic materials are accepted as feedstock for anaerobic digestion. So, Food waste is the best option for anaerobic digestion. It is a fact that is best illustrated by the research that was studied [14-17]. Thus, about 30% of the global food supply is lost or wasted each year. Therefore, it is very important for human as well as the environment to find solutions to reduce these wasted food waste or reduce environmental pollution. So, if this food waste is used for biogas production, many benefits can be obtained.

A studied conducted production of biogas from solid waste to overcome the management problems and depletion of non-renewable energy. Here, a lab scale anaerobic digester for batch type was designed and construct. Methane production from solid waste mainly food waste (green waste, kitchen waste etc.) is used. And the main organic material is food waste and cow dung is also used. Further, a 350L plastic container of height 90cm and diameter 70cm was used as a bio digester and biogas was collected in tire tubes. Also, it was found that using a mixture of cow dung and food waste retention period was 21 days. Gas started to produce on 7th days. Amount of biogas obtained was 136dm³.

This concluded that the total biogas production can be increased by using large scale bio digesters, increasing the number of units, and providing suitable temperature conditions. In addition, the results here indicated that using a mixture of food waste and dung produces more biogas than using cow dung alone [8].

In the rate of biogas production was studied in a lab scale biogas digester model for the efficient conversion of the food waste generated from PRIST University. Biogas production was found to be dependent on factors such as the maximum biogas yield, the concentration of volatile solids in the input, the density of the effluent, the density of the biogas, and the reaction rate constant for all substrates. The experiments spanned a duration of 40 days, and the rate of gas production was measured using the water displacement method. Based on the findings of this review, it is suggested that food waste proves to be a suitable feedstock for biogas production due to its easy biodegradability and high volatile solids content [15]. Research was conducted to assess the performance of a portable floating-type biogas plant made of plastic, with a volume capacity of 0.018m³, under outdoor climate conditions at IIT Delhi in India. The study involved a comparison between cow dung and kitchen waste for biogas production using the batch method, targeting a 30kg fertilizer capacity. Various parameters, including temperature, solar radiation, relative humidity, biogas composition, pH value, volume, and daily biogas production rate, were analyzed at different levels of temperature monitoring. The results consistently demonstrated that kitchen waste outperformed cow dung in terms of both biogas production and methane fraction. Thus, as the solid content of kitchen waste is lesser than cow dung, the action of microorganisms appears to be very fast. In that way, it was concluded the kitchen waste will be the best option under a community level biogas production [17].

○ *Use of Different Bacteria matter as Co-substrate with Food Waste in Biogas Production*

Furthermore, the study presented findings on biogas production derived from waste materials of fruits and vegetables, along with an assessment of their impact on plants when utilized as fertilizer. The research revealed that the cow dung slurry exhibited the highest weekly individual production rate, with an average production of 1554 cm³, followed by pineapple waste with 965 cm³ of biogas, orange waste with 612 cm³, pumpkin waste with 373 cm³, and spinach waste with 269 cm³. These results underscored that the variability in biogas production is closely linked to the nature of the substrate. Importantly, all the substrates investigated proved to be effective materials for biogas production, and their spent slurries were identified as viable sources of plant nutrients [18].

In the study, the production of biogas from a blend of fruit and vegetable wastes combined with cow manure in an anaerobic digester was investigated. The study focused on the total solid, volatile solid, moisture content, and ash content of the waste materials. The feedstock included avocado, papaya, mango, tomato, banana peel, and cow manure. Notably, the reduction in total solid and volatile solid indicated that the production of biogas from a mixture of food waste and cow manure yields a higher volume compared to that obtained from a combination of fruit and vegetable wastes with cow manure [19].

Through various studies, biogas production was studied utilizing kitchen waste as the primary component and cow dung as a co-substrate. The process involved the use of an

anaerobic digester for gas generation, maintaining a temperature range of 30°-35°C to facilitate mesophilic conditions. The pH of the manure was regularly checked and adjusted weekly. Gas production was recorded with a retention time of 20 days, and the methane content was measured using the syringe protocol. The experiment yielded a gas production of 0.05196 m³. The findings concluded that the co-digestion of kitchen waste and cow manure generates a substantial amount of biogas with a methane content of 60%. Notably, it was observed that a significant volume of gas is produced after 7-9 days of introducing the feed into the digester, suggesting the proliferation of bacteria within the digester chamber [20].

○ *Biogas Upgrading Technologies*

Biogas is generated through the anaerobic digestion of municipal, agricultural, and industrial wastes at moderately high temperatures. The process of biogas upgrading focuses on separating methane (CH₄) from carbon dioxide (CO₂) and other biogases. This involves a two-step treatment of the biogas: first, the raw biogas undergoes purification by removing toxic compounds, and then it is upgraded, with the CO₂ content adjusted to achieve a sufficient calorific value for the biogas.

Various technologies for biogas upgrading employ separation and sorption approaches, leveraging the chemical, physical, and biological properties of gas components. These technologies are designed to enhance the quality of biogas for optimal utilization as below,

- Under physical technologies; Water scrubbing, Physical absorption of organic solvent scrubbing, Pressure swing adsorption, Cryogenic adsorption
- Under chemical technologies; Chemical scrubbing
- Under biological technologies; Chemoautotrophic method, Photosynthetic methods, In-situ desorption & Ex-situ desorption [23] [26].

So, complex and expensive above-mentioned technologies are used for high level biogas purification treatments to obtain biomethane, because they allow more efficient removal of pollutants. This improvement is done through treatment and purification processes, involving technologies to remove other gases present in biogas, separate CH₄ and increase its calorific value.

The study evaluated the Thermal Integration of anaerobic digestion (AD) biogas production with amine-based biogas upgrading to enhance the overall thermal efficiency of both systems. The thermal characteristics were scrutinized for typical AD raw biogas generation and MEA absorption biogas upgrading. The case study demonstrated that AD biogas production can be effectively integrated thermally with amine-based upgrading. In the examined scenarios of typical AD biogas production and amine absorption biogas upgrading, thermal integration was found to recover 64% to 100% of the waste heat from the biogas upgrading system. This recovered heat could then be reused in the AD system, corresponding to an increase of 5.3% to 17.4% in net raw biogas production [24].

○ *Applications of Biogas Technology*

Biogas boasts a multitude of applications, primarily in electricity generation through internal combustion engines,

gas turbines, micro-gas turbines, or on-site turbines. It is also instrumental in various thermal applications such as cooking, lighting, heating, and boiling, and contributes to the production of biofuels. Biogas extends its utility to transportation as a viable vehicle fuel and plays a role in refrigeration and cooling power plants. Furthermore, it serves as a valuable feedstock for hydrogen production, offering possibilities for energy generation, electric power, and fuel for fuel cells. The technology associated with biogas can additionally be harnessed to produce organic fertilizer, presenting an eco-friendly alternative to costly chemical fertilizers.

Biogas, when upgraded, becomes a versatile fuel source that can be employed in the processing of methanol fuel. The conversion of Compressed Biogas (CBG) and Liquefied Biogas (LBG) into biomethane allows for diverse direct and indirect applications in fuel and power generation. Processes like Combined Heat and Power generation from biogas (CHP), compression to Bio-CNG, and Bio-LPG for purified biogas or biomethane contribute to the flexibility of biogas utilization. Moreover, biogas serves as a precursor for the production of Fischer-Tropsch (FT) fuels. The FT process involves a sequence of chemical reactions transforming a mixture of Carbon Monoxide (CO) and Hydrogen (H₂), known as syngas, into liquid hydrocarbons. The production of fuel from biogas entails cleaning and purification, followed by partial oxidation before reforming into syngas, facilitating the production of methanol.

○ 4.9 Use of bio-slurry as Organic Fertilizer

It is important to provide farmers with a useful way to reduce the burden of fertilizer on the country's economy today and improve the sustainability of the field. In this regard, biogas slurry can be considered as a good quality organic fertilizer to maintain the quality of products in sustainable agriculture.

Biogas slurry not only led to the flourishing growth of plants but also increase the fertility of the soil. So, proper use of bio-slurry prevents the depletion of nutrients in the soil of agricultural lands while providing very good agricultural yields [28][30]. Accordingly, the benefits of bio-slurry are shown below.

- *Social Benefits:* Farmers face various health problems due to the use of chemical fertilizers. In addition, if chemical fertilizers are not used and stored properly, it can cause poisoning. So, apply bio slurry as a solution can reduce the problems of skin diseases, itching etc. and reduce the incidence of diseases spread by fertilizers.
- *Economic Benefits:* Chemical fertilizers are very expensive compared to organic fertilizers produced from biogas and using bio-fertilizer can save more money. Apart from this, the sale of bio-fertilizer also be economically beneficial.
- *Environmental Benefits:* The utilization of bio-slurry in agriculture leads to a notable improvement in household, kitchen, garden, and social environmental conditions [26].

Biogas slurry holds significant potential for enhancing both the physical and biological qualities of soil. This potential improvement encompasses enhancements in soil structure,

increased water-holding capacity, elevated cation exchange capacity, reduced soil erosion, and the provision of nutrients to soil micro-flora, including those involved in nitrogen fixation and phosphorus solubilization.

Furthermore, there are documented instances of increased crop yields attributed to the application of biogas slurry, particularly in India. Various crops, including field crops, tobacco, castor, chickpea, mustard, onion, cabbage, banana, chili, pearl millet, and sugarcane, have demonstrated improved yields as a result of the positive impact of biogas slurry [27].

In a conducted study, alternative nutrient sources for small-scale farmers aimed at improving sustainable agriculture and encouraging organic farming were explored. The chemical analysis of biogas fertilizer, considered as an alternative organic fertilizer, was carried out to evaluate its nutritional composition in comparison to other organic fertilizers. The findings indicated that the mean percentage concentration of nitrogen (2.14 ± 0.6233), phosphorus (1.37 ± 0.888), and potassium (0.70 ± 0.3684) in bio slurry surpassed those in manure compost and farmyard manure. Moreover, with a standardized and known concentration range, biogas fertilizer was identified as an environmentally friendly option capable of increasing yields, buffering acidic soils through its liming characteristics, improving soil structure, and facilitating an integrated plant nutrition system. It was also suggested that its use could potentially reduce the reliance on chemical fertilizers by up to 50% [29].

○ Disadvantages of utilizing Biogas

- *Lack of technology development:* The primary drawbacks of biogas plants lie in the limited efficiency of the current systems, producing biogas sufficient for only certain energy needs. The large-scale sourcing of biogas remains a challenge, and governments are yet to make significant investments in this sector. There is a continued need for technological advancements in biogas plants to enhance their production capacity of biogas while maintaining a low-cost investment.
- *Effects of temperature:* Bacteria tend to digest food waste at an optimal temperature of 37%. Unlike other renewable energies, biogas production is affected by the weather. Hence in relatively colder temperatures, heat energy is needed to maintain a constant biogas supply.
- *Traces of impurities:* Biogas contains impurities even after refinement, and compression. These impurities can corrode some parts of the engine in vehicles.

V.CONCLUSION

Energy is a fundamental requirement for the comfort and basic needs of everyday life. In today's energy-demanding lifestyle, there is an imperative need to explore new renewable and eco-friendly energy sources. 'Biogas' emerges as a promising renewable energy source successfully implemented at both domestic and commercial scales. To gain a comprehensive understanding, this paper reviews the literature on biogas technology and anaerobic digestion, providing a clear overview of the fundamentals. The review

encompasses topics such as anaerobic digestion, feedstock, types of digesters, and the products of anaerobic digestion. Additionally, the paper presents parameters influencing biogas production and those considered in the design of anaerobic digesters. The advantages and disadvantages of biogas, its applications, biogas upgrading technologies, and the use of bio slurry as fertilizer are also discussed.

ACKNOWLEDGMENT

This paper is part of Techno Economic Societal Sustainable Development Training in Sri Lanka (TESS) Project: 609925-EPP-1-2019-1-NO-EPPKA2-CBHE-JP, which is co-funded by the European Commission under its ERASMUS+CBHE programme.

REFERENCES

- [1] Moses Jeremiah Barasa Kabeyi and Oludolapo Akanni Olanrewaju, "Biogas production and applications in the sustainable energy transition", Industrial engineering department, Durban university of technology, Durban, South Africa, 09 Jul 2022.
- [2] Shahab Alddin Shokri, "Biogas technology, applications, perspectives and implications", Department of agricultural economic, Rodehen Branch, Islamic Azad University, Rodehen, Iran, December 12th 2011.
- [3] Moses Jeremiah Barasa Kabeyi and Oludolapo Akanni Olanrewaju, "Development of a biogas plant with electricity generation, heating & fertilizer recovery systems", Department of industrial engineering, Faculty of engineering & the built environment Durban university of technology, Durban, SA, December 7-10, 2020.
- [4] Venko Beschkov, "biogas production: evaluation and possible applications", December 24th, 2021 DOI: 10.5772/intechopen.101544
- [5] Sebastian Gollnow, Torsten Rehl and Enno Bahrs, "Economic and environmental system analysis of a biogas plant", University of Hohenheim, Department of farm management, Germany, October 22, 2015.
- [6] Dr. Osama Mohammed Elmardi Suleiman Khayal, "Main types and applications of biogas plants", Department of mechanical engineering, Faculty of engineering and technology, Nile Valley University, Atbara-Sudan, October 2019, DOI:10.13140/RG.2.2.32559.69287
- [7] Ishmael M Ramatsa, Esther T. Akinlabi, Daniel M. Madyira and Robert Huberts, "Design of the bio digester for biogas production: review", Department of mechanical engineering science & department of chemical engineering, University of Johannesburg, South Africa, 2016.
- [8] Ali Akhter Attari, Muhammad Mehtab Attari and Muhammad Tanveer Ahamed Ranjah and Zulqarnain Haider "Biogas production from anaerobic digestion of food waste", Faculty of mechanical engineering, GLK institute of engineering science & technology, May 2013.
- [9] Karthik Rajendran, Solmaz Aslanzadeh and Mohammad J. Taherzadeh, "Household biogas digesters-a review", School of engineering, University of Borås, Borås 50190, Sweden, 8 August 2012.
- [10] Dr. Solomon Libsu and Dr. Ayalew Wonde, "Implementation of low cost technology for biogas generation from kitchen wastes: an alternative source of renewable energy", Department of chemistry, College of science, Bahir Dar University, Bahir Dar, Ethiopia, July. 11, 2011.
- [11] Peshatwar S.V, Chaudhari M.B, Mahajan Yash, Salunke Pavan, Nale Pradip, and Vipat Vishal, "Design and analysis of biogas digester", S.B. Patil College of engineering, Indapur, Pune-413106, MH, India, 11 November 2019.
- [12] Abdullah Nsair, Senem Onen Cinar, Ayah Allassali, Hani Abu Qdais and Kerstin Kuchta, "Operational parameters of biogas plants: a review and evaluation study", Sustainable resource and waste management, Hamburg university of technology, Blohmstr. 15, 22 July 2020, Energies 2020,13,3761;doi:10.3390/en13153761
- [13] Katarzyna Ignatowicz, Gabriel Filipczak, Barbara Dybek and Grzegorz Walowski, "Biogas production depending on the substrate used: a review and evaluation study", Department of technology, Branch Poznan, Poland, 2023, 16(2), 798; <https://doi.org/10.3390/en16020798>
- [13] Chamarthi Subba Rao, Vardhanapu Sudeep Kumar and Mohammed Shakeel, "Analysis on different operational parameters of a biogas plant using kitchen waste", Mechanical engineering department, Vardhaman college of engineering, Andhapradesh, India, December 2013.
- [14] Ojikutu Abimbola O. and Osokoya Olumide O., "Evaluation of biogas production from food waste", Department of mechanical engineering, Obafemi Awolowo University (OAU), Ile-Ife, Osun State, Nigeria, 2014.
- [15] P. Moanonmani, Lurwan Muazu, M.C. Kamaraj, Mukesh Goel and R. Elangomathavan, "Biogas production potential of food waste", Department of biotechnology, Center for research and development, PRIST University Thanjavur, India, Vol-2, issue-2, Mar-Apr-2017, ISSN: 2456-1878
- [16] Sulaiman Muhammad Musa, Dr Mahadi Makwayo, Khalid Da'u Khalid, Anas Abdullahi Muhammad, Nabil Isyaku Mu'az and Zaharaddeen Aminu Bello, "Biogas productions from food waste and functional working methane gas digester design", Faculty of technology, Department of mechanical engineering, Jodhpur National University, Namadi Jhanwar Road, Boranada, Rajasthan, India, 2016.
- [17] Ravi P. Agrahari and G.N. Tiwari, "Comparative study of biogas production: utilization of organic waste", Centre for energy studies, IIT Delhi, Hauz khas New Delhi, India-110016, February 2014, DOI:10.14355/ijer.2014.0301.01
- [18] Sani Aliyu, "Biogas production using different wastes: a review", Department of microbiology faculty of natural and applied science, Umaru Musa Yar Adua University, Katsina, 4/12/2019, <https://doi.org/10.47430/ujmr.1942.013>
- [19] Leta Deressa, Solomon Libsu, R.B. Chavan, Daniel Manaye and Anbessa Dabassa, "Production of biogas from fruit and vegetable waste mixed with different wastes", Department of chemistry, Faculty of natural and computational sciences, Ethiopia, 2015, DOI: 10.13189/eer.2015.030303
- [20] Thokchom Subhaschandra Singh and P. Sankaralal, "Production of biogas from kitchen waste using cow manure as co-substrate", Department of mechanical engineering, J.J college of engineering and technology, Tiruchirapalli, Tamilnadu, India, March 2015.
- [21] Hamidatu S. Darimani and Dinesh C. Pant, "Biogas production from co-digestion of grass with food waste", Department of agricultural engineering, School of engineering, Wa Polytechnic, Wa, Upper West, Ghana, 2020, 9, 27-36
- [22] Shams Forruque Ahmed, M. Mofijur, Karishma Tarannum, Anika Tasnim Chowdhury, Nazifa Rafa, Samiha Nuzhat, P. Senthil Kumar, Dai-Viet N. Vo, Eric Lichtfouse and T.M.I. Mahlia, "Biogas upgrading, economy and utilization: a review", Environmental Chemistry Letters, August 2021, DOI:10.1007/s10311-021-01292-x
- [23] Paulo s Domingues, Helena Pala and Nelson s Oliveira, "Main biogas upgrading technologies", Laboratory of separation and reaction engineering laboratory of catalysis and material (LSRE-LMS), Polytechnic Institute of Leiria, Portugal, April 2021, ISSN:2572-1119
- [24] X Zhang, J Yan, H. Li, S. Chekani and L.Liu, "Energy saving for biogas production and upgrading -thermal integration", ABB AB, Corporate research, 72178, Vasteras, Sweden, 2014, International Conference on Applied Energy-ICAE2014
- [25] Rimika Kapoor, Pooja Ghosh, Madan Kumar, and Virendra Kumar Vijay, "Evaluation of biogas upgrading technologies and future perspectives: a review", Springer-Verlag GmbH Germany, part of Springer Nature 2019, 26:11631-11661
- [26] Yalemtehay Debebe and Dr. Teshome Soromessa, "Socio economic and environmental benefits of biogas slurry", Jimma Agricultural Research Center, Jimma, Ethiopia, 2016.
- [27] Sandeep Kumar, Lal Chand Malav, Mahesh Kumar Malav and Shakeel A Khan, "Biogas slurry: source of nutrients for eco-friendly agriculture", Centre for environment science & climate resilient

- agriculture, Indian Agricultural Research Institute, New Delhi 110012 India, 2015.
- [28] J. Devarenjan, G.M. Joselin Herbert and D. Amutha, "Utilization of bioslurry from biogas plant as fertilizer", *International Journal of Recent Technology and Engineering (IJRTE)*, November 2019, ISSN: 2277-3878
- [29] Nyang'au Jared, Gatebe Erastus, Nyagah Christopher, and Ahenda Steve, "Evaluation of biogas slurry as an alternative organic fertilizer: a case study in Kenya", Department of chemistry, College of pure and applied science, Jomo Kenyatta University of agriculture and technology, Nairobi 62000-00200, Kenya, 2016.
- [30] L.T.C. Bonten, K.B. Zwart, R.P.J.J. Rietra, R. Postma and M.J.G. De Haas, "Bio-slurry as fertilizer", Alterra Wageningen UR, Nutrient Management institute NMI, SNV Netherlands Development Organisation, April 2014.
- [31] Katarzyna Ignatowicz, Gabriel Filipczak, Barbara Dybek and Grzegorz Walowski, "Biogas production depending on the substrate used: a review and evaluation study", *Department of Technology, Branch Poznan, Poland*, 2023, 16(2), 798; <https://doi.org/10.3390/en16020798>

Recycling of Blended Fiber Fabrics for Sustainable Textile Industry: Short Review of Methods and Processes

M.H.Methmini Tharanga
Department of Textile and Apparel Technology
University of Vocational Technology
Colombo, Sri Lanka
methminir@uovt.ac.lk

Abstract— The growing forecast of the environmental footprint of the textile industry due to the continued manufacture of synthetic fiber textiles has led the research community to find new methodologies to move forward as a sustainable industry contributing to circularity. Unlike 100% synthetic fiber fabrics, blended fiber fabrics challenge the circularity process. This short review highlights the methods and processes recorded in the literature during the last five years on the recycling of blended fiber fabrics towards fabric-to-fabric recycling, which stands for closed loop recycling. Blended fiber fabrics, such as Polyester/Cotton, Cotton/Wool/Polyester, Polyester/Viscose and Polyester/Wool recycling methods discovered in recent studies, have become the focus and are categorized under mechanical, chemical, and biological methodologies.

Keywords—Blended Fiber, Multi Fiber, Textiles Circularity

I. INTRODUCTION

The world's textile demand is increasing due to the rise in global population growth and the fast fashion industry movement (Ling et al., 2019). When comparing the fiber production of the world in the last decade, it is noticed that 58 million tons were produced in 2000, and it has doubled in 2020, reaching 109 million tons. Further, it is expected to exceed 100 million tons by 2025, with an increase of 34% by 2030 (Kahoush & Kadi, 2022). Out of which, about 7 million tons of textiles are annually end up as landfills. This is a global issue that has attracted the attention of researchers seeking solutions (Subramanian et al., 2020; Nørup et al., 2019). Textile waste is classified as pre-consumer waste, post-consumer waste, and post-industrial waste (Quartinello et al., 2018). As estimated, the post-consumer textile waste of garments, which has an average lifespan of 5 years, is disposed of globally at a rate of 65–92 million metric tons (Mt) annually (Egan et al., 2023). From region to region of the world, the textile waste varied due to their cultures, population density, fashion choices and lifestyles, and income. Estimated annual textile waste in China, the UK, and the US is 26, 1.7, and 15.1 million tons, respectively, which counts ~6% of the entire municipal solid waste generation. This textile waste contributes to global greenhouse gas emissions, representing 3% of them (Yousef et al., 2020). Nearly 25% of wasted textiles are recycled or reused. Less than 1% is recycled and taken back into clothing (Juanga-Labayen et al., 2022).

Both natural and synthetic fibers are used in textile manufacturing. 64% of the global textile fiber production is from petrochemicals, and the balance of 36% is contributed by 24% of cotton, 6% of synthetic cellulose, 1% wool, and other types of cellulosic fibers (Egan & Salmon, 2021; Navone et al., 2020). Fig.1 indicates the global fiber production share in 2019 clothing (Juanga-Labayen et al., 2022). Natural fibers are dominated by cotton, while linen, hemp, bamboo, banana, lotus, and viscose are also part of them. Wool and silk are the natural fibers that exist as protein fibers. Polyester is dominating as the largest fiber producer in textiles. Due to the advantages of improving the properties of textiles, such as wettability, surface smoothness, and elasticity, manufacturers are used to going for blended fibers such as cotton-polyester, polyester-wool, nylon-cotton, and polyester-polyurethane (Navone et

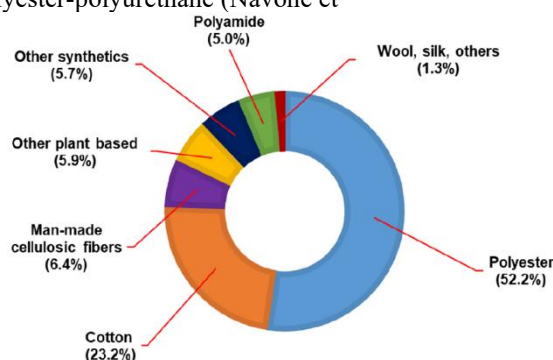


Fig. 1 Global fiber production share in 2019 clothing (Juanga-Labayen et al., 2022)

al., 2020; Quartinello et al., 2018). The blended fiber market is anticipated to grow from USD 41.5 billion in 2022 to USD 70.3 billion by 2032, as shown in fig.2. The Asia-Pacific region has a higher production of blended fiber, according to fig.3 (Nagrle, 2023). Currently, the recovery of all these blended fiber-based textiles at the end of their use undergoes either re-use as textiles or repurposing for different end uses (Navone et al., 2020). Blended fiber textiles are facing challenges in recycling due to different fiber blends that are difficult to separate, chemicals used for textile finishes, and dyes that make it necessary to find various methods and technologies for their fiber separations (Egan et al., 2023).

Mechanical or chemical recycling is the most commonly used method for the recycling of blended fiber textiles. Mechanically recycled waste textiles are used for

agricultural, construction, and decoration purposes. The depolymerization of polymers in blended textiles, such as polyester, and the dissolution of cellulosic compounds in the blend happen in the chemical recycling process (Juanga-Labayen et al., 2022). In addition, enzymatic hydrolysis (Subramanian et al., 2020) and biological methods, such as microbial and insect use (Egan & Salmon, 2021; Sashiwa et al., 2018; Biological Degradation of Textiles and the Relevance to Textile Recycling, 2021), have been applied in recent studies for the recycling of waste textiles with different fiber blends.

This short review has investigated the recent studies done on blended fiber textile recycling methods and techniques during the last five years and published in research journals.

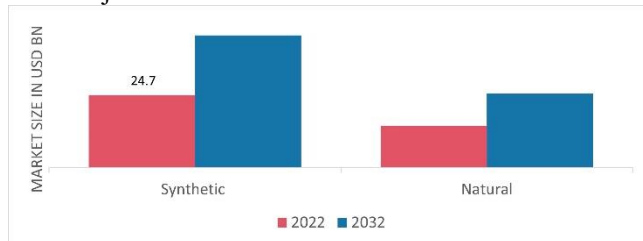


Fig. 2 Blended Fibers Market, 2022 and 2032 (USD Billion) (Nagrle, 2023)

II. METHODOLOGY

A systematic review approach is followed in writing this review paper. 42 research papers titled “textile waste recycling”, “textile Circularity”, and “textile waste management” were picked mainly from journal databases such as Elsevier, MDPI, and Springer that were published during the period of 2018–2023. Literature that complements the focus of this research review was further filtered by the key search terms of “blended fiber”, “multi-fiber”, “textile circularity”, and “closed-loop”, and finally, 22 research papers, including review papers, were referenced in this study. The methodologies applied to recycling blended fiber and textiles for a closed-loop approach have been evaluated in this review. The methodology followed in selecting complementary literature for this review paper title is illustrated in fig. 4.

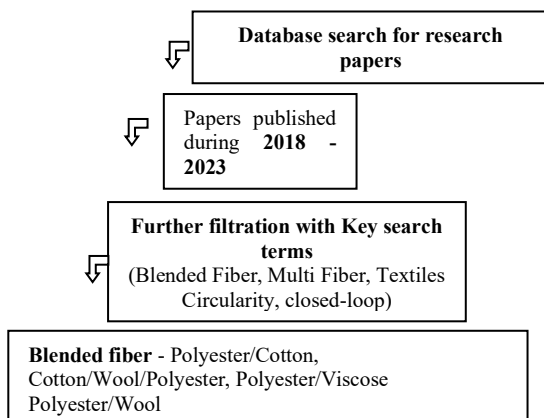


Fig. 4 Methodology exemplification in selecting relevant research articles

III. RESULTS AND DISCUSSION

The new methodologies found in the reviewed research articles are categorized by prioritizing the blend of the fibers and subdivided into mechanical, chemical, and biological methods.

Polyester/Cotton Recycling

Chemical separation of cotton-polyester blends is identified in the literature as three different approaches. One approach is that one component is dissolved and the other component is undissolved. In this method, the undissolved part is extracted and the dissolved part is recovered. Another approach is to completely destroy the cotton part and separate the polyester for recycling. The other method is to perform the depolymerization of polyester and save the cellulose in cotton (Kahoush & Kadi, 2022).

A new strategic approach to recovering cotton from polyester/cotton blended textiles presented by Yousef (2020) introduces the discharge of textile dyes from the waste textiles using Nitric Acid as an ingredient for pretrea-

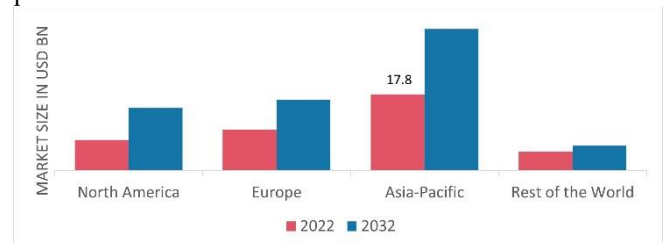


Fig. 3 Blended Fibers Market Share by Region 2022 (USD Billion) (Nagrle, 2023)

ment, the use of Dimethyl Sulfoxide (DMSO) to dissolve organic compounds in the treated textile, polyester, and left-over organic compounds from textile dyes, and the involvement of diluted hydrochloric acid and Sodium Hypochlorite during the bleaching process to purify the recovered cotton from the textile. As a preliminary test, waste jean samples of cotton (80%)/polyester (20%) were washed with water to remove the impurities and air dried. Pieces in the size range of 50-150mm² were obtained by shredding the dried samples. The capacity of a 1L ultrasonic bath was used to identify the conditions of dissolution and optimal leaching. 20g of pieces were exposed to nitric acid (HNO₃) at a concentration of 1.0 M for 20 minutes to dissolve the dyes. A 1g sample from that has been taken, and DMSO solvent treatment has been done in 60 ml of solvent for 9 hours at a constant temperature of 50 °C to dissolve organic compounds in the textile and the textile dyes and polyester. A developed reactor has been used for the pilot experimentation following the conditions identified during the preliminary testing. Leaching with nitric acid was performed at 50 °C for 20 min in a solid to liquid ratio of 1:50. Then the DMSO solvent was used to dissolve the organic components and the polyester in the fabric for 6hrs at 50°C. Sodium Hypochlorite and dilute hydrochloric acid were used to bleach the recovered fibers under the treatment of a soundwave at 40 °C for 2hrs to remove the impurities. At the end of the process, the used

acid was regenerated, and polyester was extracted from cotton, making the whole process a closed-loop strategy to recycle the blended fiber.

Haslinger (2019) has studied cotton/polyester blended textile recycling with a closed-loop approach to generating man-made cellulosic fibers (Wang & Salmon, 2022). In this study, a vertical kneader system was used to combine the cotton polyester blend with an equal number of moles of 1,5-diazabicyclo(4.3.0)non-5-ene (DBN) and glacial acetic acid ([DBNH][OAc]) for 1 hour at 80 °C, producing a 6.5 w% cellulose solution. To reduce the degradation of polyester, another sample was prepared with a 1:1.3 ratio of acetic acid, and undisclosed polyester was separated following hydraulic pressure filtration at 70 °C by a 5–6 mm fine metal filter mesh at 1–8 MPa. To increase the cellulose concentration to 10.5%, the solution filtered was added with cotton polyester blends at 80°C for 1hr. A solution of cellulose was allowed to solidify at 8°C for a few days, and direct dry-jet-wet spinning was performed to generate man-made cellulose fibers. Separated polyester was purified with fresh ionic liquid to remove the contaminated cellulose residue. Filtration and subsequent washing with de-ionized water were used to eliminate the solvent. The separated polyester is suggested to reuse in polyester filament generation.

Cotton/Wool/Polyester Recycling

Quartinello (2018) has experimented with the recovery of amino acids from wool, glucose from cotton and other cellulosic constituents, and poly from polyester by an enzymatic hydrolysis process. The use of proteases and cellulases for the extraction of amino acids and glucose, respectively, is captured in this study. Both textile waste containing 100% cellulose, polyester, and wool, as well as fiber-blend materials such as cotton/polyester, wool blends, polyamide, and textiles prepared by mixing known percentages of cotton, wool, and polyester, were used for the experimentation. A weighted 1g of each sample has been incubated for two days at 50 °C with 75 ml of 50 mM Tris-HCl buffer pH 9 and 8 U ml⁻¹ of protease while being swirled at 400 rpm on a magnetic stirrer. Following vacuum filtration with a Polyethersulfone (PES) 0.2 M filter, treated samples were added to 75 ml of mQ-H₂O and stirred at 400 rpm for 30 minutes, then filtered and dried for 6 hours at 105 °C. Cellulase cocktail (2750 U ml⁻¹) was incubated in 75 ml of 50 mM sodium citric buffer pH 4.8 for five days at 50 °C at 400 rpm. The samples were weighted both before and after each phase. Further analysis of the extracts was performed to analyze the extracts of cellulose, protein, and polyester. According to Quartinello (2018), through the protease treatment, it was able to recover about 90% of the protein from the wool fiber-mixed textiles, and approximately 80% of the cellulose fibers were recovered from the treatment of cellulose. Amino acids extracted from wool proteins are used for resins, and glucose extracted from cellulosic compounds is used as the source of carbon for the fermentation of yeast in ethanol production. Extracted poly has been identified as similar to pure polyethylene terephthalate (PET) and suggested for recycling.

Polyester/Viscose Recycling

Peterson (2022) has experimented with the alkaline hydrolysis process to separate viscose and polyester from blended textiles. 70% viscose and 30% polyester and 100% viscose and 100% polyester fabrics are taken from well-known suppliers and cut into 1cm² pieces and laundered at 60 °C as per the Swedish standard SS-EN ISO 6330:2012. Samples were oven-dried for 2hrs at 105 °C. Sodium hydroxide (NaOH, 50%), reagent-grade sulfuric acid (H₂SO₄, 95–97%), and pure acetic acid are used for the experimentation. A 1:100 solid-to-liquid ratio was followed to perform the alkaline hydrolysis of viscose/polyester, pure viscose, and pure polyester fabrics. Oven-dried fabric samples were added to heated (90 °C) 5 wt% NaOH to perform the hydrolysis for 60–1440 min, immersing the reaction vessel in an ice bath. Filtration was applied to separate the solid residue from the reaction solution with the support of knitted polyester-wire fabric. Extracted solids were subjected to neutralization in 5% acetic acid and dried for 4hrs at 105 °C after washing for further analysis. Alkali was neutralized with sulfuric acid. Due to the alkaline treatment, natural viscosity has weakened up to 35% of the cellulose. Hence it is not recommended for fiber to fiber recycling, but suggested for emerging fiber processes.

Polyester/Wool Recycling

Enzymatic digestion of wool from wool/polyester blended fabric was studied by Navone (2019). Over 95% of the weight in wool is made up of keratin proteins (Quartinello et al., 2018). Fabric samples of 100% knitted wool, 100% woven wool, 70% wool/30% polyester knit, 45% wool/55% polyester woven, 100% knitted polyester, and 100% woven polyester received from Frost textiles were used for the experimentation. The determination of the keratinase activity was performed using keratin azure as the reactant (Navone & Speight, 2018). In 2.4 ml of pH 8 or pH 10 100 mM Tris-HCl buffer, 0.01 g of keratin azure was combined with 100 µL of enzyme dilution. Incubation of the samples was done at 200 rpm at 37 °C for 1hr and then the incubated samples were centrifuged for 10 min at 4000 rpm and the absorbency of the supernatants was determined at 595 nm. Each enzyme dilution's results were verified three times. Sodium sulfite (1%, 1.5%, or 2%) or sodium thioglycolate (2%, 3%, 4%, or 5%) are used as reducing agents.

The protease that is used for this experiment is Ronozyme ProAct. 0.1g of fabric pieces cut by scissors into the size of 5mm x5mm or grounded pieces in size ≤0.6 mm with the support of a mill and sieves were kept at 37 or 50 °C for 16hrs at pH 10 in 5 mL of 100 mM Tris-HCl buffer, treating proteases of 2, 4 and 10 KU/mL at 200 rpm. Sodium sulfite 1% or Sodium thioglycolate 2% or 3% were added. A treatment consisting of two steps was also followed keeping the above followed conditions as the same and only adding 2% sodium thioglycolate at 50 °C at 200rpm for 6hrs and centrifuged for 10mins at 4000rpm, washed with water, and again adding 2% sodium thioglycolate and incubating at 50 °C at 200rpm for 14-16 hrs. The Bradford assay principle was used to measure peptide solubility after enzymatic treatment. The weight loss served as the

determinant of the degradation %. Polyester fibers that are undigested are recovered through this process without making any significant changes to their virgin properties.

Lebedyć & Sun (2022) have studied the closed loop method of recycling wool with a chemical process with solvents and reductions to extract keratin solution. With the blending of other materials and the wet processing, the extracted keratin solution is recommended for the generation of novel fibers for textile manufacturing (Lebedyć & Sun, 2021).

IV. CONCLUSION

The recycling of blended textile waste has paid huge attention to its life cycle assessment to make sure that the process followed is ecologically and economically viable. Recycling of blended fiber textiles supports circularity and the study methodologies can be supportive for future researchers to look for the possibilities to enhance the properties of regenerated novel fibers from recovered or extracted parts. Cellulose extracted from cotton-blend textile wastes is needed to be blended with other fibers to enhance the properties, such as tensile strength, of the generated fibers. The enzymatic processes are leading to recycling the blended fibers because of their compatibility with ecological processing. While searching for solutions to the recycling of waste textiles, which are more complex at blended fibers, it is important to make consumers aware of their responsibility in consumption towards reducing waste collection to landfills, changing their mindsets in accepting fast fashion movements.

ACKNOWLEDGMENT

A special thank you is extended to all of the writers of the research papers cited for their extensive insights into the most recent advancements in blended textile fiber recycling and for presenting novel solutions to reduce the environmental harm that occurs due to textile waste ending-up at landfills. I also want to express my gratitude to the University of Vocational Technology for setting up a forum for publishing research.

REFERENCES

Biological degradation of textiles And the relevance to textile recycling. (2021, November). Wageningen University and Research. <https://edepot.wur.nl/557073>

Egan, J., & Salmon, S. (2021, December 18). Strategies and progress in synthetic textile fiber biodegradability. *SN Applied Sciences*, 4(1). <https://doi.org/10.1007/s42452-021-04851-7>

Egan, J., Wang, S., Shen, J., Baars, O., Moxley, G., & Salmon, S. (2023). Enzymatic textile fiber separation for sustainable waste processing. *Resources, Environment and Sustainability*, 13, 100118. <https://doi.org/10.1016/j.resenv.2023.100118>

Egan, J., Wang, S., Shen, J., Baars, O., Moxley, G., & Salmon, S. (2023, September). Enzymatic textile fiber separation for sustainable waste processing. *Resources, Environment and Sustainability*, 13, 100118. <https://doi.org/10.1016/j.resenv.2023.100118>

Haslinger, S., Hummel, M., Anghelescu-Hakala, A., Määttänen, M., & Sixta, H. (2019, September). Upcycling of cotton polyester blended textile waste to new man-made cellulose fibers.

Waste Management, 97, 88–96. <https://doi.org/10.1016/j.wasman.2019.07.040>

Juanga-Labayen, J. P., Labayen, I. V., & Yuan, Q. (2022, March 16). A Review on Textile Recycling Practices and Challenges. *Textiles*, 2(1), 174–188. <https://doi.org/10.3390/textiles2010010>

Kahoush, M., & Kadi, N. (2022). Towards sustainable textile sector: Fractionation and separation of cotton/ polyester fibers from blended textile waste. *Sustainable Materials and Technologies*, e00513. <https://doi.org/10.1016/j.susmat.2022.e00513>

Kahoush, M., & Kadi, N. (2022, December). Towards sustainable textile sector: Fractionation and separation of cotton/ polyester fibers from blended textile waste. *Sustainable Materials and Technologies*, 34, e00513. <https://doi.org/10.1016/j.susmat.2022.e00513>

Lebedyć, M., & Sun, D. (2021, June 30). A review: can waste wool keratin be regenerated as a novel textile fibre via the reduction method? *The Journal of the Textile Institute*, 113(8), 1750–1766. <https://doi.org/10.1080/00405000.2021.1940018>

Ling, C., Shi, S., Hou, W., & Yan, Z. (2019). Separation of waste polyester/cotton blended fabrics by phosphotungstic acid and preparation of terephthalic acid. *Polymer Degradation and Stability*, 161, 157–165. <https://doi.org/10.1016/j.polymdegradstab.2019.01.022>

Nagrale. (2023, August). Blended Fibers Market Research Report Information By Source (Synthetic and Natural), By Product (Cotton/Polyester, Cotton/Polyester/Cellulose, Nylon/Wool, Elastane/Nylon/Cotton), By Application (Apparel, Home Furnishing, Technical) And By Region (North America, Europe, Asia-Pacific, And Rest Of The World) –Market Forecast Till 2032. <https://www.marketresearchfuture.com/reports/blended-fibers-market-6542>

Navone, L., & Speight, R. (2018, August 16). Understanding the dynamics of keratin weakening and hydrolysis by proteases. *PLOS ONE*, 13(8), e0202608. <https://doi.org/10.1371/journal.pone.0202608>

Navone, L., Moffitt, K., Hansen, K. A., Blinco, J., Payne, A., & Speight, R. (2020, February). Closing the textile loop: Enzymatic fibre separation and recycling of wool/polyester fabric blends. *Waste Management*, 102, 149–160. <https://doi.org/10.1016/j.wasman.2019.10.026>

Nørup, N., Pihl, K., Damgaard, A., & Scheutz, C. (2019). Quantity and quality of clothing and household textiles in the Danish household waste. *Waste Management*, 87, 454–463. <https://doi.org/10.1016/j.wasman.2019.02.020>

Peterson, A., Wallinder, J., Bengtsson, J., Idström, A., Bialik, M., Jedvert, K., & de la Motte, H. (2022, June 14). Chemical Recycling of a Textile Blend from Polyester and Viscose, Part I: Process Description, Characterization, and Utilization of the Recycled Cellulose. *Sustainability*, 14(12), 7272. <https://doi.org/10.3390/su14127272>

Quartinello, F., Vecchiato, S., Weinberger, S., Kremenser, K., Skopek, L., Pellis, A., & Guebitz, G. (2018, October 7). Highly Selective Enzymatic Recovery of Building Blocks from Wool-Cotton-Polyester Textile Waste Blends. *Polymers*, 10(10), 1107. <https://doi.org/10.3390/polym10101107>

Quartinello, F., Vecchiato, S., Weinberger, S., Kremenser, K., Skopek, L., Pellis, A., & Guebitz, G. (2018, October 7). Highly Selective Enzymatic Recovery of Building Blocks from Wool-Cotton-Polyester Textile Waste Blends.

Polymers,10(10),1107.

<https://doi.org/10.3390/polym10101107>

Quartinello, F., Vecchiato, S., Weinberger, S., Kremenser, K., Skopek, L., Pellis, A., & Guebitz, G. (2018, October 7). Highly Selective Enzymatic Recovery of Building Blocks from Wool-Cotton-Polyester Textile Waste Blends. *Polymers*, 10(10), 1107. <https://doi.org/10.3390/polym10101107>

Subramanian, K., Chopra, S. S., Cakin, E., Li, X., & Lin, C. S. K. (2020). Environmental life cycle assessment of textile bio-recycling – valorizing cotton-polyester textile waste to pet fiber and glucose syrup. *Resources, Conservation and Recycling*, 161, 104989. <https://doi.org/10.1016/j.resconrec.2020.104989> . <https://doi.org/10.1016/j.resconrec.2019.02.031>

Resources, Conservation and Recycling, 145, 359–369. <https://doi.org/10.1016/j.resconrec.2019.02.031>

Wang, S., & Salmon, S. (2022, September 5). Progress toward Circularity of Polyester and Cotton Textiles. *Sustainable Chemistry*, 3(3), 376–403. <https://doi.org/10.3390/suschem3030024>

Yousef, S., Tatariants, M., Tichonovas, M., Kliucininkas, L., Lukošiučė, S. I., & Yan, L. (2020, May). Sustainable green technology for recovery of cotton fibers and polyester from textile waste. *Journal of Cleaner Production*, 254, 120078. <https://doi.org/10.1016/j.jclepro.2020.120078>

Yousef, S., Tatariants, M., Tichonovas, M., Sarwar, Z., Jonuškienė, I., & Kliucininkas, L. (2019, June). A new strategy for using textile waste as a sustainable source of recovered cotton.

Integration of Skill Development & Waste Management for Waste to Wealth

Dr. Rajat Kumar Panigrahi

*Skill Development and Technical Education and Training
Govt. Industrial Training Institute, Berhampur*

Pinaki Patnaik

*Skill Development and Technical Education and Training
Additional Secretary to Government, SD &TE Deppt. And OSD
to Chairman, OSDA, Bhubaneswar
pinaki.patnaik@gov.in*

Abstract— Under Education Sustainable Development Govt. ITI Berhampur trainees designed and fabricated some beautiful Sculptures from the scraps in the design thinking lab. Scraps from the workshop of the technical institute generated during training practice are being up-cycled and given a sculptured shape with aesthetic look and finishing. This enhances the hands on skills such as fitting, welding, painting, filling and turning of the students. The designed sculptures are in high demand among interior decorators and have high market value. By this the trainees are earning money during their training practice at the same time they became warriors of the planet to lead sustainability, transformed the campus into an educational wonderland. This develops interest among the students to have career in the TVET sector.

Keywords— Skill development, waste management, waste to wealth, sustainable employment, economic development

I. INTRODUCTION

Skill gap minimization and green challenge initiative provided an opportunity for an innovative best practice on circular economy waste to wealth initiative enhancing hands on skill of ITI, Berhampur students. Hands on skills are abilities applied through active engagement and practical learning rather than class room lecturer or books. These skills can be achieved by practising what they are learning immediately. More and more practice will enhance the level of skill and minimise the skill gap and make them industry ready, entrepreneur opportunities, positive carbon footprint and waste management. Waste management is the systematic way of reusing through innovative methods that are recycled with attention to the least negative impact on the environment.

During training practice in training institutes, service centres of electrical, electronic equipment, automobile workshops various waste materials are generated. Wastes are normally rejected material after being used by the students for the first time they cannot be used again in training practice. As per global waste composition 4% are material waste and 17% are rubber waste. [1]

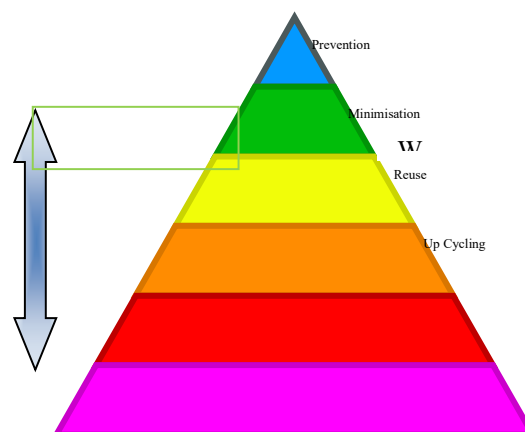


Fig. 1 Waste hierarchy pyramid

When the metal scraps are recycled for producing the recycled product they cause global warming with a potential 2.1 kg CO₂eq/kg HRC. [2]

When the buildings are demolished the iron bars, water tank, grills are the residues which are being collected for recycling by the scrap venders. Most of the TMT bars are reused with recycling. They are melted from a new object or iron rods/sheets. When these bars are up cycled and value addition is there the CO₂ emersion is prevented thus leading to positive carbon footprint. When the TMT bars are used for a long time inside the concrete slab, RCC structure their bond strength and tensile strength is reduced. [3] The TMT bars collected from the scrap yards of the city are being up cycled here at the design thinking lab by the student.

Normally in all most all cities tyres are dumped in scrap yards. When exposed to sun light the tyre are degraded. The degraded items spoil the soil and mix with the underground water. After mixing with groundwater year after year the water is contaminated. When put under sunlight years together some time the tyres catch on fire. When the tyres catch fire it pollutes the entire atmosphere. This black smoke spreads in air. These tyres are breeding place of mosquitoes. When water remains inside the tyre, the chemicals from the tyre mix with the water and temperature of the water is suitable for dengue mosquitoes to breed and spread diseases. These problems can be solved by properly up cycling the tyres and disposing them from the tyre scrap yard. [4] The scrap tyres can be up cycled into different artefacts for interior decorators, landscaping, and outdoor

park a tyre art park is developed at the campus of ITI, Berhampur.

Circular economy is the innovative methods adopted by the team by up cycling the waste material by reducing and reusing the materials. [5]

Interior decoration has a huge potential to rise in the coming days. It is expected to reach USD 58.24 billion by 2029 (Fig. 2). In India the interior decorative industry is directly proportional to the real estate market. In India the demand for the interior decorative items particularly from waste to wealth is increasing every year. The corporate houses, hostels even in flats, village the interior decorators opt for sculptures from scrap metals, e waste, tyres etc. [6]

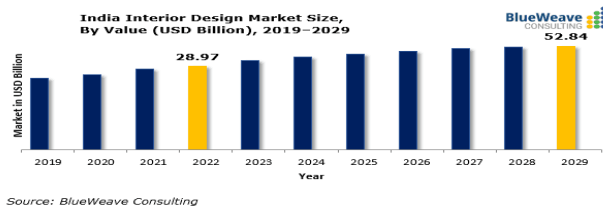


Fig. 2. Interior Design Market of India in 2029

All the discarded materials are to be manufactured such that they should be inputs for use by others. Even though zero waste is a target that is ethical, economical, efficient and visionary, this can only be achieved by up cycling the wastes.

Govt. ITI Berhampur students adopt this as an innovative good practice for up cycling the discarded materials by adding value by their skill. Zero impact on the environment and making the green TVET is the present need of the hour.

To make the environment clean, green and pollution free is the mission for TVETs and this is a great green challenge for TVETs. In a first innovative step, the ITI, Berhampur integrated their existing skills in an innovative manner to address the waste challenge. The scraps such as automobile, e waste metal scraps, electrical scraps, PVC wires tires from two-wheeler and four wheeler generated during training practice are processed after value addition upgraded into beautiful sculpture.

Annually more than 1000 Kgs scraps are generated during the training practice every year. The metal dusts are mixed with soil causing pollution to soil as well as ground water. The innovative team in the design thinking lab shape them and design them with an innovative sculpture as per the present need of the interior decorative industry. In India more than 13500 ITIs and so many training centres are there thousands of tons of scraps generated. These scraps can be better utilised for sustainability, circular economy. At the same time the hands-on skills of the students can be enhanced.

Adequate skills are required in preparing TVET graduates to fit in today's workplace. In order to fill up the skill gap between Industry and ITI there is an urgent need for hands-on skill of the trainees to be as per the need of the industry, so that they can adopt the required skill as per need of the industry with minimum training at industries.

Beautiful artefacts will help the students to become more and more self-sustainable in terms of raw material, increase their hands-on skill and generate revenue during the training practice.

II. CHALLENGES

The G20 leaders have argued that the skilled workforce is to be equipped with the existing skill and adoptable to the future skill in the national growth and overall growth of the G20 countries. All the countries agreed for mutual cooperation and strong support to face the challenges of the future workforce for fostering strong sustainable and balanced growth of each and every member of G20. A major challenge is the need to simultaneously address the changes required in the skilling echo system. Skilling up skill and re skilling required with the change in the technology and need of industries.

The growth of a country depends on its skilled workforce and their productivity. Skilled workforce is possible only with rigorous updating of the existing skill strength of the workforce and their response to adapt themselves with change in the skill market.

As per global economics the need for high skilled labour is in high demand and low skilled labours demand is declining. The problem will be further widened in an advanced economy. So economy because of demographic realities as the existing workforce will retire and it is difficult to replace them. [7]

India is an advanced developing country and capable to take advantage of this situation. As India considered youngest country in the world. The young generation in the country can easily adhere the upcoming advance skill. India will be in a position to supply skilled workforce to the rest of the world. So, it is a high challenge for the young Indian skilled workforce to be trained as per the needs of Industries.

Global economics will need high skilled labour increasingly and demand for low skills would decline. Situation would worsen in advanced economies because of demographic realities as the existing skilled workforce will retire and will not be replaceable in full.

There is thus a need for global efforts to improve skills of labour across the disciplines and in an inclusive manner with a view to containing the polarisation between the high skill high wage workers and low skill low wage workers. India is one of the advanced developing countries which would maintain its demographic advantage of having a young workforce capable of supplying labour to the rest of the economies provided it is able to take up skill development programmes of its young people suiting the emerging needs of the global economy. [8]

Adequate skills are required in preparing TVET graduates to fit in today's workplace. In order to fill up the skill gap between Industry and ITI there is an urgent need of hands-on skill of the trainees to be as peer the need of the industry. So they can adopt the required skill as per needs of the industry with minimum training at industries.

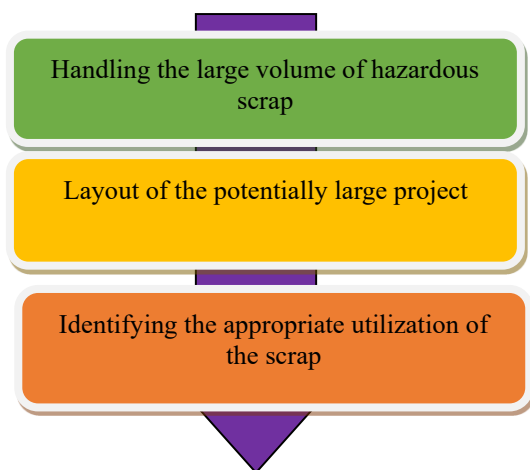


Fig 3: Basic Challenges

By providing trainees with hands-on skills in waste management and waste to wealth technologies, this approach is helping to minimize the skill gap and make them industry-ready. This is especially important in India, which has the youngest population in the world and a huge demand for skilled workers.

This positive change had to face many challenges before turning out to be a positive outcome. There was this challenge of handling such a huge volume of waste that needed a separate and dedicated team which was impossible with the existing manpower (Fig.3). Also, the waste couldn't be disposed of anywhere because of the probable threats to health and environmental pollution. There was a minute sharp and a tiny waist that could cause injury. These materials also when getting mixed up with soil, caused the loss of fertility.

On Job Training (OJT) is an important training method which can help the students to work in the real field. The parameters such as innovation, environment, guidance, interaction with technical experts autonomy help them to be a skilled professional. Due to non availability of Industries the locality and the existing industries cannot support 3000 students. The industrial environment is to be created inside the campus.

The design thinking laboratory is a valuable tool for helping trainees to develop teamwork and industry-readiness. By working together on real-world problems, trainees learn how to communicate effectively, solve problems creatively, and adapt to change. These are all essential skills for success in the workplace.

The integration of skill development and waste management for waste to wealth is a very innovative and promising approach. It addresses two important challenges: the need for skilled workers and the need to reduce waste. It is also aligned with the G20 countries' commitment to net zero targets by 2030.

Overall, the integration of skill development and waste management for waste to wealth is a very promising approach that has the potential to make a significant impact on India's economy and society.

India has the potential to become the skill capital of the world due to the huge demand for skilled workforce.

III. METHODOLOGY

Technical institutes typically generate five types of scrap: metal, electronic components, PCBs, and discarded spare parts from two-wheelers and four-wheelers. With approximately 3,600 students enrolled in multiple trades, ITI Berhampur generates around 1,000 kg of scrap every month. Some iron-dust generated during training mixes with the soil and is washed off in the rain, creating water and soil pollution. Transporting these items to dumping grounds or landfills is not a sustainable solution.

Integration of skill development and waste management for the skill gap minimization and green challenge provided an opportunity for an innovative best practice on circular economy waste to wealth initiative at the Government Industrial Training Institute (ITI) Berhampur in Odisha, India. This initiative aims to minimize the skill gap and make students industry-ready, provide entrepreneurial opportunities, reduce the carbon footprint, and manage waste.

From the demolished building the iron bars are being collected from the scrap yard of the campus. They are straightened into different sizes. (Fig. 4)

Further the govt the works department provides the iron wastes, metal window door, GI water tank which are rejected and dumped in their scrap yard. The automobile scraps such as gear, pinion, timing chain, crank, wheels, bearing, bike/cycle chain, fuel tanks and shock absorber are being collected from the institute scrap yard or from various automobile service centres of the city. The present scrap policy of the Govt. makes available a large number of scraps in their scrap yard. (Fig. 8 & Fig. 9)

E-waste such as PCB, mother board of computer, monitor, keyboard, mouse, TV, LCD Screen, radio, microwave oven, electronics toys, mobiles, earphone, medical electronics machine, washing machines when discarded they are the most hazardous e-waste and harmful to the society when the motherboards of the computers are burnt to extract gold and other precious metals they create heavy carbon footprint to the atmosphere. These types of e-waste are being collected from the institute scrap yard and the e-waste collection centre of the local body. (Fig. 10)

The canteen, the food plaza in the campus generate a large number of plastic bottles and the cold drinks bottle caps further a large number of bottle caps are being generated in the various cold bars. These bottle caps scraps are being up cycled with the innovative skill into various sculptures.

Tyres from car, scooter, bus, tractor and other two and four wheelers are being discarded frequently it is estimated each family has one discarded tyre in every year. The institute's scrap yard, automobile service centres generate a large number of scrap tires every month. (Fig. 11)

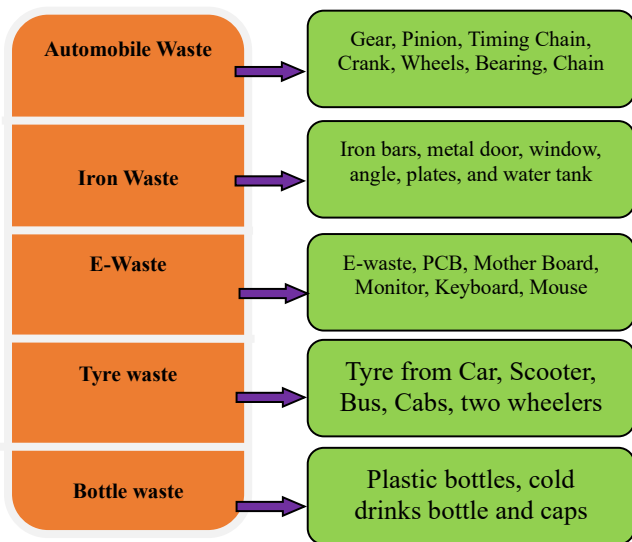


Fig 4: Separation of wastes

In the design thinking lab 3D version art of the sculpture is designed with the computer. The necessary dimensions, front view, side view and elevation are developed in a graph paper. The entire drawing is redrawn with a multiple (10, 20, 30.....) as per the need in the floor of the workshop. The engineering drawing team put the coordinates and transformed the small version of 2D drawing into a larger version. The welding art team converts the 2D art into 3D sculptures. The team is constituted with trainees from welding, painting, fitting, CNC turning (Fig. 6). The multi trade train team enhances the spirit of teamwork. The technical specifications are shared by the industry professionals. By these scrap projects the students work with their hands, heart and mind. The enthusiasm developed with them to give an aesthetic look. The sculpture developed is perfectly cleaned to remove the dust and rust. They are perfectly given a dynamic look and beautifully painted with 2K paints. To protect from corrosion it is finally painted with a special chemical. (Fig. 5)

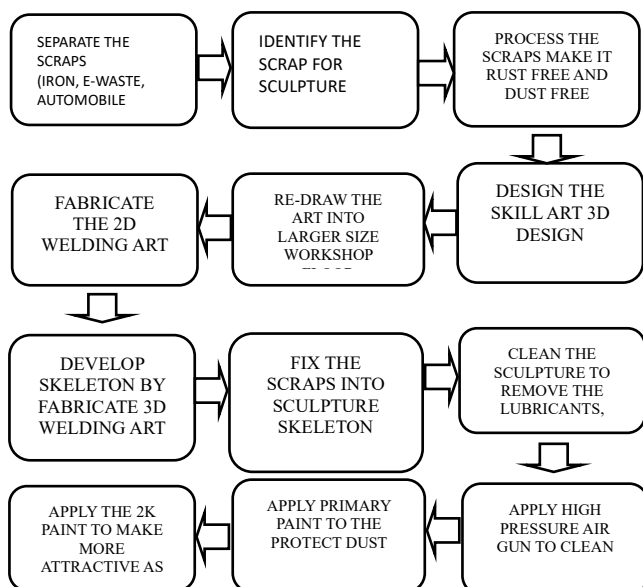


Fig 5: Methodology



Fig 6: Integration of Skill

The skilled sculptures are being used by the interior decorators in hotels, corporate houses, parks, fashion shows, and residential interior decorative purposes. There is a heavy demand for these products in the interior decorative industries as well as the theme parks established by the Govt. and various NGOs. (Fig. 7)

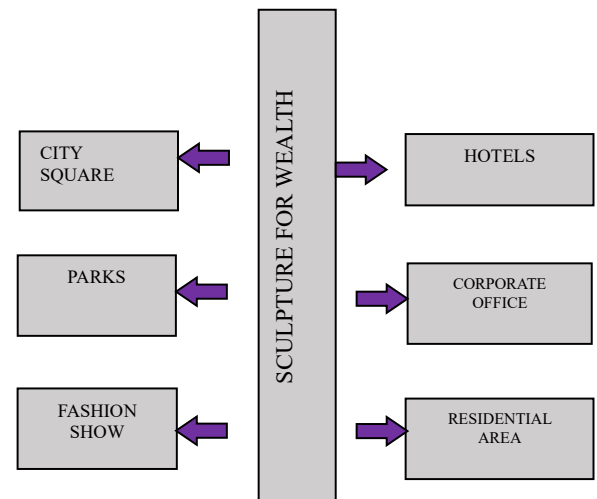
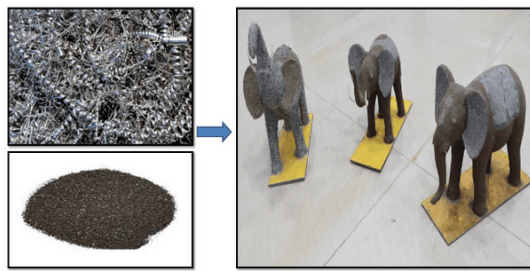


Fig 7: Sculpture for Wealth



Fig 8: Various types of scraps or wastes used for wealth



IRON DUST AND METAL SCRAPS FROM THE TURNER, CNC MILLING AND CNC TURNING Elephant for Interior Decoration

Fig 9:- Sculpture from Iron dust

This strategy has several benefits. It has majorly contributed to solving the greatest challenge of Technical Institute Waste Management. This is an absolutely environment-friendly strategy, thus, is totally eco-friendly. The most noticeable benefit of this concept is that it has opened the doors for a new area of skill development. The idea is to implement the non-conventional skills giving birth to an innovative creation.



Fig 10:- Sculpture from E Waste

This innovation was put into action with the team work from all the trades. After achieving the initial success in converting a scrap into art, it was showcased as a unique art via a park that was created especially for this purpose. The park was named as “Waste to Wealth Park” and items that were once scrap now became a piece of artefact that attracted visitors, interior designers from across regions and witnessed the skills and art of the students. There is a big potential to crack the interior decorative market.

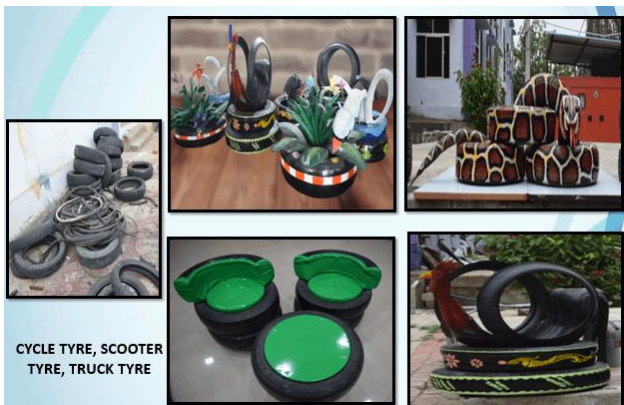


Fig 11:- Sculpture from Tyre Scrap

For the installation of indoor and outdoor locations, consuming large amounts of scraps, the sculptures are developed in three different categories.

- Small size for residential flats
- Medium size for indoor hotels, corporate houses
- Large size for city square, parks

A. Small Size:-

These small size scraps are skill art based that consumes maximum 1 to 5 Kg. of scrap. These scrap sculptures are used for interior decorator. They can also be developed based on a theme. In the international market, these scrap sculptures can be sold up to Rs. 30,000. These sculptures can be made out of automobile, plumber and mechanical scraps. Interior decorators have high demand to use these items in their decoration. (Fig. 13)

B. Medium Size:-

These medium size scraps sculptures are skill based this consume a maximum 40 to 50 Kg. of scrap. These scrap sculptures are used in office industries having a theme. In the international market, these scrap sculptures can be sold for up to 50000. (Fig. 14 & Fig 15)

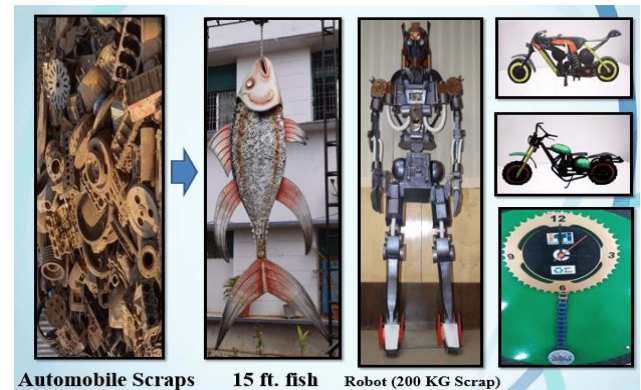


Fig 12:- Sculpture from Automobile Scrap

C. Large Size:-

These large size scraps sculptures are skill based this consumes maximum up to 5 tons of scrap. These scrap sculptures are used in Park/city squares. They can also be developed based on a theme. In the international market, these scrap sculptures can be sold for up to 20000 USD.

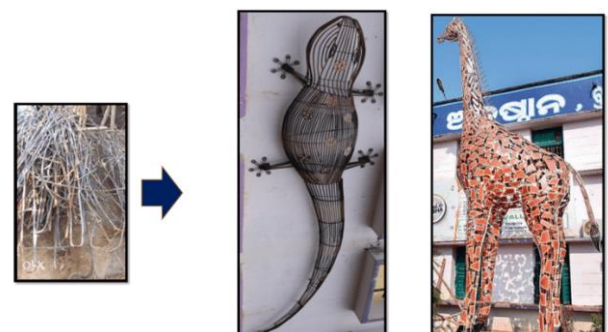


Fig 13:- Sculpture from demolished building TMT bars



Fig 14: Skilled in Odisha outlet



Fig. 15 Skill Exhibition on Vintage Bike models at ITI, Berhampur

The scrap sculptures and welding art products made out of E-waste, cold drink bottle caps are in sale by a outlet organised by Govt. of Odisha. (Fig. 16)



Fig 16: Sculpture prepared using cold drink cap

Using the waste products various fashion dress, shoes, ornaments, hand bracelets are prepared. Students participated in a Ramp Show. (Fig. 17 & Fig 18)



Fig 17: Elephant Sculpture Filled With Plastic Bottles at waste to wealth park, ITI, Berhampur



Fig 18: Skill park in city square

III. RESULT

By this innovative method Integration of skill development of waste management, trainees are gaining hands-on skills that are essential for the workplace. This innovative approach is minimizing the skill gap of trainees and making them industry ready.

The design thinking laboratory is a valuable tool for helping trainees to develop teamwork and industry-readiness and entrepreneurship . By working together on real-world problems, trainees learn how to communicate effectively, solve problems creatively, and adapt to change.

The internal revenue generation of the institute is hike every year (Fig. 19)

As skill gap minimized placement is increased from 602 to 1425 in five years (Fig. 20).

During placement the average salary of the students is increased from ₹ 11500 to ₹ 22800 in five years (Fig. 21).

During admission more and more students are attracted to take admission. The application number is increased from 3000 to 11000 in three years. (Fig. 22)

Most interestingly girl's admission is increased from 427 to 734 in last three years. (Fig. 23)

A huge amount of various scraps like automobile waste, Iron waste, tyre waste, bottle waste and e-waste are used to prepared the sculpture. (Fig. 24)

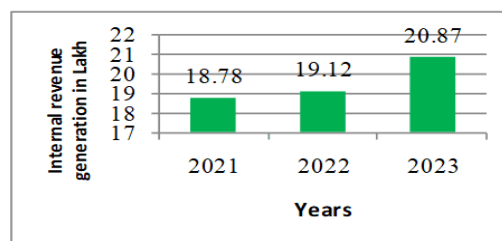


Fig. 19 Internal revenue generation in Lakh

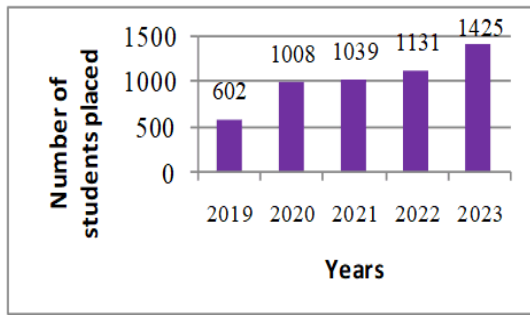


Fig. 20. Hike in placement

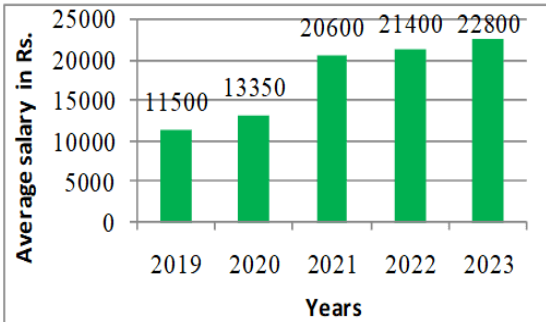


Fig. 21. Increase in Average salary in Rupees

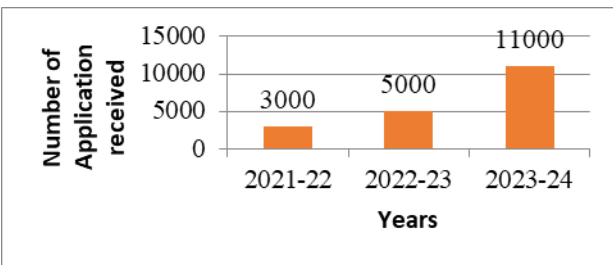


Fig. 22 Number of Applicant increase for admission

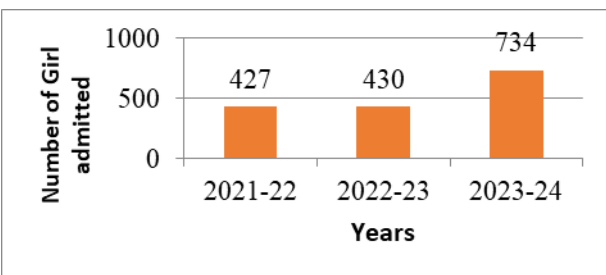


Fig. 23. Increase in girl admission

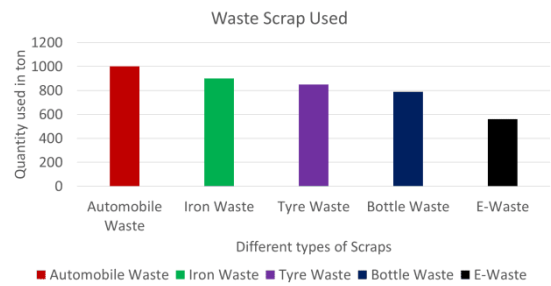


Fig. 24. Different types of scraps used for the year 2023

IV.CONCLUSION

Trainees are the future workforce of the country. The waste to wealth concept is integrated in their mindset. Throughout their life. This concept can be transferred to all the 13000 vocational training institutes in India. The young workforce will be the warrior for waste to wealth. This can enhance hands on skill, which will help the country to be the skill capital of the world.

REFERENCES

- [1] Konstantinos Kalkanis, Dimitrios E. Alexakis, Efstathios Kyriakis, Kyriaki Kiskira, Junior Lorenzo-Llanes, Nickolas J. Themelis & Constantinos S. Psomopoulos, "Transforming Waste to Wealth, Achieving Circular Economy"
- [2] Khair A1-Deen Bsisu, Zaydoun Abu Salem "Recycling of Steel Bars from Demolished Structures," International Journal of Engineering Research and Technology, ISSN 0974-3154, vol. 13, Number 1 (2020) pp. 94-99.
- [3] Ahmet Turer, "Recycling of Scrap Tires" book chapter, pp. 195-214.
- [4] Julian Suer, Frank Ahrenhold, Marzia Traverso, "Carbon Footprint and Energy Transformation Analysis of Steel Produced via a Direct Reduction Plant with an Integrated Electric Melting unit" Journal of Sustainable Metallurgy (2022) 8: 1532-1545
- [5] Wali, Elekwachi1, Wizer Collins .H2, Nwankwoala, Hycienth .O3, "Waste-To-Wealth, Towards a Sustainable Zero-Waste in a Circular Economy: An Overview", International Journal of Emerging Engineering Research and Technology Volume 7, Issue 11, 2019, PP 1-11
- [6] <https://www.blueweaveconsulting.com/report/india-interior-design-market>
- [7] <https://ncvtmis.gov.in/Pages/ITI/Search.aspx>
- [8] A Skilled Workforce for Strong, Sustainable and Balanced Growth: A G20 Training Strategy International Labour Office – Geneva, 2010
- [9] <https://www.businessstandard.in/current/corporate/urbanclap-joins-modi-govt-skill-india-mission-train-30000-professionals/story/364467.html>
- [10] M. Allam, Indian Higher Education, Private Sector and the National Policy of Education, 2014
- [11] https://www.business-standard.com/article/economy-policy/india-launches-mission-to-skill-400-million-by-2022-115071600035_1.html
- [12] <https://www.entrepreneur.com/article/327714>

Value Chain Development for Municipal Solid Waste Management in Sri Lanka: An Integrated Approach for Sustainable Urban Development

Sriyani G.T.W.

Department of Management and
Entrepreneurship,
University of Ruhuna,
Matara, Sri Lanka.
wsriyanigt@gmail.com

Gunarathne, K.G.P.V.

Department of Accountancy
University of Ruhuna Matara, Sri
Lanka
gunarathnavijitha@gmail.com

Gunawardana T.S.L.W.

Department of Business Management,
University of Ruhuna,
Matara, Sri Lanka.
tslw2013@gmail.com

Indrani M.W.

Department of Accountancy,
University of Ruhuna,
Matara, Sri Lanka
induwithana@gmail.com

Mafasiya Fairoz F.

Department of Management and
Entrepreneurship,
University of Ruhuna,
Matara, Sri Lanka
Mafasiyaf@gmail.com

Abstract- The steadily increasing urbanization rate and population growth in Sri Lanka cause a significant rise in the generation of Municipal Solid Waste. Inefficient Municipal Solid Waste Management in Sri Lanka creates many environmental, health, and socioeconomic challenges. Thus, there is a pressing need for an integrated approach that goes beyond traditional waste management practices for addressing these challenges. This study focuses on identifying the key stakeholders in the Municipal Solid Waste Management process in Sri Lanka and the possibility of value chain development as a long lasting solution for this tragedy. Based on the qualitative research and purposive sampling method, six municipal areas in Southern Province of Sri Lanka were selected. Focus group discussions, observations, and documentary survey methods were applied in data collection. Thematic analysis and SWOT analysis were applied in revealing the facts on the key themes of this study. The plus factors include: more enthusiastic young officers and having sound Solid Waste Management plans and novel ideas among the majority of municipals; apply circular economy practices like producing compost, recycling, bailing and reselling paper and plastics; having networks with several solid waste management projects in the province; and having more enthusiastic entrepreneurs who produce solid waste based value added products. The key negative factors include: absence of long-sighted vision and capital for the government; dependence on traditional technology; lack of integration of the actors in Municipal Solid Waste Management process; poor attitudes of the citizens; lack of market linkages, inability to expand the operations and hence create employment opportunities; and absence of updated databases of waste collectors and solid-waste based entrepreneurs. By integrating all the key actors of the municipal solid waste management process as a value chain, there is a possibility to inculcate a culture of applying circular economy practices with the attitude of 'waste' to 'wealth'.

Key Words: *circular economy practices; municipal solid waste management; stakeholders; sustainable development; value chain development.*

I. INTRODUCTION

Municipal solid waste management (MSWM) has become a critical issue in many countries around the world, especially among the developing nations including Sri Lanka (Saja, et al., 2021). Municipal Solid Waste (MSW) is heterogeneous and comprises everyday items such as food waste, building waste, paper, and plastic which are discarded by the residential, commercial, and industrial sectors (Adhikari et al., 2018). With the rapid urbanization and population growth, consumption pattern, industrial operations, and other human activities, the generation of waste has increased significantly. According to the World Bank, the global generation of MSW will reach 3.5 billion tons by 2050 (Muhammad et al., 2023). It is an increase of 70% (Chan, 2019). This issue harms the environment as well as public health and safety. United Nation's 2030 Agenda for Sustainable Development emphasized the necessity of applying the circular economy concept and best practices like prevention, reduction, recycling and reuse of waste for SWM. The developed countries like Sweden, Japan, Norway, Denmark, etc. reached the sustainable development goals and the top ranks in the SWM index by applying the circular economy concept and best practices for SWM (Global Waste Index, 2022). These countries maintain an up to date database of SW generation and take continuous actions to reduce the waste, apply best practices and participatory approach for waste disposal, convert the waste into value additions, and create solid waste based livelihoods, etc. rather allowing it to create many issues within a country. Among the 38 countries which were considered in preparing the Global Waste Index in 2022, 18 countries reported as the open dumping is at zero level. Countries like Sweden, South Korea and Germany claim **high recycling rates** and among them, Germany is often celebrated as a world champion for recycling. While the majority of developed countries

consider the SW as a wealth, many developing countries including Sri Lanka are struggling with this issue due to high generation of municipal solid waste (MSW) and absence of efficient management for MSW (Saja, et al., 2021). Presently, Sri Lanka emits more than 9000 MT of SW daily and the rate of waste generation increases by 1.2% each year (Report of Ministry of Health, 2020). While gradual increase in waste generation happens, lack of a proper mechanism for collecting all the solid waste in municipal areas; lack of government assistance, treatment process, value additions, stakeholder collaboration; and lack of public awareness and commitment cause to exacerbate the MSWM issue further (Gudmann Knutsson et al., 2021; Jayasinghe et al., 2021; [Samarakoon and Schenkel, 2020](#)). The most crucial incident that happened in Sri Lanka was the collapse of the Meethotamulla garbage dump in Colombo in April 2017 which created multiple deaths, displacement of families, and environmental damage. The dump had been overfilled for years, and this collapse highlighted the urgent need of managing solid waste properly. Eventhough many previous studies focused on revealing the causes for the poor MSWM and suggests several solutions for mitigating the MSWM issue, still qualitative in-depth studies which focuses on establishing an integrative approach as a long lasting solution for this issue is scarce (Saja et al., 2021; [Samarakoon and Schenkel, 2020](#)). By reviewing the literature, Asamoah and Kyeremeh (2017). emphasized the importance of establishing Private Public Partnerships (PPP) and community-based initiatives for addressing properly the deficiencies in the formal system of MSWM. Also, most of the past studies focused on the municipalities in Western Province of Sri Lanka and a very few studies were focused on other municipal areas. Therefore, by concerning the prevailing research gaps, this study mainly focuses on studying the existing MSWM process in Southern Province of Sri Lanka to identify the key actors of the MSWM process and their role, plus and minuses of the MSWM processes, and finally provide possible implications for strengthening an integrative approach as a long lasting solution for MSW management in Sri Lanka aiming to contribute to sustainable development.

II. LITERATURE REVIEW

A. *Current Status of Municipal Solid Waste Management in Sri Lanka and in Southern Province:*

The per capita of SW per day was about 10 kg in the Colombo Municipal Council, 0.75 kg in other Municipal Councils, 0.60 kg in Urban Councils and 0.40 kg in Pradeshiya Sabhas. The Southern Province has 3 Municipal Councils (MC), 4 Urban Councils (UC), and 42 Pradeshiya Sabhas (PS) (Wood, 2021, P.16). The waste collection in the municipal areas of Galle, Matara, and Hambantota districts in Southern province of Sri Lanka is estimated as 32 MT/Day, 30-35 MT/Day, and 10 MT/Day respectively. In 2018, Southern province reported the 3rd highest mid-year population of 2,637,000 (Wood, 2021, P. 14) and steadily increasing trend in MSW happens due to this high population, migration to city areas, and increasing

use of disposable materials and excessive packaging. Increasing quantities of MSW impose a tremendous pressure on the disposal and management of municipal solid waste in Matara and Galle districts. However, it was reported that municipal solid waste collection rate was only 52% (of the 3,502 tons/per day) in Western Province and 23% (of the 1,158 tons/per day) in Southern province (JICA, 2016) and apply open dumping or land-filling for the rest mainly due to low cost and less processing involved. However, the Global Waste Index (2022) reported that the rate of open dumping is zero in most of the developed countries.

Similar to other countries in the region, the composition of solid waste in Sri Lanka predominates by organic materials (55%), and plastic (12.4%) and paper (12%). Globally, Sri Lanka is estimated to be the fifth-largest contributor to ocean plastics pollution (Sri Lanka Recyclers Association – Cited by Becerra and Bryan, 2020). This study further shows that in the Southern Province, the majority of residential and commercial waste consisted of biodegradable waste including kitchen waste, garden waste, paper, and cardboard. In both residential and commercial areas, kitchen waste is reported as more than 68%. Paper and cardboard is the 2nd and 3rd largest type of waste respectively in commercial and residential sectors. Major recycling industries in the country are plastic, paper, glass, CFL bulbs, batteries and metal (De Alwis, 2019).

B. *Issues in Municipal Solid Waste Management in Sri Lanka and in Southern Province:*

Several researchers (for example: Wood, 2021; De Alwis, 2019) pointed out that though number of projects and programs being implemented in Sri Lanka to improve the waste management system, still an inefficient and unsystematic manner with minimal consideration can be seen for the disposal solution and hence create environmental and health hazards. One example for this situation is that waste collection points in several areas in Western and Southern provinces appear like mini dumping sites along the streets and in residential blocks due to insufficient storing facilities and improper management. Gudmann Knutsson et al, (2021) and Saja et al, (2021) identified the MSWM challenges specifically in the context of Southern Sri Lanka and those include: ineffective planning and implementation of waste management strategies, lack of public awareness and commitment, lack of resources and unplanned pick-up schedules, and lack of the necessary resources and infrastructure. Vitharana (2016) highlighted that Hambantota Municipal Council in Sri Lanka faces the challenge to carry out sustainable SWM with increasing SW with the development plan and due to lack of financial and technical support, public awareness and education, collaboration and public participation, and a lack of legal instruments and policies. Moreover, several researchers (for example: Rathnayake and Sellaheewa, 2022; Saja et al., 2021; Wood, 2021; Becerra and Bryan, 2020; De Alwis, 2019) highlighted the issues like: lack of commitment by the governmental authorities, limited technical capability and unsuitable business models,

inadequate human resources, knowledge capacity gaps and lack of financial resources, lack of consistent collection, sorting and disposal, and low awareness from the public on how to appropriately deal with their waste. The recent economic crisis also created in-house management issues such as shortages of skilled labour, lack of market due to low quality of recycled plastics, and higher production costs for the recycling firms (Karunaratna and Rajapaksha, 2020) as well as high inflation rate of the country, high tax rates, import restrictions for machinery parts, dollar shortage, etc. effect on recyclers (Sriyani, 2022).

Many studies noticed the lack of collaboration and integration among the stakeholders in the MSW process such as public and private sector organizations as well as the waste collectors and recyclers in the informal sector as one of the major obstacles for ensuring an efficient and productive MSW management in Sri Lanka (Wood, 2021; [Samarakoon and Schenkel, 2020](#); De Alwis, 2019). De Alwis (2019) further noticed the political interference affect drastically for the poor regional cooperation and multi-stakeholder partnerships. So, it cannot be seen a healthy collaboration among the institutions and bodies like the National Steering Committees convened by Ministry of Environment (MOE) and other Ministries on waste management as well as an encouraging cooperation between Government, scientific and research institutions and the private sector for stimulating for best MSW practices. Samarakoon and Schenkel (2020) highlighted that though the informal sector small scale solid waste collectors and recyclers contribute more in MSWM process, absence of integration of the informal sector players with the formal system, neglect and unnoticed their role and contribution to keep the environment clean, operating in a limited spaces in cities, oppositions of the neighbour people for their operations have cause to demotivate for continuing their career.

c. *Circular Economy Practices and Value chain Development for MSWM*

United States Environmental Protection Agency (EPA, 2023) defines the circular economy (CE) as “a model to reduce material use, redesign materials, products, and services to be less resources intensive, and recapture ‘waste’ as a resource to manufacture new materials”. **International NGOs** and past researchers emphasized the urgent need of meeting the CE principles and an integrated approach to enhance the value of waste rather than practicing low cost methods like land filling or dumping to dispose solid waste (UNEP, 2015). In developing the value chain of MSW, it is required to integrate all the actors in the MSW process and identify the value they add to the chain and the role of each actor. The actors in the overall MSWM process includes who involve in solid waste generation, collection, segregation, sorting, mechanical processing or recycling and trading into local, national and international markets. The value chain also includes local authorities, Universities, Business Development Service providers, etc. which facilitate in numerous ways in the

MSW process. Actors in various stages in the waste value chain play multiple roles along the waste management hierarchy. For instance, local authorities define what constitutes waste and present laws and regulatory frameworks for waste recycling, recovery, and treatment and disposal (Nikolaou et al, 2021).

Most of the researchers share the experience in international level to explore the opportunities and benefits of integration the formal and informal actors in the MSW process into municipal solid waste value chains (Nikolaou et al, 2021; Jalogot, 2016; Jayasinghe, 2015). [The ILO at its workshop on Compost and Plastic Recycling sector jointly held in December 2011 with Waste Management Authority in Western Province of Sri Lanka highlighted the importance of value chain development bringing all relevant stakeholders together to improve the competitiveness of the composting and plastic recycling sectors in order to achieve its potential for development of the local economy and to create more green jobs and making the sector effective and progressive. To achieve the CE, there is a need to establish processes to resource recovery from waste and it depends on the chain of processes and structures \(formal/informal networks of stakeholders\) created and shaped by the relations of stakeholders across the whole value chain, that bring together production, distribution, access, and management \(Iacovidou et al., 2020\). In Sri Lanka, the development of a robust value chain is essential for waste management practices for successfully facing the above mentioned environmental and health related issues and ensuring the achievement of sustainable development goals. Silva de Souza et al., \(2022\) argued that informal stakeholders within recycling value chains are important contributing parts of society that positively add to economic growth and ultimately to the efforts of transitioning towards a circular economy and it requires education, training, support, and empowerment. In a study of women in the SWM value chain, Jaysinghe \(2015\) developed the concept “Wastescape” to understand SWM in Sri Lanka. “Wastescape is used to conceptualize the space\(s\) where social, cultural and political aspects of waste management and its stakeholders operate.” Jayasinghe \(2015\) and Becerra & Bryan \(2021\) show that majority of women in Sri Lanka who work in waste are informal waste collectors and have less presence in the formal waste collecting sector. Poor women work as waste pickers and receive less value for their career. However, several women show their strength by starting recycling and value added productions as well as lead in community level SW societies. Though several community-based women organizations have been active in assisting women to develop composting businesses, or collect recyclables, informal nature, poor infrastructure, and lack of market linkages and finance limit the potential in upgrading of their businesses \(Jayasinghe, 2015\).](#)

III. METHODS

This study focused on in-depth analysis to study the involvement of the key actors in the MSWM process of the

municipal areas in Sri Lankan context, identify plus and minus factors of the MSWM process, and suggest a possible long sighted solution for this controversial social issue. Therefore, the action research method under the qualitative approach was applied. Based on both theory and practice, the action research brings together action and reflection in participation with respondents in the pursuit of practical solutions to a particular issue of pressing concern (Bradbury, 2015, p. 1). The 3 municipal areas and 3 urban council areas in the Southern Province of Sri Lanka were selected as research sites for this study. The purposive sampling method was applied by including the municipals, Central Environmental Authority, industries and the households, solid-waste based entrepreneurs, waste collectors, higher educational institutions, Business Development Service providers who have been considered as the stakeholder groups of this MSWM process in Sri Lanka. Document analysis, focus group discussions, in-depth interviews, and observations were applied in data collection and the thematic analysis based on narratives and SWOT (Strength, Weakness, Opportunities, and Threats) analysis were applied in revealing the facts on the key themes of this study. An audio recording of the focus group conversation and in-depth interviews were kept. During focus group discussions, participants were guided by the moderator who kept the discussion focused, ensured that everyone participated, and encouraged participants to explain their answers. Document analysis was applied to be aware of the existing mechanism of MSWM and the strategic plans and proposals developed for MSWM. Finally, develop the SWOT analysis and design the value chain map and conclusions are provided based on the respondents' narratives.

IV. ANALYSIS

A. *SWOT Analysis of MSWM in Southern Province of Sri Lanka:*

Based on the findings of this study, the SWOT analysis developed for the MSWM in Southern province of Sri Lanka is depicted in Table 1 (See Annex I). Strengths and weaknesses of the MSWM sector were identified relating to the key actors of the MSWM in the Southern province including: policy & legislative framework, municipalities and Urban Councils, waste generators/suppliers, informal waste collectors, and recyclers and value added entrepreneurs. Opportunities and threats were presented based on the MSW sector in Southern province.

B. *Value Chain Development for MSW in Southern Province*

Value chain development (VCD), a concept widely applied in various sectors, has the potential to transform the MSW management system in Sri Lanka by optimizing resource utilization, reducing environmental impacts, and creating economic opportunities. VCD in MSWM refers to the systematic organization of the actors who involve in waste collection, sorting, recycling, value addition, disposal, and providing supportive services. A well-structured value chain assist to create economic value to waste and more job

opportunities, reduce environmental pollution, contribute to a cleaner and healthier living environment and finally support to achieve sustainability goals. As revealed by this study, the actors in the MSW value chain include regulatory and policy level in MSW such as Central Environmental Authority (CEA) and relevant Ministries, municipals and local governance institutions, waste generators/suppliers (including households, industries such as garments, food city chain, tourist hotels and restaurants, food processing firms, shoe manufacturing firms, agricultural farms, timber mills, etc.), informal waste collectors, recyclers, value added product producing entrepreneurs, machine designers, schools and higher educational institutions, technology and R & D institutions, BDS providers, intermediary and final buyers and exporters. The ILO introduced 5 step process in VCD including: Sector selection, Project setup and initial research and evaluation, Value chain mapping and understanding relationships, Value chain analysis and intervention strategies, and Monitoring and evaluation. Based on the findings of this study and the ILO guidelines for VCD, following steps were understood as essential in developing the MSW sector Value Chain in the Southern province.

- i. Analyze the MSW sector thoroughly in order to identify market trends and sector growth potentials, types of economic activities/livelihoods create by the sector, employment intensity and potential of employment creation in the sector, percentage of women representation in the sector in different tasks (gender equality), contribution to the national and local economic development, existing good practices in the sector, etc.
- ii. By focusing on the key players and the initial assessment of the MSW sector, develop a SWOT analysis.
- iii. Mapping the MSW Value Chain by considering the roles and relationships of each actor.
- iv. Develop strategies for strengthening the existing ties and building up new relationships to strengthen the MSW sector and enhance the competitiveness, For example: establish a regulatory framework and enforcing compliance with waste management standards and CE practices; establish and facilitate better coordination mechanism among the actors; identify direct and supportive industries that can be used for outsourcing purposes, etc.
- v. Monitoring and evaluation of the progress at least six months' time.

C. *Value Chain Mapping:*

Based on the findings of the MSW sector in Southern Province of Sri Lanka, the Value Chain Map can be demonstrated as in Figure 1 (see Annex II). Accordingly, mainly three types of categories were identified. These are: i) Actors who laid the foundation for CE and proper SW management [Policy & Legislative bodies and Municipal and Urban Councils]; ii) Primary actors [SW generators including house holders and industries, SW collectors (formal and informal), and SW based community level associations], Machine designers; iii) Service providers [BDS providers, Technology Providers, Financial Institutions and educational & research institutions]. As

expressed at the focused group interviews, many claims have been made by the informal sector waste collectors and MSEs who engage in recycling and value added productions. Informal sector metal and hard plastic waste collectors collect the waste at the household level at a very low price and until segregation, they had to store these at the open areas. During the rainy season, they have to face many issues due to manual cleaning, resistance from the Nabor families, etc. Also, the mass of the collected metal waste is resold to the exporters in Colombo area and a small portion to the value-added product manufacturers in the province. The plastic waste also is resold to the plastic product and plastic pellet manufacturers in Colombo area. Due to irregular buying patterns, it is difficult to have a stable supplier chain with the provincial level plastic pellet and product manufacturers. Because of having several intermediaries in this supplier chain and increasing labour charges, transport cost, etc., the income earned from the business is insufficient to expand the business with required infrastructure. Also, the advantage of creating employment opportunities for the southern province cannot be seen in this value addition process. Even though several micro and small scale level SW based value added producers are available in the province, due to high cost of production, lack of technology know-how, and lack of market linkages, etc. they cannot expand their operations and create employment opportunities in the area. Hence, creation of a Value Chain might be beneficial for these actors to properly address the issues they faced and thereby reuse the waste and create economic activities and employment opportunities in the province.

V. Conclusion and Suggestions

VCD as a participatory process that the public, private and NGO sectors, community-based organizations, and the general public can work together to stimulate and activate local economic activities to ensure a resilient and sustainable local economy. MSW is recognized as a prominent sector which has more potential to empower the poor community people via integrating with the MSW process. A well-structured MSW value chain can recover valuable resources from waste, such as recyclable materials and organic waste, reducing the pressure on environmental and health issues as well as efficient use of natural resources through CE practices. Moreover, the recycling and waste management industry can generate more economic activities and employment opportunities for vulnerable communities, contributing local economic growth, poverty reduction, as well as minimizing pollution, conserving natural resources and reducing greenhouse gas emissions. For ensuring the the uninterrupted operation of the value chain for MSW management, it requires collaboration, dedication, and long term commitment of all the stakeholders and timely decision making and adoption of strategies prudently to face successfully the challenges faced by every actors in the chain.

Based on the findings of this study, **following suggestions can be presented for proper implementation of the**

MSW value chain in the Southern province and addressed the issues discussed in the previous sections of this paper.

- i. Require to prepare databases in district level of all waste collectors/collecting centres, entrepreneurs who operate in the recycling/up-cycling and value additions of waste,
- ii. Establish and empower village level community associations and community leadership towards best practices of MSW, starting livelihoods in waste collection, processing, reselling, recycling and value additions.
- iii. Provide equal opportunities for women to enter into the value addition process of MSW and stimulate women leadership in community based SW societies.
- iv. Have a sound 5-year strategic plan for the MSW in each municipal area by including the integration of all the key actors in the value chain of MSWM.
- v. Have monthly progress meetings at Municipal level by participating all the key actors in the MSW value chain .
- vi. Develop access to collect waste from garments and industrial zones for recycling and value additions especially for micro and small scale women entrepreneurs and enhance the access to them for micro-loans
- vii. Aware the importance of practicing rules and regulations of employee safety and health, and environmental protection.

ACKNOWLEDGMENT

This paper is part of Techno-Economic-Societal Sustainable Development Training in Sri Lanka (TESS) Project: 609925-EPP-1-2019-1-NO-EPPKA2-CBHE-JP, which is co-funded by the European Commission under its ERASMUS+ CBHE programme.

REFERENCES

- Adhikari, S., Nam,H., and Chakraborty, J.P. (2018). Conversion of Solid Wastes to Fuels and Chemicals through Pyrolysis, Waste to Biorefinery - Potential and Perspectives, Chapter 8, 236-263.
- Asamoah, K., and Kyeremeh, T.A. (2017). Decades of public-private partnership in solid waste management A literature analysis of key lessons drawn from Ghana and India, *International Journal of Management & Environmental Quality*: 28 (1), 78-93. <http://dx.doi.org/10.1108/MEQ-05-2015-0098>
- Asian Development Bank, (2020). Greater Male Environmental Improvement and Waste Management Project." www.adb.org/projects/51077-002/main
- Balasooriya, C.L.C.B, Priyankara, N.H., Alagiyawanna, A.M.N., Dayanthi, W.K.C.N., Koide, T., and Kawamoto, K. (2015). "Waste Amount and Composition Survey (WACS) in Galle and Hambantota Municipal Councils."
- Bandara, Nilanthi. (2011). "Municipal Solid Waste Management - The Sri Lankan Case. *Proceedings of International Forestry and Environment Symposium.*" University of Sri Jayewardenepura, Sri Lanka. DOI: 10.31357/fesympo.v0i0.21
- Becerra, V. and Bryan, A. S. PE,. (2021). CLEAN CITIES, BLUE OCEAN Initial Solid Waste Management Assessment (ISWMA): Sri Lanka and the Maldives, Draft Report, TETRA TECH, USAID Clean Cities, Blue Ocean Program.
- Bradbury, H. (2015). *The Sage handbook of action research*. Sage. <https://www-doi-org.proxy1.ncu.edu/10.4135/9781473921290>

- Chan, H.W. (2019). When do values promote pro-environmental behaviors? Multilevel evidence on the self-expression hypothesis. *Journal of Environmental Psychology*. <https://doi.org/10.1016/j.jenvp.2019.101361>
- Dassanayake, M. (2011). Successful Integrated Urban Planning Approach to Solid Waste Management in Sri Lanka, Planning and Implementation of “Pilisaru” National Solid Waste Management Project Sri Lanka, Central Environmental Authority, Ministry of Environment & Natural Resources Sri Lanka.
- Environmental Protection Agency (2023), What is a circular economy? <https://www.epa.gov/circulareconomy/what-circular-economy>.
- De Alwis, S., (2019). Country 3R Progress Report - Progress and achievements towards implementation of the Ha Noi 3R Declaration, Bangkok: 3R Forum in Asia and the Pacific.
- Galle Municipal Council Official Website. “Waste Management Division.”(2020).
- Galle Municipal Council Official Website. “Health Department.” (2020).
- Global Waste Index, (2022). <https://sensoneo.com/global-waste-index/>
- Gudmann Knutsson, S, Asplund, T, Höst, G., Schönborn, K.J. (2021). Public Perceptions of Waste Management in Sri Lanka: A Focus Group Study. *Sustainability*, 13, 12960. <https://doi.org/10.3390/su132312960>
- ILO [Workshop](#), (2011). Value Chain Development in Solid Waste Management Stakeholder Consultation and Validation Workshop, 19th August 2011, Colombo in Sri Lanka.
- Jaligot, R., Wilson, D.C., Cheeseman, C.R., Shaker, B., and Stretz, J. (2016). Applying Value Chain Analysis to Informal Sector Recycling: A Case Study of the Zabaleen, *Resources, Conservation and Recycling* 114, 80–91.
- Jayasinghe, R.; Liyanage, N.; Baillie, C. (2021). Sustainable waste management through eco-entrepreneurship: An empirical study of waste upcycling eco-enterprises in Sri Lanka. *J. Mater. Cycles Waste Manag.* 23, 557–565.
- JICA (2016). Data Collection Survey on Solid Waste Management in Democratic Socialist Republic of Sri Lanka Final Report, February, <https://openjicareport.jica.go.jp/pdf/12250213>
- Iacovidou, E., Hahladakis, J.N., Purnell, P. (2020). A systems thinking approach to understanding the challenges of achieving the circular economy. *Environ. Sci. Pollut. Res.* <https://doi.org/10.1007/s11356-020-11725-9>.
- Karunarathna, A. and Rajapaksha, T. (2020). Effective Plastic Waste Management in Sri Lanka, [IGES Centre Collaborating with UNEP on Environmental Technologies \(CCET\)](#), December. <https://www.iges.or.jp/en/pub/effective-plastic-waste-management-sri-lanka/en>
- Lusk, J.L.; Ellison, B. (2020). Economics of household food waste. *Can. J. Agric. Econ.* 68, 379–386.
- Muhammad, A. M., Pan Li, Qiulin Ma, Md. Akiful Haque, and Wan-Ting Chen. (2023). [Thermochemical conversions of municipal solid waste into fuels and chemicals](#), *Advances in Bioenergy*, Vol.8, Chapter Five, 239-305, <https://doi.org/10.1016/bs.aibe.2023.02.002>
- News- European Parliament, (24-05-2023). Circular economy: definition, importance and benefits.
- Nikolaou, I.E, Jones N, Stefanakis, A. (2021). Circular economy and sustainability: the past, the present and the future directions. *Econ Sustain* 1(1), 1–20.
- Premakumara, D, Chatura, W, Nadeesha, G., and Nadeeka, A. (2017). Community-based Solid Waste Management in Galle City - A Pilot Project in China Town.
- Rathnayake, R.M.N.M, & Sellaheewa, W.N, (2022). Solid Waste Management Challenges in Urban Councils of Developing Countries: Case Study with special reference to Boralesgamuwa Urban Council, Sri Lanka, *Journal of Management and Tourism Research*, 5(1), 17-34
- Saja, A. M.A., and Zimar, A.M.Z, and Junaideen, S.M. (2021). Municipal Solid Waste Management Practices and Challenges in the Southeastern Coastal Cities of Sri Lanka, *Sustainability*, 13(8), <https://doi.org/10.3390/su13084556>.
- [Samarakoon, D. and Schenkel, S. \(2020\). The Video of Digital Story Teller Synthesis Project of the Swiss Programme for research on Global Issues on Development \(r4d programme\).](#)
- Silva N. de Souza Lima Cano, Iacovidou, E., and Rutkowski, E. W. (2022). Typology of municipal solid waste recycling value chains: A global perspective, *Journal of Cleaner Production*, 336 (2022) 130386, 1-14. <https://doi.org/10.1016/j.jclepro.2022.130386>
- Sriyani, G.T.W. (2022). [Impact of Economic Crisis and Way Forward for the Survival of SMEs: A Sri Lankan Perspective](#), *Wayamba Journal of Management*, 13 (2), 70-79.
- UNEP, (2015). Global Waste Management Outlook. Prepared for UNEP and ISWA. Osaka: UNEP. <http://www.unep.org/ietc/InformationResources/Events/GlobalWasteManagementOutlookGWMO/tabid/106373/Default.aspx>.
- United States Agency for International Development (2020). CLEAN CITIES, BLUE OCEAN | Initial Solid Waste Management Assessment (Sri Lanka and the Maldives) - DRAFT, [said.gov/pdfs/PA00XWPJ.pdf](https://www.usaid.gov/pdfs/PA00XWPJ.pdf)
- Vitharana, A.D. (2016). Solid Waste Management in Hambantota Municipal Council, Sri Lanka: Current Practices, Challenges, and Prospects, *International Journal of Scientific and Research Publications*, 6(3), 390-398.
- Wood, (2021). Waste management system in Sri Lanka Review of and recommendations. The Commonwealth Litter Programme, Sri Lanka, www.gov.uk/government/publications

Determinants of Households' Pro-Environmental Behavior on Solid Waste Management: Towards Circular Economy in Sri Lanka

Wijesekara, W.A.D.S.

Assistant Director

Small Enterprise Development Division

District Secretariat, Matara, Sri Lanka

sanjeevaniwijesekara26@gmail.com

Indrani, M.W.

Professor

Department of Accounting

University of Ruhuna

Matara, Sri Lanka

induwithana@ymail.com

Gunawardana, T.S.L.W.

Professor

Department of Business Management

University of Ruhuna

Matara, Sri Lanka

gunawardana@badm.ruh.ac.lk

Mafasia, M.B.F.

Senior Lecturer

Department of Management and

Entrepreneurship

University of Ruhuna

Matara, Sri Lanka.

mafasiyaf@gmail.com

Sriyani, G.T.W.

Senior Lecturer

Department of Management and

Entrepreneurship

University of Ruhuna,

Matara, Sri Lanka.

wsriyanigt@gmail.com

Gunarathne, K.G.P.V.

Senior Lecturer

Department of Accounting

University of Ruhuna

Matara, Sri Lanka

gunarathnavijitha@gmail.com

Abstract— The main objective of this research is to find out what are the determinants of households' pro environmental behavior (PEB) to enhancing towards solid waste management towards circular economy in Sri Lanka and what are the methods to manage waste. This study is focused on households' pro-environmental behavior determinants, or the factors that affect personal or external factors. Above mentioned particulars are the specific objectives of this research. In Sri Lankan context it is very rare to find literature on determinants of employers' pro environmental behavior enhancing towards small and medium scale industries waste management and shows the contextual research gap. This study is conducted using qualitative and quantitative research methods (Mix method). To identify the determinants influencing employers' PEB relating to households, a literature review and a questionnaire survey is employed. Based on the literature review, eight potential factors are identified. A structured questionnaire is developed for data collection. It was ensured to include respondents representing the Matara, Galle, and Hambantota districts as well. Initially, 1070 questionnaires were posted to randomly chosen households in Southern province, Sri Lanka. However, only 546 respondents returned completed questionnaires. The response rate was sufficient (51%). The study used PLS-SEM to analyze the data. Scholarly findings available on the website used in the preparation of this article and the lack of evidence in relation to solid waste management and pro-environmental behavior were identified as the main limitation. It reveals that pro-environmental behavior of households has a positive impact on solid waste management. This is in line with the findings of previous research findings. According to researchers, personal and external factors have been identified as an important factor in the pro environmental behavior that could affect solid waste management. Previous research has demonstrated positive relations

between personal factors and solid waste management. Even though most of the scholars conducted research based on pro environmental behavior in different contexts they have not identified the PEB of households and the findings of the solid waste management in circular economy is vague in literature.

Keywords— *Pro-environmental behavior, Circular Economy, Theory of Planned Behaviors, Solid-waste management, Personal factors, External factors*

I. INTRODUCTION

The United Nation's 2030 Agenda for Sustainable Development established goals promoting prevention, reduction, recycling, and reuse waste in countries while many countries face the problem of insufficient of both necessary resources and infrastructure for sound waste management. Due to population growth and changes in consumption patterns, the amount of waste released into the environment has increased and there is a significant challenge for the waste management capacity in many countries. Global waste generation is foreseen to increase by as much as 70% by 2050 (Chan, 2019). Based on the goals of the 2030 Agenda of sustainable development, Goal 12 mentioned "Responsible Consumption and Production" to increase the awareness of sustainable development in terms of resource consumption among people around the world and also aims to promote a healthy lifestyle (Knutsson 2021). Moreover, the concept of a circular economy has garnered international attention over the last decade. For instance, developing a circular economy has become a focal point for the United Nations and is seen as vital for progress towards achieving several of the UN Sustainable Development Goals (UNIDO, 2017). The household activities of both urban and rural areas have a negative impact on the natural environment. Economic growth that is derived from intensive exploration of natural resources and increasing pollution and waste is environmentally unsustainable. There is growing evidence that environmental challenges such as climate change and

loss of biodiversity are caused by the activities of industries and Pro-environmental behaviors (PEB) can assist SMEs in reducing their negative environmental impact (Fatoki 2019). According to the literature, it is obvious that pro-environmental behavior is a successful method to minimize the effect of environmental pollution and maintain environmental sustainability. Although pro-environmental behavior (PEB) is determined by a broad range of socio-demographic and psychological determinants, reviewing recent studies indicates that interdisciplinary exchange about them is still limited, posing a research gap in previous studies (Ridha et.al. 2020). This endeavor merges the knowledge of both disciplines and gives an overview of recent research findings by creating an interdisciplinary survey. As Stern (2000) writes, the role of an individual's predisposition to act in a certain way can vary strongly depending on the context, the behavior and the actor. In our interdisciplinary review of the literature published in the last decade, we find that this important factor is not considered appropriately. Sri Lanka faces profound challenges in the field of waste management and waste treatment. The report "Environmental management framework" from December 2017, is a government report assessing the state of the waste management situation in Sri Lanka and suggesting steps to be taken. Solid waste collection and disposal has been an issue in Sri Lanka for several decades, where burning and dumping garbage in collection yards are the most common modes of disposal. Municipal solid waste generated is mostly disposed of in "open dumps", without any pre-treatment, cover or compaction. Some of these dumps are located in environmentally sensitive areas such as wetlands, marshes and beaches, and are sometimes polluting local water sources or the soil. If nothing is done, these problems are likely to exacerbate due to increased urbanization.

Researchers pointed out several barriers that faced pro-environmental behavior not to practice circular economy such as lack of awareness of the benefits of the Circular Economy (CE) and usually have limited technical and financial resources, and they may not see CE as one of their priorities because of their lack of knowledge, governments and policymakers' support are not at a satisfactory level (Prieto-Sandoval 2019; Rizos et.al. (2015). Green behavior or the reducing environmental pollution is the trend of all over the world although the Sri Lankan people are not giving considerable diligence and perseverance for minimizing environmental pollution because of the lack of awareness regarding the value of green behavior, incapability of recruiting employees with good green practices and limited measurement tools. Demographic factors have a considerable impact on the individual's behaving pattern which could affect the organization's productivity and goodwill (Weerakoon et.al.2021).

When referring literature there are much evidence that identification of determinants of pro environmental behavior (PEB) on household waste-related behavior in terms of Internal factors (attitude, social and personal norms) and external factors (situational factors) while omitting personal and environmental factors like stress and tedious production processes, which have been shown to impact households'

behavior in Sri Lankan context and also previous literature (Banwo and Jianguo Du ,2019; Centobelli et al., 2021) explained research on pro environmental behavior (PEB) has mainly focused on homely atmosphere and few studies have focused on several businesses such as hotel sector and apparel industry. Although, studies done on SMEs have led to important empirical results. However, it seems there is lack of empirical research on household sector in Sri Lankan context. Consequently, this study is directed to examine the determinants of pro environmental behavior of households and how can they assist to circular economy in Sri Lanka.

The main objective of this research is to find out what are the determinants of households' pro environmental behavior to enhancing towards solid waste management towards circular economy in Sri Lanka and what are the methods to manage waste. This study is focused on households' pro-environmental behavior determinants, or the factors that affect personal or external factors Above mentioned particulars are the specific objectives of this research. **In Sri Lankan context it is very rare to find literature on determinants of employers' pro environmental behavior enhancing towards small and medium scale industries waste management and shows the contextual research gap.**

II. LITREATURE REVIEW

Circular Economy (CE)

The aim of the circular economy is to improve the utilization rate of resources and obtain the maximum economic output with as little environmental cost as possible, including minimum resource consumption and minimum waste generation. CE concepts and practices provide benefits to all businesses and countries, the approach taken towards it could vary depending on the country and nature of the businesses. In the CE conception, take/make gives the meaning of how the industries find resources from the environment to transform them into products or services. The product/service is then used by consumers or other companies, and the waste is redirected and returned to the environment or the industrial process to close the loop.

The CE concept is based on maximizing use of resources and regeneration of natural systems. Reduce materials and energy which used as inputs, Reuse the byproducts of production process and used waste from one stage to another stage of the production process and Recycle (3R) are the three main principles derived from the Circular Economy (Marino 2020). Another R , Redesign or the Renewing is recently added principle to offer product service systems and for the convenience of recycle and reuse. Hence, 3R has been extended to 4R (Sohal 2021).

CE is opposed to a linear economy that is based on the make-use-throw concept. The predicted increase of world population to 10 billion by 2050, 180% increase in consumption rate from 1990s level and high consumption of natural resources will result in high volume of waste generated due to a linear economy. When these wastes are transferred and accumulated at the landfill, they cause irreparable environmental damage, though there is hidden

potential in these wastes. To capture the full potential of the wastes, a shift is required from 'cradle-to-grave' (linear model) approach to 'cradle-to cradle' (circular model) approach that supports CE (Prieto-Sandoval 2019).

Pro-Environmental Behavior

Pro-environmental behavior (PEB) is adopted by researchers to study workplace pro- environmental issues in manufacturing industries, tourism, and education. Pro-Recycling, conserving water, saving electricity, choice and use of transport, and consumption of green products, are several different practices that involve environmental behavior. that can be grouped into three major categories: reduce, reuse, recycle (Hao et.al 2022). It is a challenge to change behavior, such as recycling, online methods for conferencing as a replacement for travelling, and using public transportation to promote cleaner production and prevent the production of waste and reduce the organization impacts on the environment in some organizations. Although these activities might seem irrelevant on the individual level, they could possibly have a significant influence on the organization's environmental performance (Foster 2022).

Several studies have endeavored to understand the factors that influence pro-environmental behavior and Previous studies reveal the factors that can impact on PEB including interpersonal factors (attitudes, norms, motivation, and values) and contextual or situational factors (government regulations, availability of recycling facilities). Some scholars evaluate Socio-economic factors including age, education, income, and gender, along Psychological determinants as awareness, norms, values, identity, environmental concern and knowledge, Bonds with the society, Personal factors as pleasure, enjoyment, happiness, bond with nature) and Organizational (organizational leadership behavior, institutional support) (Fatoki 2019).

External variables and Individual variables are two main categories of the determinants of pro environmental behavior. Social norms, cost, and convenience are considered as external variables and demographic and psychological variables are categorized into Individual variables. External factors and demographic factors were used to explain the pro-environmental behavior in early studies and later researchers found that the importance of psychological factors as attitude. Although the interaction of psychological variables with one another and the motion of pro-environmental behavior systems are deficient areas to remain discovered (Centobelli et.al. ,2021). Infrastructures, technical facilities and available products are concerned as contextual factors and the previous research studies do not pay considerable attention to study how contextual factors and habits of a person affect towards Pro-environmental behavior (Sawitri 2014).

Anticipated cost and benefits, Influence and moral and normative concerns are three things to motivate a person to behave environmentally. Theory of Reasoned Action, Theory of Planned Behavior, Norm Activation Theory and Values-Beliefs-Norms Theory are most widely theories to explain the determinants of environmental behavior. Intention is very important to a person's behavior and the most widely used

theory to explore the complexity of behavior, the Theory of Planned Behavior (TPB), explains this paradigm. (Sawitri 2014).

The Theory of Planned Behavior

There are several attempts at investigating and understanding environmental behavior in different contexts and theoretical perspectives. Among them the theory of planned behavior aims to predict behaviors from attitudes as well as to explain the process through which the two are related and it has developed as an extension of theory of reasoned action. Theory of Planned Behavior (TPB) and the Theory of Reasoned Action (TRA) emphasis the value of intention when performing a particular behavior. A large variety of contexts such as sexual behavior, driving, health-related practices, and recently pro environmental behaviors such as recycling, water conservation, green consumerism, and storm water management would be able to apply the theory of planned behavior. The theory proposes that a variety of person, environmental, and behavioral variables influence the pro-environmental behavior process (Sawitria 2014).

Based on the above description the theory of planning behavior is applied for determine the determinants of employer's pro environmental behavior and designed the conceptual framework. Institutional support is very important to encourage employees' pro environmental behavior. Previous studies emphasis the positive relationship between employee's workplace PEB and leadership behavior. The empirical research findings show that employees' pro environmental behavior is positively related to pollution prevention, sustainable innovation, better environmental performance, and more efficient environmental management systems. Employees' PEB is one of the most important factors to the advancement of organizational environmental initiatives as well as sustainability of natural environment. Organizational leaders can motivate employees to engage in behaviors that support the environment. However, leaders can serve as role models to employees and send signals to employees that certain behaviors are expected and valued as motivate employees' PEB. The availability of recycling bin and the appreciation of green behaviors are several activities that the management of an organization can undertake to demonstrate their support and encourage employees PEB. Many firms have not been able to find a balance between economically oriented and environmentally oriented actions. Lack of vision, unwillingness to change, lack of engagement and communication with employees and limited financial resources are constrained of institutional support for PEB (Fatoki 2019).

III. METHODOLOGY

This study focuses on examining the determinants of households' pro-environmental behavior on solid waste management: towards circular economy in Sri Lanka. It was ensured to include respondents representing the Matara, Galle, and Hambantota districts as well. Initially, 1070 questionnaires were posted to randomly chosen households

in Southern province, Sri Lanka. However, only 446 respondents returned completed questionnaires. The response rate was sufficient (42%). Next, it was decided to contact other households through telephone calls to get an appointment for personal interviews. Accordingly, another 150 respondents were contacted through telephone calls and 123 households agreed for interviews. However, only 100 questionnaires (out of 123 questionnaires) were usable to the survey as there were twenty-three incomplete questionnaires. As such, a total of 546 usable questionnaires were considered for the analysis. A structured questionnaire was used in the study. It consisted of five parts i.e., demographic data, background information, waste disposal behavior, waste collection system, and suggestions. The data collection took place during November 2022 and February 2023. The five study constructs i.e. personal factors and external factors were used as multi-item constructs. The personal factors were obtained from Nyang'au et al. (2015) and Sam et al. (2012). External factors were measured with the four items of the Chatzoglou et al. (2010) 's study. Solid waste management in circular economy adopted from Chatzoglou et al. (2010) and consisted of nine. All the variables were addressed by using a five-point Likert Scale ranging from 1= strongly disagree to 5= strongly agree. The result is a fairly detailed measurement and data collection sections making it possible for others to reproduce the research, to reanalyze the data, and to judge the adequacy of the methods and the data collection.

After reviewing the body of literature, researcher construct the theoretical model including personal variables such as Environmental commitment (Personal Values, Attitude, Norms) Environmental awareness, Sense of Responsibility, Physical Stress, Psychological Stress, and external variables as Influencing Others, Tedious Production Process, Training and propose the corresponding research hypothesis.

Several studies examined the willingness to engage in PEB, including attitudes, behaviors, and intention of protecting the environment. These values can be differentiated through their emphasis on different motivational goals. Literature provides much evidence to managers' attitudes and subjective norms are strongly related to an organization's initiative of establishing corporate environmentalism. Several authors suggest that further attention is necessary to an individual level determinant which may influence managers' pro environmental behavior (Bhattacharyya 2020). Wan, Shen, and Yu did another research under the topic of "The determinants of willingness to support recycling activities in Hong Kong". There has persistently exposed.

"The safety orientation displayed by safety-specific transformational leadership can influence subordinates' safety climate perceptions such that employees believe safety is prioritized over other organizational issues" through the empirical studies and It was affirmed by Ito, Leung, and Huang that *"environmental commitment had a significant impact on PEB"*.

Organizational greening strategies, employees' knowledge of the environment, and environmental programs lead to pro-

environmental practices in any organization, and employees are proud of their company when they perceived the social consciousness of the company's (Fosters, 2022). Previous research consciously resists non-environmental behaviors and are willing to use green products (Zhao et.al.,2021). According to the above description developed another hypothesis, gender is a considerable variable and there is a moderating effect on PEB. The following hypotheses are developed based on previous literature.

H₁: Environmental commitment has a positive effect on solid waste management.

H₂: Environmental awareness has a positive effect on solid waste management.

H₃: Sense of Responsibility has a positive effect on solid waste management.

H₄: Physical Stress influences solid waste management.

H₅: Psychological Stress influences solid waste management.

H₆: Influencing Others has a positive effect on solid waste management.

H₇: Tedious Production Process influences solid waste management.

H₈: Training has a positive effect on solid waste management.

IV. DATA ANALYSIS

Discriminant validity ensures that a construct measure is empirically unique and represents phenomena of interest that other measures in a structural equation model do not capture (Hair et al., 2010). Technically, discriminant validity requires that "a test not correlate too highly with measures from which it is supposed to differ" (Campbell, 1960, p.548). The discriminant validity of the latent variables was tested using Fornell and Larcker (1981) approach. Table 1 shows the discriminant validity of each latent variable. The discriminant validity of the latent variables requires that each latent variable's AVE is greater than the latent variable's squared correlation with any other construct in the model. The other entries in Table 1 shows the square of correlations (R²) between constructs. No non-diagonal entry exceeds the AVE of the specific construct. The covariance-based (CBSEM) approach and the variance- based partial least squares path modelling (PLS) are two statistical methodologies for estimating SEM with latent variables. Jöreskog and Wold (1982) viewed CB-SEM and PLS-SEM as complementary rather than competitive statistical methods. More specifically, Wold (1982) recognized CB-SEM's potential for the social sciences but was concerned about the informational and distributional requirements which are regarded as unrealistic for empirical research. To correctly apply CB-SEM and PLS-SEM, researchers must understand the purposes for which each approach was developed and apply them accordingly. Structural equation models with good measurement properties generally achieve comparable results with either approach, especially when the CB-SEM's model specifications have been correctly set up (Reinartz et al., 2009).

PLS-SEM only permits recursive relationships in the structural model (i.e., no causal loops). Therefore, the structural paths between the latent constructs can only head in a single direction (Volckner et al. 2010). CB-SEM develops a theoretical covariance matrix based on a specified set of structural equations. The technique focuses on

estimating a set of model parameters in such a way that the difference between the theoretical covariance matrix and the

Table 1: Discriminant validity of variable constructs
Source: Survey Data (2023)

The CB-SEM model estimation requires a set of assumptions to be fulfilled, including the multivariate normality of data, minimum sample size, and so forth

Latent Variables	1	2	3	4	5	6	7	8
Env. Commitment	0.85							
Env. Awareness	0.62	0.83						
Sense of Responsibility	0.53	0.43	0.81					
Physical Stress	0.50	0.33	0.54	0.78				
Psychological Stress	0.48	0.45	0.46	0.67	0.76			
Influencing Others	0.41	0.56	0.21	0.61	0.58	0.71		
Tedious Production Process	0.32	0.47	0.38	0.52	0.37	0.54	0.68	
Training	0.27	0.36	0.30	0.45	0.44	0.32	0.41	0.66

(e.g., Diamantopoulos & Siguaw, 2000). A SEM with latent constructs has two components (i.e., inner model and measurement model). SEM does not only allow to analyze a set of latent factors like dependent and independent variables in regression analysis (Segars & Grover, 1993) but also provides a comprehensive means to assess and modify theoretical models (Karahanna & Straub, 1999).

Impact of Personal Factors on Solid Waste Management

Table 2 shows the summary of the coefficient of determination (R^2). The study measures the coefficient of determination (R^2) of the endogenous latent variable i.e., solid waste management. The percentage of explained variance (R^2) is 0.67 for solid waste management. Also, table 2 summarizes these relationships and shows the values of standardized path coefficients (β), standard errors (se), t-values (t), and significance values (p) of path coefficients including model goodness of fit statistics.

estimated covariance matrix is minimized (e.g., Rigdon, 1998).

Table 2: Results of PLS Path Model Estimation

	Solid Waste Management ^a
	Estimates (t-values)
Path	
Personal Factors	
Environmental commitment	0.42 (8.97)***
Environmental awareness	0.31 (6.01)***
Sense of Responsibility	0.27 (2.69)**
Physical Stress	0.48 (9.23)***
Psychological Stress	0.15 (0.49)
External Factors	
Influencing Others	0.36 (5.01)***
Tedious Production Process	0.12 (0.39)
Training	0.25 (2.67)**
Model goodness-of-fit statistics	
X ² (df)	254.314 (76)
SRMR	0.06
d ULS	1.89
d G	1.54
NFI	0.71
rms theta	0.17
Coefficient of determination (R^2)	0.67

***p < 0.001; **p < 0.01; *p < 0.05

^a Dependent variable Source:

Source: Survey data (2023)

Under the personal factors, the results reveal that environmental commitment has a positive and statistically significant relationship with solid waste management. This relationship is supported by data ($\beta=0.42$, $t=8.97$, $p<0.000$) in harmony with postulated theory, results show that an environmental awareness has a positive and statistically significant effect upon solid waste management. There is a positive and statistically significant relationship between environmental awareness and solid waste management ($\beta=0.31$, $t=6.01$; $p<0.000$). There is a positive and statistically significant relationship between sense of responsibility and solid waste management ($\beta=0.27$, $t=2.69$; $p<0.05$). Physical Stress has a positive and statistically significant relationship with solid waste management. This finding is supported by the data ($\beta=0.48$, $t=9.23$; $p<0.000$) and it is in expected direction. There is a positive relationship between Psychological Stress and solid waste management ($\beta=0.15$, $t=0.49$; $p<0.136$). There is a positive relationship, but the relationship is not statistically significant. External factors of the pro environmental behaviors of the households indicate that the positive relationship with solid waste management in circular economy except tedious production process, other factors are statistically significant with endogenous variables. There is a positive and statistically significant relationship between influencing others and solid waste management ($\beta=0.36$, $t=5.01$; $p<0.000$). Meanwhile, training has a positive and statistically significant relationship with solid waste management ($\beta=0.25$, $t=2.67$; $p<0.05$), tedious production process has a positive but statistically not significant relationship with solid waste management ($\beta=0.12$, $t=0.39$; $p<0.201$).

II. DISCUSSION AND CONCLUSION

This study is to investigate the determinants of households' pro-environmental behavior on solid waste management: towards circular economy in Sri Lanka. The main objective of this study is to find out the determinants of households' pro-environmental behavior on solid waste management. It reveals that pro-environmental behavior of households has a positive impact on solid waste management. This is in line with the findings of Chan, (2019). According to Chan (2019), personal and external factors have been identified as an important factor in the pro- environmental behavior that could affect solid waste management. Previous research (Sparrowe et al., 2001; Cross & Cummings, 2004) has demonstrated positive relations between personal factors and solid waste management (Burt, 1992). Among these personal factors physical stress as a pro-environmental behavior significantly affects solid waste management. Moreover, the findings of the study revealed that there is a significant positive relationship between personal and external factors with solid waste management. The waste sorting and purchase of environmentally friendly goods are increasing the most. Meanwhile, the performance of conservation behaviour increased the least. The change in the performance of switching of lights when leaving the room was one of the least and people were not inclined to perform this behaviour frequently in 2022/2023 (Minealgate and Liobikienė 2023).

ACKNOWLEDGMENT

This research was supported/partially supported by the EU co-funded the Techno-Economic-Societal Sustainable Development Training in Sri Lanka (TESS) project 609925-EPP-1-2019-1-NO-EPPKA2-CBHE-JP, which is co-funded by the European Commission under its ERASMUS+ CBHE programme. This project aims to develop new interdisciplinary educational programs and redesign existing programs in Solid Waste Management (SWM).

/REFERENCES

- Banwo A.O., and Jianguo Du (2019), "Workplace pro-environmental behaviors in small and medium-sized enterprises: an employee level analysis", *Journal of Global Entrepreneurship Research*, pp 19-34
- Centobelli P., Cerchione R., Esposito E., Passaro R., Shashi (2021), "Determinants of the transition towards circular economy in SMEs: A sustainable supply chain management perspective", *International Journal of Production Economics*, 242 (2021)108297, PP.1-13
- Chan, H.W. (2019). When do values promote pro-environmental behaviors? Multilevel evidence on the self-expression hypothesis. *Journal of Environmental Psychology*. <https://doi.org/10.1016/j.jenvp.2019.101361>**
- Fatoki O., (2019) "Hotel Employees' Pro-Environmental Behaviour: Effect of Leadership Behaviour, Institutional Support and Workplace Spirituality". *Sustainability* 2019, 11, 4135, pp.2-15.
- Foster, B.; Muhammad, Z.; Yusliza, M.Y.; Faezah, J.N.; Johansyah, M.D.; Yong, J.Y.; ul-Haque, A.; Saputra, J.; Ramayah, T.; and Fawehinmi, O. (2022), "Determinants of Pro-Environmental Behaviour in the Workplace". *Sustainability* 2022, 14, 4420. <https://doi.org/10.3390/su14084420>
- Hair F.Jr, J., Sarstedt, M., Hopkins, L. and G. Kuppelwieser, V. (2010), "Partial least squares structural equation modeling (PLS-SEM): An emerging tool in business research", *European Business Review*, Vol. 26 No. 2, pp. 106-121. <https://doi.org/10.1108/EBR-10-2013-0128>**
- Marino A., and Paolo Pariso, (2020), "Comparing European countries' performances in the transition towards the Circular Economy", *Science of the Total Environment* 729 (2020) 138142 PP. 1-12.
- Prieto-Sandoval V, Jaca C, Santos J, Baumgartner RJ, and Ormazabal M. (2019) "Key strategies, resources, and capabilities for implementing circular economy in industrial small and medium enterprises". *Corp Soc Resp Env Ma*. 2019; 26:1473–1484
- Ridha A.E., Matondang N., and Sitepu M.H., (2020) "Pro-environmental behavior for small medium enterprise", *TALENTA CEST II 2019 IOP Conf. Series: Materials Science and Engineering* 801 (2020) 012069
- Rizo V., Behrens A., Kafyeke T., Hirschnitz-Garbers M., and Ioannou A., (2015) "The Circular Economy: Barriers and Opportunities for SMEs" CEPE working document, www.ceps.eu
- Sawitri D.R., Hadiyantob H., Hadic S.P. (2014) "Pro-Environmental Behavior from a Socio-Cognitive Theory Perspective", *Procedia Environmental Sciences* 23 (2015) pp. 27 – 33.
- Sohal A., Nand A.A., Goyal P., Bhattacharya A.(2022) 'Developing a circular economy: An examination of SME's role in India', *Journal of Business Research*, 142, PP.435–447
- Weerakoon W.M.S.M. B., Sellar T., Arulrajah A.A., (2021), 'Employee Green Behaviour of Selected Hotels in Polonnaruwa Area of Sri Lanka', *Sri Lankan Journal of Human Resource Management* Vol. 11, No. 1, 2021, pp. 37- 52.

ENHANCING THE SUSTAINABILITY OF SRI LANKAN WASTE-TO-ENERGY PLANTS: A CIRCULAR ECONOMY APPROACH

Debashree De

*Strategy, organisation and
Entrepreneurship, Essex Business
School, UK
d.de@essex.ac.uk*

Chamara Jayanath Kuruppu Gowindage

*USN School of Business
Norway
Chamara.Kuruppu@usn.no*

Abstract— This paper explores the crucial role of segregated waste collection in facilitating the transformation from waste to energy, thereby underpinning a circular economy model. It argues that proper segregation of waste is a prerequisite for efficient Sri Lankan waste-to-energy (WtE) waste-to-energy (WtE) conversion, which helps to optimize the value of waste resources while minimizing environmental impacts. The study draws on primary data sources to demonstrate that waste segregation during collection is an essential step for sustainable waste management. Results indicate that well-implemented segregation systems significantly enhance the quality of recoverable materials, improve energy conversion efficiency, and reduce environmental pollutants. Furthermore, the paper shows how these systems, when integrated within a circular economy model, catalyzes sustainable development by minimizing waste and reducing resource consumption. The findings underscore waste segregation as a critical step toward effective WtE processes and a sustainable circular economy. The paper concludes by suggesting future research directions to overcome potential barriers in implementing such systems.

Keywords—Waste to Energy, segregation, circular economy, Sri Lanka

I. INTRODUCTION

Waste-to-energy (WtE) refers to the technologies that treat waste to recover energy in the form of heat, electricity or alternative fuels such as biogas. WtE plants have become an important part of the global effort to reduce waste. The concept of "Waste-to-Energy" covers a wide range of technologies that differ in complexity and scale. These include the production of cooking gas from organic waste in household digesters, the collection of methane gas from landfills, and the thermal treatment of waste in large-scale incineration plants using methods such as incineration, pyrolysis, and gasification (Psomopoulos et al., 2009). Additionally, Refuse Derived Fuel (RDF) can be coprocessed in cement plants or through gasification (Khan et al., 2016).

WtE plants have become a significant part of global efforts to reduce waste. However, the sustainability of these plants often depends heavily on the quality and quantity of the waste feedstock available (Consonni et al., 2015). For instance, if waste is not properly segregated, it can lead to

decreased energy recovery efficiency and increased environmental impacts (Laurent et al., 2014). Hence, a circular economy approach that incorporates segregated waste collection is imperative to enhance the sustainability of WtE plants (Zaman, 2015).

Each WtE technology comes with its own set of advantages and disadvantages, and the selection of a suitable method depends on several factors, including the type and quantity of waste, the resources available, and the potential environmental impact (Malinauskaite et al., 2017). These technologies contribute to waste reduction and the production of renewable energy, aligning with the global trend toward sustainable development (Velis, 2014). To enhance the sustainability of WtE plants, a circular economy approach that incorporates segregated waste collection is necessary.

Segregated waste collection is the process of separating different types of waste at the source, such as households or commercial establishments. This approach enables the recovery of valuable materials from waste streams, such as metals, plastics, and paper, which can be reused or recycled. The remaining organic waste can be used as feedstock for WtE plants.

The circular economy approach to WtE plants involves designing and operating these facilities in a way that maximizes resource recovery and minimizes waste generation. This approach involves three key principles: reduce, reuse, and recycle. By reducing the amount of waste generated, reusing materials, and recycling valuable materials, WtE plants can become more sustainable and efficient.

One of the main benefits of a circular economy approach to WtE plants is that it reduces the need for virgin materials. This reduces the environmental impact of resource extraction, transportation, and processing. In addition, it reduces the amount of waste that ends up in landfills, which can release methane and other harmful greenhouse gases.

To implement a circular economy approach to WtE plants, it is necessary to establish effective waste management systems that incorporate segregated waste

collection. This requires collaboration between municipalities, waste management companies, and WtE plant operators. It also requires public education and awareness campaigns to encourage individuals and businesses to adopt sustainable waste management practices.

The benefits of a circular economy approach to WtE plants extend beyond environmental sustainability. It also creates economic opportunities by generating new jobs in the waste management and recycling industries. In addition, it can reduce the costs associated with waste disposal and energy production.

Enhancing the sustainability of WtE plants through segregated waste collection is essential for achieving a circular economy that maximizes resource recovery and minimizes waste generation. It is time for municipalities, waste management companies, and WtE plant operators to work together to implement this approach and create a more sustainable future.

The primary aim of this research is to comprehensively investigate and understand the multifaceted challenges and issues faced by waste-to-energy (WTE) plants, particularly in developing country-Sri Lanka, and how these issues affect their efficiency and sustainability.

The paper delves deeper into the specific operational, regulatory, and logistical barriers and opportunities that are associated with implementing segregated waste collection systems at WTE plants in these regions. By doing so, the paper aims to identify practical solutions that can enhance the sustainability and efficiency of these facilities.

Furthermore, the study will explore the potential of a circular economy model to optimize the functionality of WTE facilities. This investigation seeks to ascertain the degree to which such a model can contribute to the reduction of waste, the maximization of resource utilization, and the mitigation of environmental impacts, thus driving the transition towards more sustainable and efficient WTE facilities.

By addressing these objectives, the research aims to provide actionable insights that policymakers, waste management agencies, and WTE plant operators can utilize to overcome the identified challenges, leverage potential opportunities, and adopt circular economy principles, thereby promoting a more sustainable and efficient waste management infrastructure.

Research question:

1. What are the key barriers and opportunities in implementing segregated waste collection to enhance the sustainability of WTE plants in Sri Lanka?
2. To what extent can a circular economy model contribute to the optimization of waste-to-energy facilities?

II. LITERATURE REVIEW

The transition to a circular economy model, which emphasizes the reprocessing and reuse of waste materials, has been touted as a critical solution to addressing increasing environmental concerns, including waste management and energy production (Ellen MacArthur Foundation, 2013). Among these solutions, waste-to-energy (WTE) technologies play an integral role in this paradigm shift by converting waste materials into useful forms of energy such as heat or electricity (Psomopoulos, Bourka, & Themelis, 2009).

A. Waste-to-Energy Plants and Sustainability

A key concern with WTE technologies is their sustainability, especially regarding their carbon emissions and overall environmental impact (Arena, 2012). There have been several approaches proposed to enhance the sustainability of WTE plants, including improving operational efficiency, reducing pollutant emissions, and utilizing waste heat for district heating or cooling systems (Kothari, Tyagi, & Pathak, 2010). The successful implementation of such strategies largely depends on the type of waste processed, the technology used, and the specific local or regional circumstances (Münster & Lund, 2010).

B. Segregated Waste Collection and WTE

An emerging area of interest in the literature is the potential for segregated waste collection to enhance the sustainability of WTE plants (Malinauskaite et al., 2017). Segregated or separated waste collection involves the sorting of waste materials at the source, which can lead to more efficient recovery of valuable materials and a reduction in contamination levels. This, in turn, can improve the efficiency of WTE operations, resulting in increased energy production, reduced emissions, and the recovery of valuable by-products like metals or minerals (Malinauskaite et al., 2017).

C. Circular Economy Approach

The circular economy model provides a framework that aligns well with segregated waste collection in the context of WTE technologies. The model emphasizes keeping resources in use for as long as possible and maximizing their value through repeated cycles of recovery, reuse, and recycling (Ellen MacArthur Foundation, 2013). This model creates the potential for synergies between segregated waste collection and WTE plants, such as enhanced waste resource management, energy generation, material recovery, and emissions reduction (Ghisellini, Cialani, & Ulgiati, 2016).

Several case studies illustrate the feasibility and benefits of adopting this approach. For instance, research in Denmark and Sweden has demonstrated that implementing a circular economy model with segregated waste collection and WTE technologies can contribute to reduced landfilling,

improved energy efficiency, and considerable greenhouse gas (GHG) emissions savings (Eriksson & Finnveden, 2015; Bernstad Saraiva Schott & Cánovas, 2015).

D. Challenges and Opportunities

Despite these promising developments, various challenges need to be addressed to fully realize the potential of this approach. These include logistical issues associated with waste segregation, public participation and awareness, technological requirements, and policy and regulatory frameworks (Ghisellini, Cialani, & Ulgiati, 2016; Eriksson & Finnveden, 2015). Nevertheless, the opportunities for integrating segregated waste collection with WTE technologies in a circular economy context are significant and further exploration.

The literature suggests that enhancing the sustainability of WTE plants through segregated waste collection within a circular economy framework holds significant promise for improved waste management, energy production, and environmental protection. However, the successful implementation of this approach requires addressing various technical, social, and policy challenges. As the demand for sustainable waste and energy management solutions continues to grow, so does the need for research and innovation in these areas.

Research in the field of waste-to-energy (WTE) plants, segregated waste collection, and their integration within the framework of a circular economy approach is a continually developing area.

Much of the research on this topic has focused on developed nations or specific geographic regions. Therefore, a research gap exists in understanding how these practices could be implemented and optimized in various socio-economic and geographical contexts, particularly in developing nations.

While studies have investigated certain aspects of WTE plants and segregated waste collection, a comprehensive lifecycle analysis that covers all stages from waste generation to energy production and subsequent waste disposal, particularly in the circular economy context, seems lacking. There is limited research on the development and application of novel technologies that could make segregated waste collection and WTE processes more efficient, scalable, and sustainable. Research is needed on how local, regional, and national policies and regulations can incentivize segregated waste collection, promote the sustainability of WTE plants, and foster circular economy principles. The role of public awareness, attitudes, and behaviors in segregated waste collection is another area with substantial research gaps. Understanding these factors could be key to increasing the participation rate and efficiency of these programs.

The economic feasibility of enhancing the sustainability of WTE plants through segregated waste collection in the context of a circular economy is another potential research gap. Understanding the economic costs and benefits, as well

as potential business models, could help promote these practices.

Much of the current research is relatively short-term, so longterm studies on the sustainability and efficiency of WTE plants utilizing segregated waste collection under a circular economy approach are needed.

Studies comparing the efficiency and effectiveness of different waste segregation and collection methods, and their impact on WTE plant performance and sustainability are limited. A thorough investigation of the environmental, social, and health impacts of implementing segregated waste collection in WTE plants under a circular economy model is yet to be fully explored.

These areas could provide fertile ground for new research that advances our understanding of how to enhance the sustainability of waste-to-energy plants through segregated waste collection within a circular economy context.

III. THEORY

Enhancing the sustainability of Waste-to-Energy (WTE) plants through segregated waste collection in the context of a circular economy, the theoretical lens used is Stakeholder Theory. This study identifies and analyze the various stakeholders involved in the waste-to-energy process, from waste producers, collectors, to WTE plant operators and endusers of the energy produced. Understanding their interests and influence can provide insight into the challenges and opportunities of implementing segregated waste collection.

IV. METHODOLOGY

To examine the impact of segregated waste collection on enhancing the sustainability of Sri Lankan Waste-to-Energy (WtE) plants, the study adopted a case study approach. This qualitative research method allows for an in-depth examination of a specific case or cases within their real-world context (Yin, 2014). The methodology is divided into case selection, data collection, and data analysis stages.

A. Case Selection

For this study, research selected a Sri Lankan WtE plant that employs segregated waste collection as part of its waste management strategy. The waste to energy plant is selected as it is one of the best waste to recovery plant with best of the practices.

B. Data Collection

Data was collected from both primary and secondary sources. Primary data was gathered through in-depth interviews with plant personnel, including plant managers, waste collection and segregation staff, and technical experts involved in the plant's operation. We used semi-structured interview guides to ensure that key topics were covered while allowing for open-ended responses (Creswell, 2013).

We also conducted site visit and direct observations of waste collection, segregation, and energy generation processes.

Secondary data was collected from plant records, annual reports, and waste collection and segregation documentation. This included information on waste intake, segregated waste types, energy output, waste treatment techniques, emission levels, and the disposal process of residual waste.

C. Data Analysis

Data analysis was performed through thematic analysis, a method commonly used in case study research to identify patterns or themes within the data (Braun & Clarke, 2006). The study transcribed and coded the interview responses and reviewed plant documentation to identify recurring themes and patterns related to the impact of segregated waste collection on the sustainability of the WtE plant. The study then categorized the themes into sub-themes and analyzed them in relation to the efficiency, and economic feasibility of the plant.

V.FINDINGS

In the Figure 1, provides a flowchart that visually represents the entire process of waste handling in a Sri Lankan WtE plant, starting from waste collection and segregation to final energy generation. The flowchart include stages such as:

1. Collection of waste from various sources
2. Transportation of waste to the WtE plant
3. Segregation of waste into different categories (e.g., organic, inorganic, recyclables, hazardous)
4. Treatment of segregated waste (e.g., composting, recycling, incineration)
5. Energy generation from treated waste
6. Management of by-products (e.g., ash disposal, emission control)

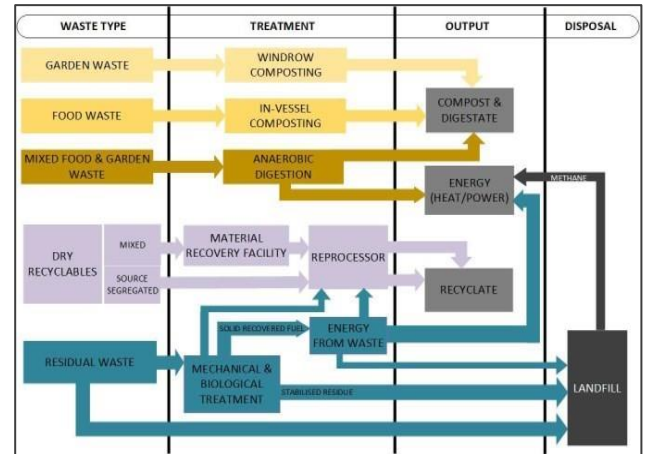


Figure 1 flowchart of integrated waste Handling process in a sri lankan waste-to- Energy plant

Strategies or guidelines of waste management

1. 4R concept
2. Circular Economy
3. Zonal Concept of waste management
4. Seven steps Of Municipal Solid waste management
5. Polluter pay Principal and Extended Producer Responsibility
6. PDCA (monitoring)
7. Simultaneous approach for waste management
8. Provincial Platform for waste management
9. Interpersonal Communication and Education

4R concept: This refers to "Reduce, Reuse, Recycle, and Recover." This concept emphasizes minimizing waste generation, reusing items, recycling, and recovering resources (energy or materials) from waste (Troschinetz & Mihelcic, 2009).

Circular Economy: This approach encourages keeping resources in use for as long as possible, extracting the maximum value from them, and then recovering and regenerating products and materials at the end of their life cycle (Ghisellini et al., 2016).

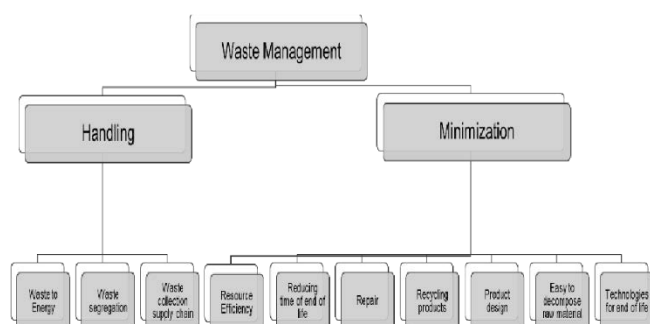
Waste minimization and the circular economy are closely aligned concepts that share the goal of reducing resource consumption and waste generation (Tomic et al., 2020). By implementing waste minimization strategies, businesses and consumers can contribute to the establishment of a circular economy, where resources are reused, recycled, and recovered, reducing the demand for new materials and the environmental impact associated with waste disposal.



Figure 2 the circular economy model for waste minimization

Zonal Concept of Waste Management: This involves segregating a city or region into zones for the purpose of waste management to enhance efficiency and effectiveness of waste collection and treatment (McDougall et al., 2008).

FIGURE 3 THE CLASSIFICATION OF WASTE MANAGEMENT INTO HANDLING AND MINIMIZATION MINIMIZATION



Seven Steps of Municipal Solid Waste Management: This includes waste generation, on-site handling, collection, transfer and transport, processing and recovery, disposal, and monitoring (Tchobanoglous et al., 1993).

Polluter Pays Principle and Extended Producer Responsibility: The Polluter Pays Principle implies that whoever is responsible for damage to the environment should bear the costs associated with it. Extended Producer Responsibility is a strategy to add environmental costs associated with goods throughout their life cycles to market prices (OECD, 2016).

PDCA (monitoring): Plan-Do-Check-Act (PDCA) is a repetitive four-step management model used in business for the control and continuous improvement of processes and products. In waste management, it can be used for monitoring and improving waste management systems (ISO, 2015).

Simultaneous Approach for Waste Management: This involves the implementation of various waste management

strategies together, instead of separately, such as waste reduction, segregation, recycling, and disposal, to achieve maximum efficiency (Zurbrugg et al., 2014).

Provincial Platform for Waste Management: This refers to coordination at the provincial level for efficient and sustainable waste management, which can include developing regional waste management plans, infrastructure, and education programs (EPA, 2020).

Interpersonal Communication and Education: Education and communication are crucial for fostering environmentally responsible behaviors, such as proper waste disposal, recycling, and waste reduction. This includes public awareness campaigns, school education programs, and community engagement (Dahlén & Lagerkvist, 2010).

TABLE 1 TARGETS OF STRATEGIC PLAN FOR WASTE MANAGEMENT IN THE WESTERN PROVINCE (2019 TO 2023) AND WASTE TREATMENT & DISPOSAL INDEX, TARGETS.

Index	2019	2020	2021	2022	2023
Waste collection %	55	56	58	59	61
Source Segregation %	40	45	48	52	56

Index	2019	2020	2021	2022	2023
Open dumping %	89	70	20	0	0
Composting by LA%	4	4	6	6	6
Recycling by LA%	3	4	5	6	7
Composting by clusterbased facility %	4	7	10	12	13
Other cluster-based treatment & disposal landfill %	1	15	60	77	74
WMI	11%	30%	80%	100%	100%

The Waste Treatment and Disposal Index (WTDI) can be conceptualized as a metric that quantifies the effectiveness, efficiency, and environmental impact of waste treatment and disposal practices. The index can be useful for assessing the performance of waste management systems, comparing different waste treatment and disposal technologies, and tracking progress over time.

Waste Treatment and Disposal Index (WTDI): WTDI indicates the amount of waste properly managed out of the total waste collection in percentage wise.

$$\text{WTDI (\%)} = \left(\frac{\text{Recovered Waste Q} + \text{Landfilled waste Q}}{\text{Collected waste Quantity}} * 100 \right)$$

WTDI can be calculated by the formula given below.
This index is relevant to the respective year.

FIGURE 4 WTDI TRENDS

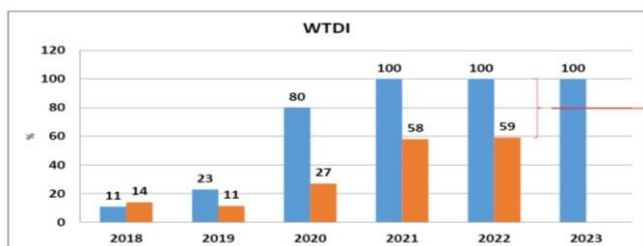


FIGURE 5 MSW COLLECTION IN A SRI LANKAN PROVINCE

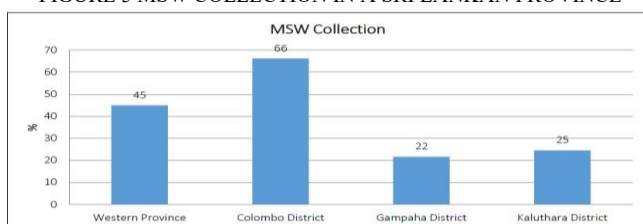


FIGURE 6 WASTE RECOVERY OVERVIEW: PERCENTAGE DISTRIBUTION OF RECYCLED, COMPOSTED, LANDFILL AND ENERGY-WASTE IN A SRI LANKAN WASTE-TO-ENERGY PLANT

	Type of Waste Recovery (Mt/Month)									
	Total Composting/Animal Feeding	Percentage of Composting/Animal (%)	Total Recycling	Percentage of Recycling (%)	Energy Recovery (Waste to Energy)	Percentage of Energy recovery (%)	Sanitary Landfilling	Percentage of Sanitary Landfilling (%)	Open Dumping	Percentage of Open Dumping (%)
Colombo District	2720.0	8.1	612.3	1.8	18551.0	55.5	0.0	0.0	11513.1	34.5
Gampaha District	1394.8	17.5	117.7	1.5	1349.7	16.9	101.0	1.3	5004.8	62.8
Kaluthara District	1424.4	39.1	29.0	0.8	365.3	10.0	0.0	0.0	1824.3	50.1
Western Province	5539.2	12.3	759.0	1.7	20266.0	45.0	101.0	0.2	18342.3	40.8

FIGURE 7 COMPARATIVE ANALYSIS OF WASTE TREATMENT AND DISPOSAL METHODS IN A SRI LANKAN WASTE-TO-ENERGY PLANT

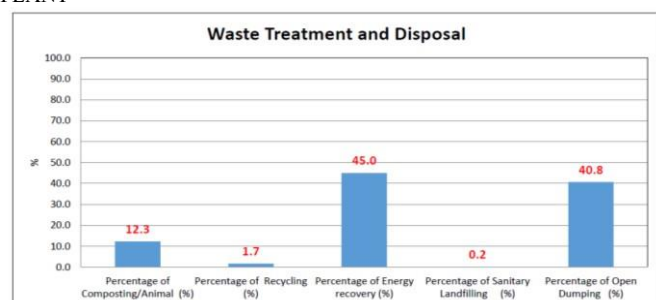


FIGURE 8 WASTE TREATMENT AND DISPOSAL INDEX (WTDI) SCORES ACROSS PROVINCES IN A SRI LANKAN WASTE-TO-ENERGY PLANT

District	WTDI
Colombo	66%
Gampaha	37%
Kalutara	50%
Western Province	59%

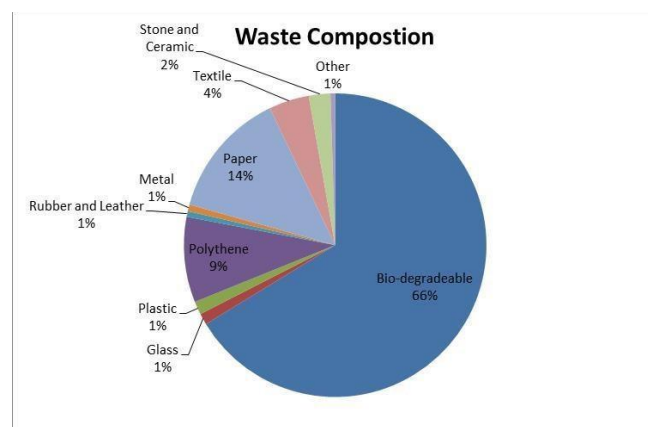
Applying a circular economy framework to waste-to-energy (WTE) plants involves rethinking and redesigning the entire waste management system to optimize resource use, minimize waste, and maximize the value extracted from waste throughout its lifecycle.

Here are some key components of such a circular economy framework:

Prevention and Minimization of Waste Generation: Reducing waste at the source is a fundamental principle of the circular economy. This includes practices such as designing for durability, repair, and reuse, promoting consumption reduction, and encouraging consumers to choose products with less packaging or waste (Stahel, 2016).

Segregated Waste Collection: Different types of waste have different potentials for energy recovery and recycling. Segregating waste at the source improves the efficiency of the waste-to-energy process and allows for better resource recovery (Rizos et al., 2016). The figure 9 shows the waste composition of the WTE.

FIGURE 9 WASTE COMPOSITION IN A SRI LANKAN WASTE-TO-ENERGY PLANT



Optimized Waste-to-Energy Processes: WTE technologies has been chosen and designed considering the specific types of waste available, the potential energy yield, and the environmental impacts. Optimizing these processes

maximize energy recovery and minimize pollution (Korhonen et al., 2018).

Recycling and Composting: Not all waste should go to WTE plants. Recycling and composting have been prioritized for waste that can be turned into new products or organic fertilizer, reducing the need for virgin resources and synthetic fertilizers (Ghisellini et al., 2016). The WTE in Colombo has ensured a good waste segregation. The WTE has helped in improving the energy recovery

Residue Management: the WTE plants produce residues, such as ash. These residues have been treated as resources, not as waste, and reused in cement plants. This is a very good example, in construction materials (Zaman, 2015).

This paper delves into the pivotal role of segregated waste collection in driving the transformation from waste to energy, forming the backbone of a circular economy model. The central argument posits that the meticulous segregation of waste serves as a fundamental prerequisite for the efficient conversion of waste to energy in the context of Sri Lanka. This process, known as waste-to-energy (WtE) conversion, not only optimizes the value of waste resources but also minimizes the environmental footprint associated with waste management.

Drawing on primary data sources, the study underscores that the segregation of waste during the collection phase is an indispensable step for fostering sustainable waste management practices. The results presented in the paper highlight that well-implemented waste segregation systems significantly elevate the quality of recoverable materials, enhance energy conversion efficiency, and mitigate environmental pollutants.

Moreover, the paper elucidates how these segregated waste collection systems, when seamlessly integrated within a circular economy model, act as catalysts for sustainable development. By minimizing waste and reducing resource consumption, these systems contribute to the overall resilience and longevity of the circular economy framework. The findings emphasize waste segregation as a critical step toward ensuring the effectiveness of WtE processes and the realization of a sustainable circular economy.

In conclusion, the paper suggests future research directions aimed at overcoming potential barriers in implementing segregated waste collection systems. Recognizing the significance of this groundwork, the discussion sets the stage for continued exploration and innovation in waste management practices, pushing the boundaries of sustainable development. Ultimately, the integration of segregated waste collection within the waste-to-energy framework emerges as a transformative strategy for steering societies toward a circular economy that is both economically viable and environmentally responsible.

VI. CONCLUSION

This paper underscores the fundamental role of segregated waste collection systems in advancing waste-to-energy (WtE) conversion processes and supporting the implementation of a circular economy model. The research establishes a clear connection between efficient waste segregation and the optimization of the value derived from waste resources, along with significant reductions in environmental impacts. Empirical findings suggest that well-executed segregation systems are vital for enhancing material recovery quality, improving energy conversion efficiency, and curtailing environmental pollutants.

These systems, when thoughtfully integrated within a circular economy framework, can act as catalysts for sustainable development, helping societies minimize waste, curtail resource consumption, and bolster energy efficiency. To that end, this study offers a persuasive argument for policy initiatives to place waste segregation at the forefront of strategies aiming to amplify the effectiveness of WtE processes and create a more sustainable circular economy.

The results also highlight the necessity for future research and policy recommendations that focus on overcoming potential obstacles that could hinder the implementation of such systems. This work thus sets the stage for subsequent investigations into the various facets of waste management, contributing to a comprehensive understanding of sustainable waste-to-energy practices within the circular economy paradigm.

ACKNOWLEDGMENT

This research has received funding from ERASMUS+Techno-Economic-Societal Sustainable Development Training in Sri Lanka (TESS)

REFERENCES

- [1] Consonni, S., Vigano, F., & Grosso, M. (2015). Waste management & sustainable consumption: reflections on consumer waste. Routledge.
- [2] Dahlén, L., & Lagerkvist, A. (2010). Pay as you throw: strengths and weaknesses of weight-based billing in household waste collection systems in Sweden. *Waste Management*, 30(1), 23-31.
- [3] Environmental Protection Agency (EPA) (2020). Sustainable Materials Management (SMM).
- [4] Ghisellini, P., Cialani, C., & Ulgiati, S. (2016). A review on circular economy: The expected transition to a balanced interplay of environmental and economic systems. *Journal of Cleaner Production*, 114, 11-32.
<https://doi.org/10.1016/j.jclepro.2015.09.007>

- [5] ISO (2015). ISO 14001:2015 - Environmental management systems.
- [6] Khan, M. Z., Sultana, M., Al-Muyeed, A., & Uddin, M. T. (2016). Co-processing of Refuse Derived Fuel in Cement Kiln in Bangladesh: Potential Option for Proper Waste Management. *International Journal of Environmental & Agriculture Research*.
- [7] Korhonen, J., Honkasalo, A., & Seppälä, J. (2018). Circular Economy: The Concept and its Limitations.
- [8] *Ecological Economics*, 143, 37–46. <https://doi.org/10.1016/j.ecolecon.2017.06.041>
- [9] Laurent, A., Bakas, I., Clavreul, J., Bernstad, A., Niero, M., Gentil, E., ... & Hauschild, M. Z. (2014). Review of LCA studies of solid waste management systems–Part I: Lessons learned and perspectives. *Waste management*, 34(3), 573-588.
- [10] Malinauskaite, J., Jouhara, H., Czajczyńska, D., Stanchev, P., Katsou, E., Rostkowski, P., ... & Spencer, N. (2017). Municipal solid waste management and wasteto-energy in the context of a circular economy and energy recycling in Europe. *Energy*, 141, 2013-2044.
- [11] McDougall, F. R., White, P. R., Franke, M., & Hindle, P. (2008). *Integrated solid waste management: a life cycle inventory*. John Wiley & Sons.
- [12] [OECD (2016). *Extended Producer Responsibility: Updated Guidance for Efficient Waste Management*. OECD Publishing, Paris.
- [13] Psomopoulos, C. S., Bourka, A., & Themelis, N. J. (2009). Waste-to-energy: A review of the status and benefits in USA. *Waste management*, 29(5), 1718-1724.
- [14] Rizos, V., Behrens, A., Kafyeke, T., Hirschnitz-Garbers, M., & Ioannou, A. (2016). The circular economy: Barriers and opportunities for SMEs, Centre for European Policy Studies.
- [15] Stahel, W. R. (2016). The circular economy. *Nature*, 531(7595), 435–438. <https://doi.org/10.1038/531435a>
- [15] Tchobanoglous, G., Theisen, H., & Vigil, S. (1993). *Integrated solid waste management*. McGraw-Hill.

Stakeholder Analysis in Pursuit of Developing Curriculum for a Master's Degree in Waste Management and Circular Economy

Dayananda Ambalangodage
Department of Accounting
University of Sri Jayewardenepura
Nugegoda, Sri Lanka
dayananda27@sjp.ac.lk

Chamara Kuruppu
School of Business
University of Southeastern Norway
Borre, Norway
chamara.kuruppu@usn.no

Anil Jayantha Fernando
Department of Accounting
University of Sri Jayewardenepura
Nugegoda, Sri Lanka
anil@sjp.ac.lk

Kingsley Karunaratne
Department of Accounting
University of Sri Jayewardenepura
Nugegoda, Sri Lanka
Kingsley@sjp.ac.lk

Kennedy D. Gunawardana
Department of Accounting
University of Sri Jayewardenepura
Nugegoda, Sri Lanka
kennedy@sjp.ac.lk

Ranil C. Peiris
Department of Information Technology
University of Sri Jayewardenepura
Nugegoda, Sri Lanka
cranil@sjp.ac.lk

Abstract— This paper aims to analyze stakeholder views and opinion to develop an appropriate curriculum for a proposed master's degree in waste management and circular economy by the university of Sri Jayewardenepura to build the capacity in the field of higher education in Sri Lanka under The TESS project (Techno-Economic-Societal Sustainable Development Training in Sri Lanka) funded by the European union Erasmus+ programme. The sample (Research Site) was selected in such a manner to represent different perspectives of stakeholders. Accordingly, university academics, university students, schoolteachers, school principals, government officials engaged in waste management at the ministry of environment, local government authorities, provincial councils, representatives from central environmental authority, Coastal Conversation & Coastal Resource Management department, and non-governmental organizations, industry experts and entrepreneurs engaged in waste management business are identified as key stakeholders. Data is collected through peer discussion, focused group interviews, and individual interviews. All stakeholders emphasized the importance of higher education in waste management, and a master's degree is viewed as an excellent opportunity for people to improve their capacity to cope with the waste issue in Sri Lanka. Further, they stress the need of a vibrant curriculum that conveys current information primarily from technical and theoretical viewpoints while emphasizing the importance of combining such knowledge in finding solutions to real-life practical problems in waste generation and management. Technology is regarded as a main enabler of waste management learning and implementing solutions for waste management. The importance of looking at waste and waste management from global and collective approaches to find sustainable solutions. Further, stakeholders want the education to see waste as a resource rather than a problem so that it would help create more entrepreneurial opportunities, and rooms for innovations and to engage in new business models to create value especially within a circular economy perspective. The need for introducing new methods in teaching, learning and assessment is also highlighted by the stakeholders as the subject areas has a practical relevance. Analysis further finds that education and

awareness on waste management should reach a wider array of people including households, and manufacturers who mainly generate waste. Hence, education should not be limited to selected groups of people but, avail for everyone. The research provides insight into the scope, nature, content, delivery, and assessment of waste management in higher education and a framework for introducing a new degree in waste management and circular economy.

Keywords— Circular Economy, Sustainability, Stakeholders, Stakeholder Analysis, Waste Management

I. INTRODUCTION

Waste has become a global issue and therefore everyone has a stake in contribution to find solutions for waste and waste management at different capacities. Profound education and good practices could play a critical role in the pursuit of managing waste and finding a lasting solution to this global issue of waste. TESS, Techno-Economic-Societal Sustainable Development Training in Sri Lanka (TESS Project) is a project funded by the European Union programme of Erasmus+ with the aim of building capacities in the Higher Education in Sri Lanka.

Curriculum development for a newly introduced master's degree programme in waste management and circular economy is one of the work packages of the TESS project. The need for stakeholder analysis has been identified as a key pillar of the process on the ground, that the outcome of the analysis has high potential to lay a strong foundation to execute the master's degree program.

Stakeholder analysis is a process of identifying and evaluating the views and opinion of people who either directly or indirectly are likely to influence or being influenced by a particular phenomenon. Stakeholders in waste management were identified as university academics, university students, schoolteachers, school principals, government officials engaged in waste management at the ministry of environment, local government authorities, provincial councils, representatives from central environmental authority, Coastal Conversation & Coastal Resource Management

department, and non-governmental organizations, industry experts and entrepreneurs. Stakeholder identifying process involved creating a list of all the different individuals and groups who are likely to be associated with waste and waste management and potential to disseminate the knowledge on was and waste management.

The purpose of stakeholder analysis is to identify the needs, expectations, and concerns of these stakeholders, in the pursuit of developing curriculum for a master's degree programme to build the capacity in higher education as a crucial part of the TESS project. Views and opinions of stakeholders were considered in determining the scope, nature, content, delivery modes, and assessment of the said master's degree programme to ensure that the new degree program will meet the needs of the target audience and to have a positive impact on the wider community when dealing with waste.

The importance of identifying stakeholders, engaging with them and collecting data in strategic decision making specially within private sector organisations is highly visible (Carroll & Buchholtz, 2002; Christopher, Payne, & Ballantyne, 2002; Rutterford, Upton & Kodwani, 2006) and it has stepped into public sector organizations as well with an increasing trend around the world (Maassen, 2000; Wit, 2000; Peters, 1996 & Kettle, 2002). The importance has been further increasing specially in the higher education sector as the operations of the sector are likely to have multiple and sustainable impact on the society in managing critical issues and finding lasting solutions for critical issues. On the other hand, the support and the consent of stakeholders plays a significant role as the stakeholder theory explains (Donaldson and Preston, 1995), irrespective of the fact that whether the organization is for profit or not for profit (Bryson, 2005), particularly in a high education context.

Concepts of Stakeholder Analysis

The concept of stakeholder engagement provides opportunities for every stakeholder to engage in and contribute in many ways depending on the subject matter. A summary of the concepts of stakeholder analysis with a short description, reference and research's view is given in table 1 below.

TABLE 1: CONCEPTS OF STAKEHOLDER ANALYSIS

Concept	Reference	View
Stakeholders (parties that will affect or being affected by the actions others)	(Nutte & Backoff, 1992), (Polonsky, 1995)	Waste management is not an outcome of actions of single or selected people instead it connects to many engaged in the process of waste management.
Stakeholder identification and classification	(Polonsky, 1995), Johnson and Scholes (2002), Reed (2008).	It is challenging to identify relevant stakeholders for collecting data for any strategic decision.

Stakeholder Analysis and common objectives	Oliver, 1991,	The role of stakeholder analysis is significant, especially when the subject matter is to promote and achieve common objectives. Ultimate objectives of waste management are linked to common objectives of achieving sustainability at a global level. The need for classifying stakeholders for analysis purposes would keep the objective intact.
Degree of influence of stakeholders	Freeman (1984)	degree of influence of the stakeholder matters in determining courses of actions connected to waste management operations and achieving set objectives.
Significance of stakeholder analysis.	Burby, 2003, Margerum, 2002, Bryson, 1995, Moore, 1995, Baumgartner & Jones, 1993, Eden & Ackermann, 1998.	Success of any course of action is always high when stakeholders actively engage in the process. Hence, a stakeholder analysis can help develop a sound foundation for curriculum development.
Goal congruence and stakeholders	Bryson (2005), Mitchell, Agle & Wood (1997)	effective stakeholder consultation would help build strong alliances and ensure smooth operations of actions.
Risk of identifying the relevant stakeholders. there is possibility that non-stakeholders are identified as stakeholders	Mitchell <i>et al.</i> , 1997, Rowley, 1997	There is a greater risk as non-stakeholders could be identified as stakeholders unless a process of stakeholder analysis is done as the different identities and complexities of stakeholders. Techniques such as snowball helped minimize this risk
Stakeholder prioritization and consensus though conflicting views and tendency to compete for resources.	(Neville & Menguc, 2006), (Gomes & Gomes, 2009), Mitchell <i>et al.</i> , 1997).	This concept highlights the importance of focusing on common goals as stakeholders, with conflicting views and tendency for to compete for resources would create challenges. Stakeholder prioritization would bring a solution to this issue. However, developing curriculum might not create big issues with competing stakeholders as consensus can be easily reached as the subject is education and a common issue.
stakeholders with strategies and actions	Gomes & Liddle, 2009, (Reed, Graves, Dandy, Posthumus, Hubacek, Morris, Prell, Quinn and Stringer, 2009	Different stakeholders into the strategies and actions would create some minor challenges as they could turn out to be opportunities or threats sometimes. Incorporating the views of stakeholders into the strategies and actions would be a solution.

Balance in Stakeholder analysis	(Brookes, 2003, (Wit <i>et al.</i> , 2000).	The tendency of dominance by high-profile academia when deciding curriculum might disregard the importance of stakeholders. This issue may create a mismatch between industry needs and the teaching learning process. This gap may reflect at many levels unless stakeholder analysis is well incorporated when designing higher education programme, as stakeholders may not actually have much influence in determining curriculum of universities.
---------------------------------	---	--

II.METHODOLOGY

Data analysis was carried out by using a qualitative approach Schilling (2006) as the objectives of the research need to bring about the context specific realities to determine the nature and scope of the curriculum development. Hence, it is needed to have views and ideas from those who play key roles in waste management throughout the country. More than 60% of waste is generated in the western province. Hence, the interview sample (Research Site) included a majority from the western province while representing different fields from a wide range of disciplines. Accordingly, 136 stakeholders, as detailed out in table 2 were interviewed either as focused groups or individuals.

Coding was done by referring to identified themes and dimensions to find out the general content and commonalities of responses (Miles and Huberman, 1994). Scope of the need analysis extended to identify and analyze knowledge gap labour, market opportunities, and competencies needed for employment, and to determine (PLOs), course modules, learning contents, modes of teaching learning, and assessment methods aligned with attributes and the requirement of Sri Lanka Qualification Framework (SLQF). Ideas and views were gathered from stakeholders in both public and private sectors.

Qualitative research approach was used as the methodological approach and content analysis and interpretivism were used as methods of analyses. Accordingly, data and information were gathered from meetings and discussions with stakeholders, and engagement with the process of forming an apex body on waste management by university of Ruhuna, informal interviews & discussions and own learning experience of the team.

TABLE 2: A SUMMARY OF STAKEHOLDERS INTERVIEWED

Date	Duration	Number of Stakeholders	Remarks
5.04. 2020	1 hours and 35 minutes	5	Industry experts
8.04. 2020	1 hour and 20 minutes	3	Industry experts
10.9. 2020	2 hours	3	Industry experts
23.9.2020	2 hours and 15 minutes	5	Representatives from Municipalities, Provincial Councils
28.9. 2020	1 hours and 45 minutes	4	Representatives from Municipalities, Provincial Councils
29.9. 2020	2 hours and 35 minutes	6	Representatives from Municipalities, Provincial Councils, Ministry of Environment
7.10. 2020	1 hours and 20 minutes	5	Representatives from Municipalities, Provincial Councils
17.05.2021	2 hours and 10 minutes	5	Representatives from NGOs
21.05.2021	2 hours and 30 minutes	2	Coastal Conversation and Coastal Resource Management
7.06.2021	3 hours	34	Representatives from diverse groups – School Teachers & Principals, University students, Zonal education Directors, Planning Officers, Local Government Authorities from provinces
9.07. 2021	2 hours	4	Representatives from Colombo Municipality
5.08. 2021	2 hours	3	Representatives from Ministry of Local Government and provincial Council
25.11. 2021	5 hours	20	Diverse stakeholders – Hambantota District Apex Body Discussion
2.12. 2021	5 hours	22	Diverse group of stake holders – Matara District Apex Body Discussion
10.12. 2021	5 hours	15	Diverse stake holders- Galle District Apex Body Discussion

Preliminary interviews with opinion formers in relation to waste management to define the exact direction of the analysis, to identify key stakeholders to be interviewed, and to decide the scope and content of interviews and discussions. Accordingly, data was collected mainly through peer discussion, focused group interviews, and individual interviews, covering the areas of PLOs, scope of the curriculum, content requirement of course units, modes of deliveries, student assessment, suggestions to improve waste management approaches and practices in Sri Lanka. Research site comprised of a range of stakeholders namely university academics, university students, schoolteachers, school principals, government officials engaged in waste management at the ministry of environment, local

government authorities, provincial councils, representatives from central environmental authority, Coastal Conversation

& Coastal Resource Management department, and non-governmental organizations, industry experts and entrepreneurs engaged in waste management business. Stakeholders were identified by referring to the literature and general knowledge of the team members and results of discussions had among academia and industry experts. Accordingly, initial discussions were held with industry people at seminars conducted to form forming an apex body for waste management in Galle, Matara, and Hambantota districts resulted more practical solutions in waste management from social, environmental, and economic point of views. This design of the data collection was used as the nature of the study is exploratory, and it gives each interviewee the opportunity to freely express their views and thoughts. Questions were asked to explore the current and how they are linked to the objectives of the study

III. DATA ANALYSIS AND DISCUSSION

Whilst stakeholder theories are relatively mainstream, (Donaldson and Preston, 1995; Singhapakdi *et al.*, 1996), limited research has addressed stakeholder engagement (Bryson, 2005). There is a of stakeholder theory evident, this research aimed to start with a relatively to identify the stakeholders, their relative importance, and the factors, affecting their importance. Defining stakeholders is of importance (Mitchell *et al.* 1997; Reed, 2008), and this research identified 136 stakeholders that are relevant to the introduction of a master's degree by the university of Sri Jayewardenepura. Desk research was also carried out and the outcome of it was summarized based on the following major areas.

- Need of higher education to manage waste in a sustainable manner.
- Dealing with Waste in a circular economy
- Seeing waste as a resource instead of as an issue
- Role of technology and how it is integrated with teaching learning environment and waste management practices.
- Appropriate blend of teaching learning methods and delivery modes
- Modes of student assessment
- Relevance of research in waste management
- Visibility of learning outcomes at practice after completion of the degree
- Regular review and continuous improvement of curriculum

It was found that collective and integrated approaches would be strategic and sustainable solutions for this global issue of waste and best practices are required to be promoted at individual and corporate levels as well. There is an urgent need to impart the required knowledge on waste and ways of managing it as the starting point and

therefore curriculum in any level of education should accommodate these aspects.

It was recommended to see waste as a resource instead of looking at it as a troublemaking issue as waste can generate value and has potential of creating business opportunities. However, it is needed to have support from the government to make it possible by providing required infrastructure and financial support, proper guidance, adequate awareness, legal framework, and effective monitoring.

The use of technology at all levels of waste hierarchy was also found to be a key leverage in waste management. Attitude on waste prevailing in Sri Lankan context was regarded as highly negative and as a result everyone is likely to preserve self-interest at high social and environmental costs. Resistance against the construction of waste management plants, on irrational and individual agendas can be shown as an example of attitudinal behavior of people, irresponsible and politically motivated decisions of authorities. Hence, multiple actions of awareness on waste, waste management and consequences in absence of sustainable solutions for waste management are essential. Learning environment is required to be arranged with more opportunities for students to become active learners to find practical solutions rather than becoming passive cognitive learners.

Active research initiatives could further enhance the capacity of stakeholders as this issue of waste has a practical relevance to engage in. Stakeholders highlighted the importance of capacity people to reflect what they have learned in finding solutions for real-life issues and situations.

Further, the need for deviating from traditional teacher-based learning was highlighted, instead it was proposed to introduce technology and new teaching learning methods to keep students engaged in and interact in the learning process. Opportunities for foreign exposure in learning either through field visits or knowledge dissemination by foreign experts and academics were also stressed on the ground that the waste management specially in developed countries are being tackled in innovative and sustainable manner.

Student assessment was regarded as a critical aspect of the curriculum. It was noted that there is a risk that assessment methods may not focus on learning outcome from what students have really learned during the course due to many weaknesses and constraints prevailing in teaching methods. Stakeholders further stressed the importance of communicating the assessment methods properly at the beginning of each course and the programme. In turn, examiners should adhere to the methods, rules, regulations, and guidelines as stipulated to test learning outcomes. As knowledge is likely to expand rapidly mainly due to changes in technology and isomorphism, the need for regular curriculum review and prompts revisions to and of the course modules offered are essential parts of a good curriculum.

With reference to practical solutions for waste management, many stakeholders were highly concerned about the problem of landfills with waste. Stakeholders

from local government authorities and provincial councils paid more attention towards stakeholder knowledge on waste and management of municipal waste, starting from waste generation points. Waste reduction, reuse and recycling were regarded as key factors of reducing the number and area of landfills which is a critical issue in Sri Lanka at present. Authorities from the ministry of environment and department of coastal conservation and central environment authority further stressed the need for reducing landfills with waste with appropriate use of technology, policy implementation and implementation of different business models to use waste as a resource to generate value to the economy thus promoting the concept of circular economy. The environmental assessment of landfills based on stakeholder analysis.

Proper competencies enhanced with appropriate knowledge, skills and attitudes must be considered in general in developing a curriculum for waste management, almost all stakeholders stressed. Appropriate knowledge was referred to a composite one and embedded in wider socio-political context. Skills required for capacity building highlighted by stakeholders mainly include communication skills, adaptability, ability to adjust in a changing environment, interpersonal skills, critical thinking, digital skills, technological skills, and analytical and problem-solving skills. Focus on self-awareness, aesthetic sense, respect to environment and societal values, professionalism in action and engage in ethical conduct as a responsible citizen were the key attitudes identified by the stakeholders. Non recognition of the task of waste collectors is one of the biggest attitudinal and social problem and as a result, the social and economic condition of those waste collectors is seen not being improving a bit even thus leading a complete social rejection that is turn create problems in the job market as well. This is a critical deviation of the situation prevailing in developed countries and therefore, capacity building in higher education needs to think of way to enhance professionalism, use of technological skills and maintain ethical conduct in waste management where artificial intelligence, robotic process automation, or machine learning are possible enablers to improve the demands in the job market.

Collaboration among policy makers, educational intuitions and industry partners would help sustain the waste management practices and therefore, such industry exposure must be arranged in the curriculum. A holistic approach for waste management will always be effective and inclusion learning outcome to deal with Environment – Social-Governance (ESG) assessment and reporting are imperative.

Roles of traditional waste managers were seen to have confined to value reporter and value preserver and that needs to be changed to be value enabler and value creator according to industry experts. Hence, the curriculum needs to have these important skills incorporated.

The need for higher education opportunities especially from managerial perspective was highly welcome especially by officials at local authorities, provincial councils, ministry of environment and central

environmental authority, as the all the available learning opportunities and channels highly tend toward technical and technological aspects of waste. Some stakeholders were surprised to hear the intention of introducing a master's degree program in waste management by a management faculty of a university as such tasks have been already well institutionalized as a task of an engineering or a science faculty.

There were mixed opinions on inclusion of a research component in the curriculum. Those who argued against mentioned that most research studies in management have no practical relevance and they are carried out just for the name shake. Hence, it is better to keep it optional so that students who have real intention of doing research can choose it at their discretion. Further, it is essential to have qualified and competent faculty members to supervise such research to deliver a quality work and the real situation in higher education institutions in Sri Lanka is not promising as such qualified people limited. On the other hand, stakeholders stressed the need for having a research component compulsory highlighted that such engagement would allow students to apply the knowledge gathered from course units can be applied in real life situations and further, real research into the nature of waste and waste management would allow students to find solutions to the problem of waste in innovative and creative ways. Hence, it is required to follow appropriate research methodology courses before starting the research to make students ready and capable of doing real research successfully.

The most cited stakeholder group are officials from local authorities, provincial councils, central environmental authority, and the ministry of environment. School teachers, university students, university academics, education planning directors provided views mainly on the content, relevance, delivery, and assessment of students. The second most identified stakeholder group was industry experts who provided views on industry collaboration, the need for training, research, and possibilities of implementing different business models. The staff of the university were both 'academic' and student. This was considered important because academic staff 'had interests that went beyond the university alone, such as a commitment to their subject area', whilst students also could view it from learner perspective.

Stakeholder grouping generally perceived and referred to stakeholders to simplify their understanding and overview, and hopefully simplifies conceptualization of the variety of stakeholders cited, as well as providing some indication of their commonalities. Primary purpose of the stakeholder analysis that is to develop a curriculum for a master's degree in waste management and circular economy was achieved and the structure of curriculum developed with a two-year program including a research component. The structure of the curriculum is given in table 3.

TABLE 3: STRUCTURE OF THE CURRICULUM OF THE DEGREE PROGRAM

Course Code	Title (under Year and Semester)	CV	CH	NH
Year 1- Semester 1				
MWM5301	Waste Management and Circular Economy	3	45	150
MWM5302	Waste Management Regulations and Policies	3	45	150
MWM5303	Information Technology and Applications	3	45	150
MWM5304	Innovative Enterprise	3	45	150
MWM5305	Emergency Management	3	45	150
Year 1- Semester 2				
MWM5306	Waste Management Systems	3	45	150
MWM5307	Accounting and Social Responsibility	3	45	150
MWM5308	Environmental, Social, and Governance Frameworks for Waste Management	3	45	150
MWM5409	Research Methodology	4	60	200
Year 2- Semester 1				
MWM6401	Business Models and value Creation	4	60	200
MWM6302	Green Technology and Ecology	3	45	150
MWM6303	Climate Change, and SDGs	3	45	150
MWM6304	Seminar in Waste Management and Circular Economy	3	45	150
Year 2- Semester 2				
MWM6305	Leadership for Transformational Change	3	45	150
MWM6166	Dissertation	16	90	1510
Total		60	750	3710

CV= Credit Value

CH= Direct Student Contact Hours

NV= Notional Hours

IV.CONCLUSION

Stakeholder views were gathered covering a wide range of representatives from those who are engaged in waste management activities in both public and private sector organization, policy makers, NGOs, industry experts, academics, and students. Peer discussion, interviews and focused group discussion were conducted to collect data. Qualitative approach was used to analyse data which referred to education needs in waste management, nature of waste and management aspects, role of technology in waste management, waste management practices, relevance of a master degree to build capacity, learning outcomes expected from a master degree, course structure, learning content, delivery methods of knowledge, learning environment, internship, relevance of research in waste management, visibility of learning outcomes at practice after completion of the degree, student assessment methods, review and continuous improvement of curriculum.

Data with multiple dimensions and perspectives helped design the curriculum in such a manner as laying a foundation for building capacities of people in waste management through effective learning experiences. There is lacuna in high education opportunities in waste management in Sri Lanka compared to other opportunities and there is a significant demand for a master's degree in waste management. All 136 stakeholders and groups are either directly or indirectly engaged in waste management practices and education. Analyses revealed that there are diverse and dynamic views and opinions on waste management and learning, but all have a kind of touch with the global issue of waste and the need for sustainable waste management solutions ranging from collective efforts to individual practices.

Program learning outcomes (POLs) were designed in such a manner by considering the outcome of the stakeholder analysis for the purpose of building the capacity of people. Accordingly curriculum was developed to reflect the needs of society and to build the capacity address those issues, with two year master degree including a research component by incorporating an appropriate course structure, learning content, delivery modes, and student assessment in line with PLOs the proposed master's degree in waste management and circular economy to cater for the need of addressing the issue of waste within the identified scope of the TESS project, resources and capacities available.

ACKNOWLEDGMENT

This paper was developed, as a result of implanting Techno-Economic-Societal Sustainable Development Training in Sri Lanka (TESS) Project: 609925-EPP-1-2019-1-NO-EPPKA2-CBHE-JP, which is co-funded by the European Commission under its ERASMUS+ CBHE programme.

REFERENCES

- Baumgartner, J. and Jones, B. (1993) *Agendas and Instability in American Politics*, Chicago, IL: University of Chicago Press.
- Brookes, M. (2003) "Higher education: Marketing in a quasi-commercial service industry", *International journal of Nonprofit and Voluntary Sector Marketing*, Vol. 8, No.2, 2003, pp.134-142.
- Bryson, J. (1995) *Strategic Planning for Public & Non-Profit Organisations* (Revised Edition), San Francisco, CA: Jossey-Bass.
- Bryson, J. (2005) 'What to do when stakeholders matter', *Public Management Review*, Vol. 6, Issue 1. Routledge.
- Burby, R. (2003) 'Making Plans That Matter: Citizen Involvement and Government Action' *Journal of the American Planning Association*, Vol. 19, Issue. 1. pp33-50.

- Carroll, A.B. and Buchholtz, A.K. (2002) *Business and Society: Ethics and Stakeholder Management*, Southwestern College Publishing; 5Rev Ed edition.
- Christopher, M., Payne, A. and Ballantyne, B. (2002) *Relationship Marketing: Creating Stakeholder Value*, Butterworth-Heinemann; 2 Rev Ed edition.
- Donaldson, T. and Preston, L. (1995) "The stakeholder theory of the corporation: Concepts, evidence, & implications", *Academy of Management Review*, Vol. 20, No. 1, pp. 65-91.
- Eden, C. and Ackermann, F. (1998). *Making Strategy: The Journey of Strategic Management*. London: Sage Publications.
- Freeman, R.E. (1984) *Strategic Management: A stakeholder approach*, Boston: Pitman
- Gomes, R.C. and Gomes, L.O.M. (2009) Depicting the arena in which Brazilian local government authorities make decisions – what is the role of stakeholders? *International Journal of Public Sector Management*, Vol.22 No.2, pp.76-90.
- Gomes, R.C.J. and Liddle, J. (2009) Stakeholders Cross Cultural Analysis – Who are the stakeholders in municipal districts? The case of Brazil and England. (Forthcoming) *Public Management Review*.
- Johnson, G. and Scholes, K. (2002) *Exploring Corporate Strategy*, Prentice Hall, Harlow, England.
- Kettle, D. (2002) *The Transformation of Governance: Public Administration for Twenty-First Century America*, Baltimore, MD: Johns Hopkins University Press.
- Maassen, P. (2000) 'The Changing Roles of Stakeholders in Dutch University Governance', *European Journal of Education*, Vol. 35, No. 4. pp. 449-464(16)
- Margerum, R. (2002) 'Collaborative Planning: Building consensus & a distinct model of practice' *Journal of Planning Education & Research*, Vol. 21. pp237-53
- Miles, M.B. and Huberman, A.M. (1994) *Qualitative Data Analysis: An Expanded Sourcebook*, Sage: USA.
- Mitchell, R., Agle, B. and Wood, D. (1997) 'Toward a Theory of Stakeholder Identification and Salience: Defining the Principle of Who and What Really Counts', *Academy of Management Review*, Vol. 22, No. 4.
- Moore, M. (1995) *Creating Public Value*, Cambridge, MA: Harvard Press.
- Neville, B. and Menguc, B. (2006) 'Stakeholder Multiplicity: Toward an Understanding of the Interactions between Stakeholders', *Journal of Business Ethics*, Vol. 66, pp377-391
- Nutt, P.C. & Backoff, R.W. (1992) *Strategic Management of Public and Third Sector Organisations*, San Francisco, Jossey-Bass.
- Oliver, C. (1991) 'Strategic Responses to Institutional Processes', *The Academy of Management Review*, Vol. 16, No. 1 pp.145-179.
- Peters, B. (1996) *The Future of Governing: Four emerging models*, Lawrence, KA, University Press of Kansas.
- Polonsky, M. (1995) A stakeholder theory approach to designing environmental marketing strategy, *Journal of Business and industrial marketing*, Vol. 10, No. 3, pp. 29-46.
- Reed, M. (2008) Stakeholder participation and environmental management: A literature review. *Biological Conservation* 141 (2008) pp.2417-2431.
- Reed, M. Graves, A. Dandy, N. Posthumus, H. Hubacek, K. Morris, J. Prell, C. Quinn, C. and Stringer, L. (2009) 'Who's in and why? A typology of stakeholder analysis methods for natural resource management. *Journal of environmental management* 90 (2009) pp.1933-1949.
- Rowley, T. (1997) 'Moving beyond dyadic ties: a network theory of stakeholder influences' *The Academy of Management Review*, Vol. 22, No. 4. pp.887-910.
- Rutterford, J., Upton, M. and Kodwani, D. (2006) *Financial Strategy: Adding Stakeholder Value*, John Wiley & Sons; 2nd Edition.
- Schilling, J. (2006) "On the Pragmatics of Qualitative Assessment: Designing the Process for Content Analysis". *European Journal of Psychological Assessment*. 2006. Vol.22 (1): pp.28-37.
- Stake, R.E. (1995) *The art of case study research*, Sage, Thousand Oaks, California.
- Wit, K. and Verhoeven, J. (2000) 'Stakeholders in Universities & Colleges in Flanders', *European Journal of Education*, Vol. 35, No. 4.

Advances in Agriculture and Food Technology Innovations

Utilization of Cinnamon (*Cinnamomum verum*) to Suppress the Glycaemic Impact of Wheat Bread

U.S. Wijewardhana
Department of Food Science and
Technology
University of Sri Jayawardenepura
Nugegoda, Sri Lanka
uswijewardhana@sci.sjp.ac.lk

M.A. Jayasinghe
Department of Food Science and
Technology
University of Sri Jayawardenepura
Nugegoda, Sri Lanka
madhura@sci.sjp.ac.lk

I. Wijesekara
Department of Food Science and
Technology
University of Sri Jayawardenepura
Nugegoda, Sri Lanka
isuruw@sci.sjp.ac.lk

K.K.D.S. Ranaweera
Department of Food Science and
Technology University of Sri
Jayawardenepura
kkdsran@yahoo.com

Abstract— Type II diabetes has reached pandemic dimensions affecting and terminating the lives of people on a daily basis. Diet is a prominent factor in the onset and progression of type II diabetes, highlighting the importance of dietary interventions to prevent and manage the disease. Hence, the objective of the study was to determine the effectiveness of cinnamon in reducing the glycaemic index of wheat bread. Breads were formulated with different percentages of cinnamon powder and the product with the best sensory perception was selected through sensory evaluations. The effectiveness of cinnamon in hindering the glycaemic impact of bread was evaluated by calculating the glycaemic index against a control, via a human trial. The calculated glycaemic index of cinnamon-incorporated wheat bread was 45.06 ± 12.3 which was a 21.08% reduction compared to control bread. Results indicate that the incorporation of functional ingredients such as cinnamon into high glycaemic foods could be a promising way of reducing glycaemic index and consequently aid in controlling and managing type II diabetes.

Keywords—Diabetes, Glycaemic impact, Bread, Cinnamon

I. INTRODUCTION

Diabetes has become a health crisis affecting almost every household around the world. Two-thirds of the diabetic population live in developing countries and South Asian countries have escalating number of people suffering from the disease [1]. Sri Lanka has a high percentage of diabetic population and available data shows a definite upward trend [2]. Type II diabetes is the most common among diabetes types and diet is a significant root cause in the etiology of the disease. Dietary factors are of utmost importance to prevent and manage the occurrence of the disease even though dietary interventions are rarely implemented.

Bread is a staple food product in almost every household around the world. Made mostly from refined wheat flour, bread is high glycaemic and elicits quick blood glucose responses upon eating. Long-term consumption of high glycaemic foods increases the risk of onset and progression of type II diabetes [3]. Alternative low glycaemic breads are available in the market, formulated with high fibre and added resistant starches, decreasing their palatability. Therefore, refined wheat breads are still preferred due to their taste even with the risk of diabetes.

The addition of functional ingredients to reduce the glycaemic index of diet is comparatively less researched. Spices and herbs have been used for thousands of years to treat various ailments through traditional medicinal systems. Most spices and herbs of Asian origin possess anti-diabetic/ hypoglycaemic properties [4]. Cinnamon (*Cinnamomum verum*) is such a spice that is considered to possess anti-diabetic properties and could be beneficial in the management of type II diabetes. The effectiveness of cinnamon in reducing the glycaemic impact of wheat bread was investigated via a human study by calculating glycaemic index (GI).

II. METHODOLOGY

a. Product formulation

Different selected percentages (0.5%, 1%, 1.5% and 2%) of cinnamon powder were added to wheat flour, salt, yeast, and fat and kneaded with a sufficient amount of water to make a dough. The formulated dough was kept for bulk fermentation for an hour and shaped and proofed for another hour. Finally, the dough was baked for 40 minutes at 200°C.

b. *Sensory evaluation and selection of the best sample*

Bread products formulated by incorporating different percentages of cinnamon powder were evaluated for sensory attributes; Appearance, Aroma, Texture, Taste, and overall acceptability to select the best sample. Products were evaluated using a five-point hedonic scale, by a semi-trained sensory panel of 30 panellists. Results were statistically analyzed by Friedmann test (Minitab 17) and according to mean ranks best sample was selected.

c. *Human study and calculation of GI*

Ethical clearance for the human trial was obtained from the Faculty of Medicine, University of Sri Jayewardenepura prior to the beginning of the study (Ref. no 13/22).

The best-selected sample proceeded to the calculation of GI in order to assess the effectiveness of cinnamon in lowering the glycaemic impact of bread. Healthy adults with normal blood glucose levels (80-120 mg/dL) and BMI (18.5-23.5), 18-45 years of age were selected on a voluntary basis. They were asked to come on 3 different days with an overnight fast (8-12 hours) for the blood collection after glucose (standard), control bread, and cinnamon bread ingestion. Finger prick blood was collected in 0, 15, 30, 45, 60, 90, and 120-time //intervals, and samples were analyzed using a glucose oxidase assay kit (Megazyme) and a USDA-approved glucometer.

Blood glucose variation after each ingestion was plotted against time for each individual and Incremental Area Under the Curve (IAUC) was calculated. The glycaemic index for each individual was calculated using the following formula:

$$\text{Glycaemic index} = \frac{\text{IAUC of test food}}{\text{IAUC of glucose}} \times 100$$

III. RESULTS AND DISCUSSION

//Diet modifications can be considered a successful and more economical way of preventing and managing type II diabetes as diet is a major root cause in the development of the disease. The objective of the study was to formulate a low glycaemic bread product with acceptable sensory attributes. There are several ways to reduce the glycaemic index of a food, the addition of functional ingredients being one of them [6]. It was important for the novel bread to be a palatable one as most alternatives in the market are repelled by consumers. Therefore, the one with the highest sensory acceptability was selected through the sensory evaluations.

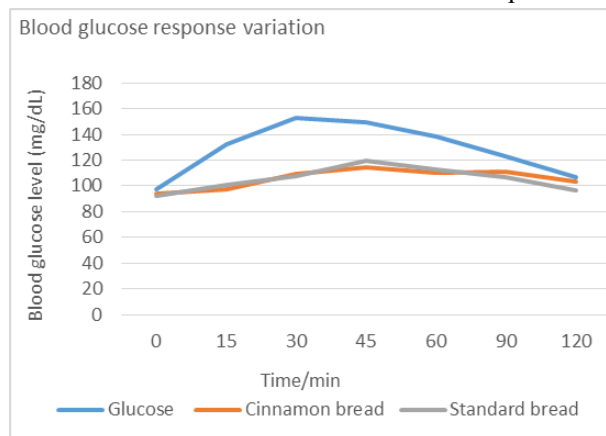
Compared to control bread (no added spices), cinnamon-incorporated bread had shown a better sensory profile with an improved taste. Figure 1 illustrates the ranks obtained by breads incorporated with different cinnamon percentages and accordingly, sample 553 was selected to proceed with the human study.

The selected product was subjected to the evaluation of glycaemic index along with a control bread for comparison. The glycaemic index of both control and cinnamon bread for each individual was calculated and averaged to have the final values. Control and cinnamon bread have elicited GI values of 57.1 ± 14.9 and 45.06 ± 12.3 respectively. Commercial bread usually has a GI value around 70-80

which is considered high glycaemic. Control bread in the study has shown a much lower GI may be due to kneading and fermentation time, and baking time-temperature differences.

The glycaemic index of cinnamon-incorporated bread is lower than the control bread even though the reduction is not significant. As a percentage, the reduction of GI is 21.08% compared to control bread. This indicates that the incorporation of cinnamon into wheat flour as a functional ingredient has been able to reduce the glycaemic impact of wheat bread.

Cinnamon is recognized as a potent antioxidant, anti-inflammatory, anticancer, and antidiabetic agent [7]. Data from similar studies where cinnamon is incorporated into



the diet are scarce. However, the effect of direct cinnamon supplementation on humans has been studied by several researchers in clinical trials and has shown significant reductions in fasting glucose and HbA1c levels at the end of supplementation [8][9]. Cinnamon is considered a natural insulin-sensitizing agent, facilitating glucose uptake into cells and increasing insulin sensitivity. Anti-inflammatory activity of cinnamon aids in reducing oxidative stress in the body, alleviating metabolic syndrome [10]. This evidence suggests that the incorporation of hypoglycaemic ingredients such as cinnamon into the diet is beneficial in reducing the glycaemic index and consequently helps to prevent and manage type II diabetes.

IV. CONCLUSION

The glycaemic index of the cinnamon bread was lower than that of the control bread even though the reduction is not significant and thus can be considered beneficial to diabetic population as well as the general public.

ACKNOWLEDGMENT

Authors would like to acknowledge the International Foundation of Science (Grant no: 1-3-E-6463-1), Sweden and Research Council, University of Sri Jayewardenepura (ASP/RE/SCI/2021/13) for the provided grants.

REFERENCES

- [1] P. Saeedi *et al.*, "Global and regional diabetes prevalence estimates for 2019 and projections for 2030 and 2045: Results from the International Diabetes Federation Diabetes Atlas, 9th edition," *Diabetes Res Clin Pract*, 157: 10784, Sept.2019.

- [2] P. Katulanda et al., "Original Article : Epidemiology Prevalence and projections of diabetes and pre-diabetes in adults in Sri Lanka-Sri Lanka Diabetes, Cardiovascular Study (SLDCS)," *Diabetic Medicine*,
- [3] W. Willett, J. Manson, and S. Liu, "Glycemic index, glycemic load, and risk of type 2 diabetes," *Am J Clin Nutr*, 76(1), 274-280, 2002, <http://dx.doi.org/10.1093/ajcn/76.1.274S> PMID: 12081851
- [4] B. Jacob and R. Narendhirakannan, "Role of medicinal plants in the management of diabetes mellitus: a review," *3 Biotech*, 9(1),4, 2019
- [5] D. J. Jenkins et al., "Glycemic index of foods: a physiological basis for carbohydrate exchange," *American Journal of Clinical Nutrition*, 34, 362–366, 1981.
- [6] M.S. Wee and C.J. Henry, "Reducing the glycemic impact of carbohydrates on foods and meals: Strategies for the food industry and consumers with special focus on Asia," *Comprehensive reviews in food science and food safety*, 19(2), pp.670-70, 2020.
- [7] J. Gruenwald, J. Freder, and N. Armbruester , "Cinnamon and Health," *Crit Rev Food Sci Nutr*, 50(9), 822-34, 2010, <http://dx.doi.org/10.1080/10408390902773052> PMID: 20924865.
- [8] A. Khan, M. Safdar, M.M. Ali khan, K.N. Khattak, and R.A. Anderson, "Cinnamon improves glucose and lipids of people with type 2 diabetes," *Diabetes Care*, 26(12),3215-8,2003, <http://dx.doi.org/10.2337/diacare.26.12.3215> PMID: 14633804.
- [9] B. Mang et al., "Effects of a cinnamon extract on plasma glucose, HbA1c, and serum lipids in diabetes mellitus type 2," *Eur J Clin Invest*, 36(5), 340-4, 2006 <http://dx.doi.org/10.1111/j.1365-2362.2006.01629.x> PMID: 16634838.
- [10] A.B. Medagama, "The glycaemic outcomes of Cinnamon, a review of the experimental evidence and clinical trials," *Nutr J*, 14(1),108, 2015.

Development of Green Pepper (*Piper nigrum*) and Garlic (*Allium sativum*) based Sauce and Evaluation of Colour Degradation during the Storage

M.L.P.Thathsarani

Department of Agriculture & Food Technology
University of Vocational Technology, Ratmalana, Sri Lanka
pawarnalokuge@gmail.com

U.A.S.K. Edirisinghe

Department of Agriculture & Food Technology
University of Vocational Technology, Ratmalana, Sri Lanka
sagarakamal@gmail.com

S.N.C.M. Dias

Centre for Environmental Studies and Sustainable Development
The Open University of Sri Lanka Nawala, Sri Lanka
sndia@ou.ac.lk

Y.N. Amarathunga

Department of Nutrition
Medical Research Institute Colombo, Sri Lanka
yashora_ama@yahoo.com

Abstract—Plant based supplementary food has enormous attention due to their high therapeutic properties and health benefits. Green pepper (*Piper nigrum*) is an unmaturing stage of the pepper and rich in piperine as active substances, antioxidants and anti-diabetic properties, beneficial for decreasing gastritis, abdominal pain & non communicable diseases (NCDs). Garlic offers an immune system boost to help prevent colds and the flu, the cholesterol level and reduce the risk of cancers & heart diseases. The development of green pepper (*Piper nigrum*) and garlic (*Allium sativum*) based sauce is facing challenges due to maintaining the green colour and other sensory parameters of the product. Cold water, use of lime extract and use of citric acid were tested for green pepper and prepared samples were stored under room temperature and refrigerated condition using glass bottles and amber colour bottles for 60 days. The chlorophyll content according to ESS method 150.1 (1991) was measured. The Formula-157 (56% green pepper pulp, 16% garlic paste, 14% sugar, 5% spicy mixture, 4% ginger pulp and 3% salt) was selected as the most acceptable composition during the sensory evaluation. The 100g of final product contains 68.6 ± 1.52 of moisture, 27.7 ± 0.2 of carbohydrate, 19.3 ± 0.05 of sugar, 1.8 ± 0.05 of protein, 1.7 ± 0.1 of crude fiber, 0.8 ± 0.05 of ash, 0.6 ± 0.1 of fat and 0.5 ± 0.1 of salt. According to the microbiological analysis, the final product has a three month shelf life and the pH of the sauce varied from 4.62 ± 0.11 to 4.18 ± 0.05 during storage period. The “cold water+citric acid” treatment was the best method for green pepper and then the final product should be stored in amber colour bottles under the refrigerated condition to reduce the colour degradation during storage.

Keywords— Green pepper, green pepper based sauce, colour degradation, supplementary food

I. INTRODUCTION

Prevailing socio-economic cultural changes, move on to healthy food and business of the society. Therefore, the demand for processed and convenient food has increased. The sauce as a famous convenience supplementary food has high demand among people without the age limit. Besides that the demand for healthy plant based food has increased among consumers due to containing bioactive compounds. Consumption of plant based food have many health benefits that decreases the risk of non-communicable diseases and vitamin deficiencies. As main ingredients, green pepper

includes volatile oil, alkaloids and other active substances. Pepper (*Piper nigrum*) acts as a bioavailability enhancer, anti-inflammatory, antioxidant, anti-diabetic, antidiarrheal, bioavailability, enhancer, immunomodulator, lipid metabolism accelerator, anticancer [1, 2]. Garlic prevents and reduce the illnesses as colds and the flu, improves blood pressure and reduces the cholesterol level and chronic diseases [3]. Although pepper is a highly demanded spicy crop in Sri Lanka [4], local manufacturers were unable to produce green pepper based sauce due to facing some challenges related to preserve the colour and other sensory attributes continuously. Development of this sauce product is a ready to eat vegan food supplement, developed with functional ingredients, namely green pepper, garlic, spices and condiments as a spicy product.

This research study is supported to introduce this value-added green pepper garlic based sauce as a demanded food supplement with absolutely no coloring agents, emulsifiers, flavors and flavor enhancers. Also this study was conducted to determine the nutritional composition, shelf life and the best color retention method for this sauce during storage period.

II. BACKGROUND STUDY

Pepper is one of the most widely used and popular spice in the world and known as “King of the Spices” [4]. According to the previously published report by the Department of Export Agriculture (DEA), the total extent of pepper in Sri Lanka was 32,291 ha [2]. Green pepper is an unmaturing stage of pepper crop and rich in nutrients. According to the previous studies, green pepper is rich in vitamins, minerals, volatile oil, alkaloids, lignans, coumarins, fibers, some trace elements and other active components as antioxidant, anti-inflammatory, insecticidal substances. [1]. Garlic is a vital crop for culinary purposes, its pungent flavor providing a special taste to meals and rich in therapeutic properties as allicin [5] [6]. As well as spices and condiments such as chili powder, ginger, onion, cardamom, cinnamon, nutmeg and cloves are added for contributing rich flavor, odor and appearance. Especially garlic and ginger are included to make erectile dysfunction,

low sperm count, diabetes, high blood pressure, and increasing sperm count [7] [8]. Sauces can be produced as liquid, semi-liquid or solid texture as paste, emulsion or suspension form including spices, condiments, seasonings and other ingredients [9]. The plant sauces play a vital role to enhance the functional properties and add value to the human diet [10]. Development of a plant based sauce using highly demanded spicy crop as pepper will be the best value added product with high commercial value. Mainly the purpose of this research was to introduce this green pepper garlic based sauce product as a solution for different challenges which facing most of the manufactures in Sri Lanka.

III. METHODOLOGY

This research study was conducted in four major phases. At the first phase four sauce samples were introduced by changing the concentration of green pepper pulp and garlic paste while keeping the other parameters constant. In the second phase, sensory evaluation was conducted and selected the final best product. In the third phase, physiochemical, nutritional and microbiological evaluation were conducted. Finally, the colour degradation analysis was conducted to reduce discoloration during the storage period.

a. Phase 1 : Preparation of green pepper garlic based sauce

i. Preparation of green pepper pulp:

The unripe, unmaturred, cleaned green pepper was hot water blanched for 2-3 minutes, then prepared the green pepper pulp by grinding with water using a laboratory scaled blender.

ii. Preparation of garlic paste:

Unpeeled, washed, chopped garlic was grinded with 1:1 of water using a laboratory scaled blender and prepared the garlic paste.

iii. Preparation of ginger pulp:

Unpeeled, cleaned, chopped ginger was dipped into 85 °C of hot water (1:2 ginger: hot water) for 5-10 minutes, then filtered the ginger pulp by a laboratory scaled sieve.

iv. Preparation of spicy mixture:

The spices (onion, cinnamon, cardamom, cloves) were unpeeled, cleaned and chopped. Then the prepared spicy mixture was covered with a muslin cloth [11].

v. Preparation of the sauce:

Initially, prepared green pepper pulp and garlic paste boiled at 55 to 60 °C for 2 to 3 minutes. Then prepared ginger pulp, sugar, citric acid and salt were added and heated up to 65 to 68 °C with continuously stirring. Then the prepared spicy mixture bag was dipped in the sauce mixture and concentrated by stirring. Step by step the brix value was determined and the vinegar was added at the endpoint. When the Brix value of the mixture was reached 26°, the mixture was removed from the cooker, and pH value was measured. The sauce mixture was filled into sterilized glass bottles and stored in a refrigerated, dry place (8±2 °C).

b. Phase 2: Sensory Evaluation

The four sauce samples were introduced according to the two factor factorial method by changing the concentration of the green pepper pulp and garlic paste (F123- 48:24 %, F145 -52:20 %, F157- 56:16 %, F164- 60:12 %) while keeping the other parameters constant (Sugar – 14%, Ginger pulp-4%, Spicy mixture- 4%, Salt-2%, Citric acid-2%, Vinegar-2%). To select the best green pepper garlic based sauce sample, sensory evaluation was conducted for prepared four sauce samples (F123, F145, F157, F164) and control with 30 semi trained panelists on 5-point hedonic scale as described in a previous study [12]. Each category was rated from 1 (strongly dislike) to 5 (strongly like) and the scores were analyzed by a non-parametric test.

c. Phase 3: Determination of nutritional composition, shelf life and physiochemical parameters of the best selected products

i. Nutritional analysis:

To determine the nutritional content of best selected sauce product, moisture, fat, ash, protein, crude fiber, carbohydrate, sugar and salt content were evaluated according to the standard methods described in the AOAC 2019 guideline [13].

ii. Shelf life evaluation:

Total plate count and yeast and mold count were determined at 15 days intervals for three months according to the SLSI 516 standard. To determine the storage stability of sauce pH value was analyzed at 15 days intervals for three months according to the AOAC 2000 guideline [13].

Phase 4: Color degradation analysis of the final product

Twelve treatments (Table:1) were conducted for the best selected sauce sample and determined the chlorophyll content according to ESS method 150.1 (1991) at intervals of 15 days for 60 days to select the best treatment to preserve the colour of the best selected sauce product [14].

TABLE 1: DIFFERENT TREATMENTS TO REDUCE COLOR DEGRADATION OF SAUCE

Test	Blanching Temp (°C)	Cold treatment	Time (min)	Bottle Type	Storage condition
1	85	Cold water	5	Glass	Room
2	85	Cold water	5	Glass	Refrigerator
3	85	Cold water	5	Amber	Room
4	85	Cold water	5	Amber	Refrigerator
5	85	Cold water+Lime	5	Glass	Room
6	85	Cold water+Lime	5	Glass	Refrigerator
7	85	Cold water+Lime	5	Amber	Room
8	85	Cold water+Lime	5	Amber	Refrigerator
9	85	Cold water+citric	5	Glass	Room
10	85	Cold water+citric	5	Glass	Refrigerator
11	85	Cold water+citric	5	Amber	Room
12	85	Cold	5	Amber	Refrigerator

Statistical analysis

All the data was analyzed by one-way ANOVA, using Minitab software. Turkey test was used to determine significant differences between the means for all comparisons ($P < 0.05$).

IV. RESULTS AND DISCUSSION

A. Sensory evaluation

Sensory results revealed that the best selection of green pepper garlic based sauce is F-157 which includes 56% of green pepper pulp and 16% of garlic paste. According to the figure 1, F-157 sample was scored highest median score for the odour (4.00 ± 0.52), taste (4.30 ± 0.53), texture (4.00 ± 0.52), and colour (3.62 ± 0.49) and overall acceptability (4.00 ± 0.45) compared with other three samples and the control. Some panelists reported as the pepper and garlic mixed odor and taste comes from the F-157 was better than the other samples. The appearance of a product has a major influence on the quality of the product. The results of the sensory test were shown in Table 2, F-164 sample got the highest score of appearance (3.80 ± 0.60). However, there was no significant difference in colour attribute between the F-164 and F-157 samples. Considering the sensory results, the sample which contained 56% of green pepper pulp and 16% of garlic paste was selected as the best sauce sample for further analysis.

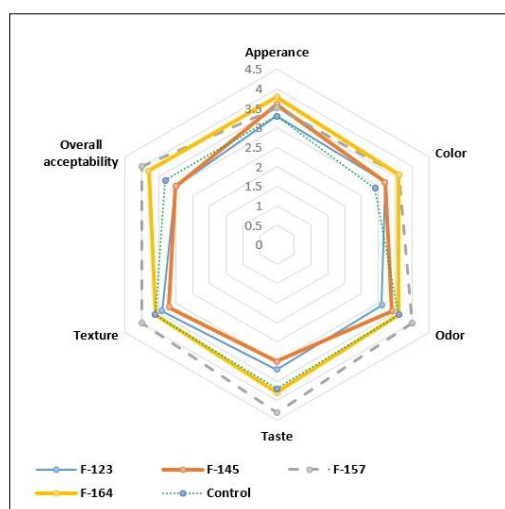


Fig 1: Spider web analysis of sensory attributes for best selected sauce

B. Proximate Analysis

Proximate analysis was conducted to determine the nutrients of sauce which is shown in Table 3. According to the results, it is revealed that there was a significantly ($P < 0.05$) high amount of moisture level in the control sample compared to the best selected sample F-157. According to the comparison, the moisture content in tomato sauce is reported as 66.65 ± 0.14 % lower than the moisture content of the green pepper garlic-based sauce due to containing high amounts of total solids in tomato pulp [15]. Sugar is

the one of the most important ingredients of spicy sauces because sugar contributes to the flavor, texture, and quality of sauce. The sugar requirement in Chillie or spicy based sauces should be 20–30 g/ 100g as mentioned in the SLSI 581:2008 [16]. However, total sugar content of the sample (19.30 ± 0.05 g/100g) was significantly less than the total sugar content of the control sample (23.6 ± 0.22 g/100g). Moreover, the total sugar content of the sample was higher than the reported sugar level in ketchup/ sauces in a previous study as 11.97 – 17.79 g/100g [17]. The protein content of the sauce sample (1.80 ± 0.05 g/100g) was significantly higher than the control sample (1.70 ± 0.02 g/100g). The final brix value of the sauce was recorded as 26° while the recommended brix value for tomato sauce shall not be less than 25° . Finally, it is revealed that there was a significant difference in the nutrition composition between the best selected sauce sample and the control.

C. Shelf life evaluation

There was an increasing number of aerobic plate count during the three months period when sauce was stored in sterile glass bottles at refrigerated condition ($8 \pm 2^\circ \text{C}$), which shown in the Table 4. SLSI 516:2013 has reported that the acceptable level of aerobic plate count of sauce is $10-10^6$ CPU per g while the acceptable level of yeast and moulds count is 0-110 CPU per g [18]. Initially, there were less yeast and moulds in the sauce compared with the bacteria due to low pH condition. The preferred pH level for yeast growth is pH 3 to above [19]. Microbial growth can be increased due to applying the low cooking temperature during the sauce preparation (65°C). The initial pH of the sauce was recorded as $\text{pH } 4.62 \pm 0.11$ and then the pH level gradually decreased during the three months storage period as shown in Table 4. The FDA reported as pH 4.4 to 5.4 is the acceptable pH range for sauces [19]. The acidity level was increased during the storage time due to addition of vinegar and citric acid [19]. Therefore based on the microbiological evaluation results the best selected sauce product is safe for consumption within three months under refrigerated condition ($8 \pm 2^\circ \text{C}$).

D. Color degradation analysis

Colour is one of the main attributes which caused the first impression about the product in the customer mind. Discoloration was the main problem that had to be faced during the storage period of the green pepper garlic-based sauce. Due to the oxidation of the green pepper within time caused the discoloration of the final product. Chlorophyll is the main component for the green colour of the product. Chlorophylls are highly susceptible to colour degradation during sauce preparation and the colour change of chlorophylls from brilliant green to olive brown (pheophytin, pheophorbide) due to senescent tissues [20] [21]. Heat, oxygen, enzyme chlorophyllase, light, chemicals and acidic level can be caused to the colour degradation of the final product [21, 22].

TABLE 2: SENSORY EVALUATION OF FINAL PRODUCT COMPARED TO THE CONTROL SAMPLE

Sample	Appearance	Colour	Odour	Taste	Texture	Overall Acceptability
F-123	3.29±0.46 ^b	3.20±0.61 ^b	3.10±0.60 ^c	3.20±0.66 ^c	3.60±0.49 ^b	3.30±0.46 ^b
F-145	3.58±0.50 ^b	3.23±0.63 ^b	3.40±0.67 ^b	3.00±0.58 ^c	3.40±0.72 ^b	3.00±0.45 ^b
F-157	3.71±0.57 ^a	3.62±0.49 ^a	4.00±0.52 ^a	4.30±0.53 ^a	3.20±0.66 ^a	4.00±0.45 ^a
F-164	3.80±0.60 ^a	3.60±0.56 ^a	3.60±0.49 ^a	3.80±0.55 ^b	4.00±0.52 ^a	3.50±0.52 ^a
Control	3.29 ± 0.46 ^b	2.90±0.48 ^b	3.60±0.56 ^a	3.70±0.46 ^b	3.60±0.49 ^b	3.80±0.40 ^b

a, b, c Different superscript letters indicate significant differences ($P < 0.05$)

TABLE 3: THE PROXIMATE COMPOSITION OF THE SAUCE

Proximate value	Amount (g/100 g wet basis)	
	Best selected sauce	Control
Moisture	68.5 ± 0.70	69.8 ± 0.45
Carbohydrates	27.7 ± 0.20	24.7 ± 0.20
Crude fiber	1.70 ± 0.10	1.4 ± 0.24
Crude protein	1.80 ± 0.05	1.7 ± 0.02
Crude fat	0.60 ± 0.10	0.5 ± 0.20
Total ash	0.80 ± 0.05	1.10 ± 0.02
Total Sugar	19.30 ± 0.05	23.6 ± 0.22
Salt	0.50 ± 0.10	0.54 ± 0.04
Energy, Kcal/100g	125	117

TABLE 4: SHELF LIFE RESULTS OF THE SAUCE

Day	Aerobic plate count, CFU per g	Yeasts & Molds count, CFU per g	pH value
1 day	0.2×10^3	Less than 10	4.62±0.11
15 days	0.6×10^3	Less than 10	4.54±0.15
30 days	2.4×10^3	Less than 10	4.46±0.15
45 days	3.3×10^3	Less than 10	4.37±0.15
60 days	4.8×10^3	Less than 10	4.28±0.05
75 days	8.6×10^3	Less than 10	4.22±0.01
90 days	9.3×10^3	Less than 10	4.18±0.05

The values are Mean ± SD of three independent determinations

TABLE 5: EFFECTS OF TREATED (COLD WATER, COLD WATER + LIME EXTRACT, COLD WATER + CITRIC ACID) FOR GREEN PEPPER, STORED THE FINAL SAUCE PRODUCT (GLASS BOTTLES, AMBER COLORED BOTTLES), UNDER ROOM CONDITION (25 ± 2 °C) AND REFRIGERATED CONDITION (8 ± 2 °C)

Treatment	Day 5 (µg/L)	Day 15 (µg/L)	Day 30 (µg/L)	Day 45 (µg/L)	Day 60 (µg/L)
1	34.57±0.31	30.67±0.12	28.26±0.02	22.52±0.23	18.77±0.14
2	34.63±0.05	31.25±0.06	28.79±0.06	23.12±0.15	19.32±0.08
3	34.89±0.23	31.76±0.08	28.82±0.04	23.76±0.18	19.45±0.08
4	34.95±0.51	31.88±0.23	28.91±0.03	23.88±0.12	19.89±0.06
5	35.12±0.24	34.75±0.25	29.85±0.26	27.78±0.24	24.56±0.05
6	35.78±0.12	34.88±0.15	33.65±0.03	31.54±0.08	28.74±0.15
7	35.32±0.26	34.65±0.03	33.68±0.42	31.65±0.62	28.68±0.42
8	35.89±0.05	34.82±0.12	33.75±0.26	31.72±0.31	30.12±0.08
9	36.25±0.14	35.15±0.17	34.28±0.52	31.45±0.07	31.02±0.25
10	36.85±0.52	35.86±0.08	34.78±0.21	31.79±0.05	31.41±0.26
11	36.36±0.06	35.29±0.31	34.49±0.12	31.71±0.22	31.21±0.14
12	36.87±0.24	35.32±0.42	34.84±0.05	31.87±0.36	31.33±0.07

Furthermore, the ability of chlorophyll retention in parsley leaves and colour changes during storage was studied in a previous study and they reported that colour degradation was induced due to oxidation [23]. The results of colour retention analysis with chlorophyll determination were shown in Table 5. According to the results, the colour degradation was gradually increased during the storage period. The highest chlorophyll value (36.87 ± 0.24 µg/L) was reported in the treatment 12 (cold water+citric acid treatment, amber colored bottles, refrigerated condition). However, there was no significant difference recorded in cold water + citric acid treated sauce samples which were stored in glass and amber colour bottles under refrigerated condition (Treatment 10 and 12) during the initial days. The lowest chlorophyll content recorded in the only cold water treated sauce samples during the period. Therefore, twelfth treatment was the best colour retention method (cold water + citric acid treated, stored in amber colour bottles under the refrigerated condition) due to recording the highest chlorophyll content during the 60 days of storage period. According to the results, it is revealed that colour degradation of sauce can be reduced by using amber colored bottles and storing the sauce in a refrigerated condition.

CONCLUSION

The third composition (F-157) which contained 56% of green pepper pulp, 16% of garlic paste, 14% of sugar, 5% of spicy mixture, 4% of ginger pulp and 3% of salt) was selected as the best sauce product. The nutrition analysis revealed that the best selected sauce sample is rich in fiber, protein and carbohydrates compared with the control sample. The total soluble solids of sauce was 26°, pH value of the sauce varied from 4.62 ± 0.11 to 4.18 ± 0.05 during the

storage period. The sauce product can be stored under the refrigerated condition (8 ± 2 °C) for three months in sterilized glass bottles. The cold water+citric acid treatment was the best method for green pepper before the sauce preparation and the colour degradation can be reduced by storing the final sauce product using amber colour bottles under the refrigerated condition.

ACKNOWLEDGMENT

The study was made possible with the support of the Department of Nutrition, Medical Research Institute, Sri Lanka, Department of Agriculture and Food Technology, University of Vocational Technology Ratmalana, Sri Lanka and The Open University of Sri Lanka. All authors are grateful to Dr. Renuka Jayatissa, Head, Department of Nutrition and Dr. Darshan De Silva, Head, Department of Pharmacology for providing the permission to conduct this study at Medical Research Institute.

REFERENCES

- [1] D. R. Joshi, A. C. Shrestha and N. Adhikari, "A review on diversified use of the king of spices: *Piper nigrum* (black pepper)," *International Journal of Pharmaceutical sciences and research*, vol. 9, no. 10, pp. 4089-4101, 2019.
- [2] P. Sivarajah and R. Wickramasinghe, "IMPACT OF LAND SIZE ON PRODUCTIVITY, INCOME AND PROFITS FROM PEPPER CULTIVATION IN SRI LANKA," *AGROFOR International Journal*, vol. 1, no. 3, pp. 127-132, 2016.
- [3] P. B. Bongiorno, P. M. Fratellone and P. LoGiudice, "Potential health benefits of garlic (*Allium sativum*): a narrative review.," *Journal of Complementary and Integrative Medicine*, vol. 5, no. 1, pp. 1-24, 2008.
- [4] Radheshyam, S. K. Yadav, A. Gupta and Dharamveer, "A Review on Pharmacological, Nutraceutical, and Pharmacognostical Study of *Piper nigrum*," *International Journal of Pharmaceutical Sciences Review and Research*, vol. 66, no. 1, pp. 1-7, 2021.
- [5] M. S. Rahman, "Allicin and other functional active components in garlic: Health benefits and bioavailability," *International Journal of Food Properties*, vol. 10, no. 2, pp. 245-268, 2007.
- [6] S. V. Rana, R. Pal, K. Vaiphei and S. K. Sharma, "Garlic in health and diseases," *Nutrition research reviews*, vol. 24, no. 1, pp. 60-71, 2011.
- [7] C. K. Wang, "Health benefits of onion bioactives on hypercholesterolemia, cardiovascular diseases, and bone mineral density," *Food Frontiers*, vol. 1, no. 2, pp. 107-108, 2020.
- [8] K. Singletary, "Cinnamon: overview of health benefits," *Nutrition Today*, vol. 43, no. 6, pp. 263-266, 2008.
- [9] A. E. Raits, Ciprova and K. Ozolina, "Designing of thermal treatment parameters for tomato sauces," *Proceedings of the 18th International Scientific Conference "Engineering for Rural Development"*, pp. 22-24, 2019.
- [10] H. H. S. Kim, L. Bowen, C. Chen and L. G. Duncan, "Effects of tomato sauce consumption on apoptotic cell death in prostate benign hyperplasia and carcinoma," *Nutrition and cancer*, vol. 47, no. 1, pp. 40-47, 2003.
- [11] N. Thakur, M. Thakur, G. Thakur and S. Lal, "Increased shelf life and safety of ketchup prepared from organically raised tomato," *Journal of Pure and applied Microbiology*, vol. 12, no. 3, pp. 1351-1354, 2018.
- [12] M. A. Amerine, R. M. Pangborn and E. B. Roessler, *Principles of sensory evaluation of food*, Elsevier, 2013.
- [13] AOAC, *AOAC Publications of Official Testing Method-Association of Analytical Chemists*. 17th Edition, Arlington, Va, USA: Official Methods of Analysis, 2000.
- [14] F. Rey and A. Aminot, *Standard procedure for the determination of chlorophyll a by spectroscopic methods*, France: ICES Techniques in Marine Environmental Science, 1991.
- [15] S. Akhtar, M. Riaz, A. Ahmad and A. Nisar, "Physico-chemical, microbiological and sensory stability of chemically preserved mango pulp," *Pak. J. Bot.*, vol. 42, no. 2, pp. 853-862, 2010.
- [16] SLSI, "Specification for Chilli Sauce 516:2008," SRI LANKA STANDARD INSTITUTION, Colombo, Sri Lanka, 2008.
- [17] A. M. Sharoba, B. Senge, H. A. El-Mansy, H. E. Bahlol and R. Blochwitz, "Chemical, sensory and rheological properties of some commercial German and Egyptian tomato ketchups," *European Food Research and Technology*, vol. 220, pp. 42-151, 2005.
- [18] SLSI, "Methods of test for Microbiology of food and animal feeding stuffs," SRI LANKA STANDARDS INSTITUTION, Colombo, Sri Lanka, 1991.
- [19] M. Rahman and N. Thajudin, "Product development of Kembayau (*Canarium odontophyllum*) exotic fruit sauce," *Journal of Tropical Resources and Sustainable Science (JTRSS)*, vol. 3, no. 1, pp. 19-28, 2015.
- [20] S. J. Schwartz and J. H. Von Elbe, "Kinetics of chlorophyll degradation to pyropheophytin in vegetables," *Journal of Food Science*, vol. 48, no. 4, pp. 1303-1306, 1983.
- [21] N. Koca, F. Karadeniz and H. S. Burdurlu, "Effect of pH on chlorophyll degradation and colour loss in blanched green peas," *Food Chemistry*, vol. 100, no. 2, pp. 609-615, 2007.
- [22] M. I. Gunawan and S. A. Barringer, "Green color degradation of blanched broccoli (*Brassica oleracea*) due to acid and microbial growth," *Journal of Food Processing and Preservation*, vol. 24, no. 3, pp. 253-263, 2000.
- [23] N. Yamauchi and A. E. Watada, "Regulated chlorophyll degradation in spinach leaves during storage," *Journal of the American Society for Horticultural Science*, vol. 116, no. 1, pp. 58-62, 1991.

Electrically Assisted Membrane Separation Processes and Its Application in Food Industry Innovations

H.M.T.M.Ranasinghe

Department of Agriculture and Food
Process Technology
University of Vocational Technology
Ratmalana, Sri Lanka
fpt19b107@uovt.ac.lk

J.D.K.V.Juliyange

Department of Agriculture and Food
Process Technology
University of Vocational Technology
Ratmalana, Sri Lanka

fpt19b103@uovt.ac.lk

W.G.D.A.M.Watagodapitiya
Department of Agriculture and Food
Process Technology
University of Vocational Technology
Ratmalana, Sri Lanka
fpt19b105@uovt.ac.lk

T.A Warahena

Institute of Chemistry Ceylon
Rajagiriya, Sri Lanka

I.S.Faaris

Department of Agriculture and Food
Process Technology
University of Vocational Technology
Ratmalana, Sri Lanka
fpt19b116@uovt.ac.lk

Abstract- *Electrically Assisted Membrane Separation Processes (EAMSP) are a promising innovation in the food industry, combining electric fields with membrane techniques for enhanced separation efficiency, reduced fouling, and improved selectivity. This approach is particularly beneficial for concentration, purification, and fractionation in food processing. EAMSP's gentle and precise separation preserves sensory and nutritional qualities while finding applications in juice concentration, protein separation, bioactive compound recovery, and contaminant removal. Beyond its functional advantages, EAMSP contributes to sustainability by minimizing energy usage, waste production, and reliance on harsh chemicals. This technology is poised to drive significant innovation in the food sector.*

Keywords—*electrically assisted membrane separation processes, food processing, electrodialysis, nanofiltration, fouling*

I. INTRODUCTION

Electrically Assisted Membrane Separation Processes (EAMSP) refer to a group of techniques that combine membrane separation technologies with the application of an electric field to enhance the separation process. Membrane separation is a widely used method for separating components in various fluids, such as liquids or gases, based on their size, charge, or other specific properties. The introduction of an electric field can significantly improve the efficiency, selectivity, and overall performance of these separation processes. There are several variations of EAMSPs, each with its own specific applications and benefits. Some common techniques include: Electrodialysis (ED), Electro filtration (EF), Electroosmotic Dewatering (EOD), Electrochemical Membrane Processes, and Membrane Capacitive Deionization (MCDI). The so-created electric field's influence on particle movement, ion transport, and fluid dynamics enables

better process control. Moreover, EAMSP often operates at lower pressures and temperatures compared to conventional methods, leading to energy savings. These processes find application across diverse industries like water treatment, food processing, pharmaceuticals, and environmental cleanup. The technique chosen depends on separation needs, feed solution characteristics, and desired product quality.

APPLICATIONS OF ELECTRICALLY ASSISTED MEMBRANE SEPARATION PROCESS WITHIN THE FOOD INDUSTRY

As a method of processing and separation in the food industry, membrane technology is finding widespread use. Membrane separations can be utilized as the latest technology for processing novel products and foods or as an alternative to traditional methods. Compared to conventional technologies, membrane procedures provide advantages including cost-effective cold pasteurization and sterilization, shelf-life extension, and a green image. Additionally, they help recover key components in diluted effluents and wastewater treatment applications while maintaining natural flavor and nutritional value (Dhineshkumar V et al., 2017). By selecting the suitable operational settings and membrane materials, membranes may potentially separate ions, molecules, and colloids with sizes ranging from sub-nanometer to several micrometers from liquids (Badireddy, A.R. et al., 2023). Microfiltration-MF, Ultrafiltration-UF, Nanofiltration-NF, and Reverse Osmosis-RO are examples of pressure-driven membrane processes that make it easier to separate different particle sizes. MF is typically used to separate soluble feed components from suspended particles and bacteria. Proteins and peptides are examples of soluble macromolecules that can be separated using UF. NF is used simultaneously for concentration and partial demineralization (Dhineshkumar et al., 2017). Membrane processes are widely employed, particularly in the dairy, wine and beer, fruit juice, and sugar sectors. Furthermore, removal of microorganisms from food,

purification or concentration of water, whey, vinegar, soy, concentration or separation-purification of proteins, polypeptides, fats, sugars, mucus, starch, and lysozyme are some other applications (Nazia N. et al., 2018). Major barriers to wide-scale adoption of membrane technologies include fouling and concentration polarization. When foulants build up on the membrane's surface, the result is fouling, which raises the operating pressure and creates gel layers. On the other hand, concentration polarization happens when foulants concentrate, leading to increased fouling, higher back diffusion, and increased osmotic pressure gradients. These problems are caused by intricate interactions between foulants and membrane components (Badireddy, A.R. et al., 2023). The use of electric fields to help with fouling mitigation during membrane filtration is what makes electro filtration, a desirable prospect, becoming increasingly common. In order to increase the economic competitiveness of membrane separation processes, effective antifouling techniques are highly sought for.

II. FOOD QUALITY ASPECTS

Membrane separation processes can help retain valuable nutrients such as vitamins, minerals, and proteins while removing unwanted compounds like fats and cholesterol, leading to improved nutritional quality in food products (Zhang et al., 2017). Since the process is typically carried out at lower temperatures compared to conventional methods, the flavor and aroma of the food are better preserved. Membrane separation processes do not involve high temperatures, which can help minimize heat-induced damage to heat-sensitive components, resulting in better food quality. These processes can efficiently remove harmful contaminants, microbes, and pathogens, improving the safety of food products.

III. FOOD MANUFACTURING PRODUCTIVITY ASPECTS

Membrane separation processes can be operated continuously, reducing the need for frequent start-ups and shutdowns, leading to increased productivity and reduced downtime. These processes can simplify food manufacturing by combining multiple unit operations into a single step, leading to a more streamlined production process. In some cases, membrane separation can be faster than traditional methods, enabling higher throughput and increased productivity. Membrane systems are often easier to clean and maintain resulting in shorter cleaning cycles and less production downtime.

IV. COST CONSIDERATIONS

Implementing membrane separation systems may require higher initial capital investment compared to traditional methods. The long-term benefits in terms of improved productivity and product quality can outweigh the initial costs. Depending on the specific process and application, membrane separation can require lower energy consumption compared to conventional methods, leading to potential cost savings in the long run. By selectively separating components, membrane processes can reduce waste generation and associated disposal costs. Proper

maintenance of membranes is essential for optimal performance. Regular maintenance costs should be factored into the overall cost analysis.

V. ENVIRONMENTAL AND ENERGY IMPACT

Membrane processes are renowned for their remarkable energy efficiency when compared to various other separation methods. When concentrating apple juice and passion fruit juice, MF and UF techniques prove to be advantageous with their notably low energy requirements. In terms of energy consumption, RO demonstrates superior efficiency. Yet, it's essential to acknowledge that the pumps responsible for generating the necessary pressure in RO systems are powered by either electric or combustion engines.

TABLE 1: ENERGY REQUIREMENT IN VARIOUS FILTRATION PROCESSES

Filtration process	Device type	Energy serving
Reverse osmosis	Energy recovery turbine	30–40%
	Pressure exchanger	50–60%
Ultrafiltration	Energy recovery turbine	40–50%
	Pressure exchanger	60–68%
Microfiltration	Energy recovery turbine	65–75%
	Pressure exchanger	75–80%
Diafiltration	Energy recovery turbine	45–65%
	Pressure exchanger	65–70%

The environmental consequences of membrane processes are relatively limited. These processes don't involve the use of harmful chemicals that need to be disposed of, and they don't produce heat. The energy requirements for different filtration processes are outlined in the provided table.

VI. TYPES OF FOODS

Dairy industry: Milk is an intricate blend of various types of biomolecules such as proteins, lipids, lactose, and minerals. However, it also contains undesirable constituents like bacteria. Here, membrane technologies play a role in concentrating and segregating milk and its by-products, eventually enhancing their commercial value. Particularly, the processing of whey stands as the primary use of membrane technology in this industry, constituting more than 70% of all membrane applications. The incorporation of techniques like tangential flow or cross-flow MF, the introduction of the uniform transmembrane pressure (UTP) concept, and enhancements in ceramic-based membranes have all contributed to the amplified adoption of MF in dairy processing. There are three major applications of MF within the dairy industry. There are bacteria elimination from milk, the pretreatment of cheese whey (fat reduction and bacteria elimination), the enhancement of cheese milk through micellar casein enrichment.

Fruit and vegetable juices: UF serves as a key player in the processing of various fruit and vegetable juices. In this method, juice is initially extracted using a press and subsequently directed through an UF module prior to

undergoing concentration through processes like evaporation or further membrane operations. During UF, membranes retain the concentrated pulp fraction as well as undesired enzymes. The resulting UF-clarified permeate can be subjected to pasteurization and, if required, further concentration. As a result of the adoption of low temperatures during the process, RO has emerged as a desirable technique for effectively concentrating fruit juices, resulting in premium products with both nutritional and sensory qualities intact. For the concentration of orange and apple juices, a recent innovation known as high-concentration reverse osmosis has been launched. A dual-membrane setup is used in this novel approach. A membrane retains sugars and aromatic chemicals in the first stage, resulting in a concentrated solution. This retentate is then passed through a second membrane, which allows part of the sugars to flow through, yielding the final concentrated product.

Vegetable oils processing: The manufacturing process of edible oils entails a number of critical stages aimed at guaranteeing optimal product quality by removing contaminants such as water, dust, phospholipids, free fatty acids, gums, waxes, oxidation products, colors, and trace metals such as iron, copper, and sulfur. Degumming, deacidification/neutralization, bleaching, dewaxing, and deodorization is all part of this procedure. The latter stages of this process often include the employment of high temperatures, harsh chemicals, and significant energy inputs through steam or electricity. Membrane-based processes (MF, UF, NF) hold the promise of potentially replacing the entire sequence of required steps in edible oil processing, offering a straightforward, competitive, and environmentally conscious approach. However, there remains a need for advancements in membrane technology to achieve higher flux and selectivity while mitigating fouling.

Brewing and wine industry: Ranked as the world's second most consumed beverage, beer processing faces an ongoing struggle to achieve uniform quality and distinct flavor profiles, all while minimizing production expenses and adopting environmentally conscious procedures. The adoption of membrane technology applications is gaining prominence in this context, given their ability to elevate product excellence, while conserving energy, and mitigating water wastage. Beer production involves mashing, boiling, fermentation, and maturation, followed by a pasteurization phase to ensure microbiological stability and preservation. A variety of filtering stages are required during the brewing process to remove solid particles such as yeasts, malt, and hops from the product mixture. This separation of particles from liquids, which is traditionally accomplished through dead-end filtration with diatomaceous earth (DE), presents challenges in terms of economic viability, environmental effect, and technological issues.

Futuristic food: The qualities of existing membranes are regarded appropriate for MF and UF. However, other elements including process design, process control, specific application knowledge, and substantial operational know-how are critical in the use of MF and UF in the chemical and

food industries. Aside from known membrane processes and applications, new membrane operations such as membrane contactors and membrane reactors are gaining attention in industrial settings. These procedures are becoming routine unit operations in process engineering, substantially amplifying membrane engineering's overall impact on industrial production. It is critical to ensure that all membrane-based activities adhere to the concepts of process intensification and sustainable industrial development.

VII. CONCLUSION

In summary, Electrically Assisted Membrane Separation Processes (EAMSP) represent a significant leap forward in food industry innovation. By combining electric fields with membrane techniques, EAMSP enhances separation efficiency, reduces fouling, and improves selectivity, making it ideal for concentration, purification, and fractionation processes. EAMSP not only maintains sensory and nutritional qualities during gentle separation but also finds applications in various areas such as juice concentration, protein separation, bioactive compound recovery, and contaminant removal. Beyond functional benefits, EAMSP aligns with sustainability goals by reducing energy usage, waste generation, and reliance on harsh chemicals. As a versatile and transformative technology, EAMSP has the potential to reshape the food industry by addressing challenges and fostering efficient, sustainable, and high-quality food production. Its promising trajectory positions it as a driving force for innovation in the food sector, offering solutions that meet consumer demands and environmental imperatives simultaneously.

REFERENCES

- Akmal Nazir, Kashif Khan, Abid Maan, Rabia Zia, Lidietta Giorno, Karin Schroën, Membrane separation technology for the recovery of nutraceuticals from food industrial streams, April 2019, Trends in Food Science & Technology, pages 426-438
- Charcosset, C. (2020). Classical and Recent Applications of Membrane Processes in the Food Industry. Food Engineering Reviews. doi:https://doi.org/10.1007/s12393-020-09262-9.
- Dhineshkumar V, Ramasamy D. Review on membrane technology applications in food and dairy processing. J Appl Biotechnol Bioeng. 2017;3(5):399-407. DOI: 10.15406/jabb.2017.03.00077
- Kotsanopoulos, K. V., & Arvanitoyannis, I. S. (2013). Membrane Processing Technology in the Food Industry: Food Processing, Wastewater Treatment, and Effects on Physical, Microbiological, Organoleptic, and Nutritional Properties of Foods. Critical Reviews in Food Science and Nutrition, 55(9), 1147-1175. doi:10.1080/10408398.2012.685992
- Nissar, N., Hameed, O. and Nazir, F. (n.d.). Application of Membrane Technology in Food Processing Industries: A review.[online] Available at: http://www.ijarse.com/images/fullpdf/1524923988_JK1938IJARSE.pdf [Accessed 27 Jun. 2020].
- Shen, Y. and Badireddy, A.R. (2021). A Critical Review on Electric Field-Assisted Membrane Processes: Implications for Fouling Control, Water Recovery, and Future Prospects. Membranes, 11(11), p.820. doi:https://doi.org/10.3390/membranes11110820.
- S. De, B. Sarkar, S. Dasgupta, Electric field enhanced membrane separation system Principles and typical applications, January 2009
- Zhang, W., Zheng, Y., Zhang, S., & Chen, X. (2017). Membrane technology for the separation of isoflavones and anthocyanins from plant extracts. Food Chemistry, 218, 383-395.

PRODUCTION OF A NUTRITIONAL COMPOSITE POWDER MIXTURE USING SELECTED GRAINS

D.M.M.M Premarathna
Department of Agriculture and Food
Technology
University of Vocational Technology,
Rathmalana,
Sri Lanka
sankafernandoz12@gmail.com

U.A.S.K Edirisinghe
Department of Agriculture and Food
Technology
University of Vocational Technology,
Rathmalana,
Sri Lanka
sagarak@uovt.ac.lk

Malkanthi Thenabadu
Department of Agriculture and Food
Technology
University of Vocational Technology,
Rathmalana,
Sri Lanka
mal.thenabadu@gmail.com.,

Abstract— Nutritional Powder Mixture or breakfast cereal is a good source of nutrients which is rich in protein and is developed using three main ingredients which are very rich and common in daily diets. Oats (*Avena sativa*), mung beans (*Vigna radiata*), and maize (*Zea mays l*) are mixed with ratios using Taguchi's method. Initially, eight samples were prepared and named T1-T8, those samples were roasted using the dehydrator, and the selected optimum time-temperature combination is 150°C 15 Min. And ground finalized the best sample (T5) after conducting a sensory evaluation (30 untrained panelists) and using Friedman and one-way ANOVA test sensory evaluation results were calculated. T5 sample was selected as the best sample (code-532) (Oats 60 g, Maize 25 g, Mung beans 10 g) and headed to further developments and for further proximate analysis and microbiological analysis. In the proximate analysis, fat percentage was 7.8, the protein percentage was 17.5, the fiber percentage was 2.8 the Ash percentage was 9.8 and the Moisture percentage 8.2 were analyzed. In microbiological stability was tested over three-week periods and the coliforms and E. coli were absent in the respective sample and the yeast and molds count were observed in a lower limit. As a breakfast cereal, this product can be used and the ingredients are also very natural and healthy.

Keywords— Breakfast cereal, Oats, Mung bean, Maize

I. INTRODUCTION

Breakfast is the first meal of the day, which is eaten two to three hours after waking up. It is the meal that breaks the fast after the longest period of sleep and consists of food and beverage from at least one of the food groups listed in My Plate [7,9,50]. It has been reported that men who do not eat breakfast have a 27% increased risk of coronary heart disease and lower cognitive performance. [21,59] Breakfast cereal products are currently divided into two categories: cooked cereals and cold breakfast cereals. Cornflakes are a type of cold breakfast cereal that is ready to eat. [57,56] The role of Cereal Based Breakfast in a balanced diet has been organized for many years. [21,78,80]

Oats-based breakfast cereals are currently trending the market demand worldwide. Among the cereals, Maize (*Zea mays*) and Mung Beans (*Vigna radiata*) are widely cultivated

in the dry zone like Anuradhapura, Polonnaruwa and they can be used for many products in the Sri Lankan market. Thus, the Oat with locally available cereal-based products is concerned to develop instead of imported cereal breakfast products in this study.

Introducing a cereal-based breakfast powder is a main objective and as specific objectives, selecting the best formulation using organoleptic parameters and evaluating the physio-chemical parameters of the selected formula, and evaluating the shelf life of the selected product. Breakfast cereals consumers had a superior micronutrient profile and dietary fiber intake compared with skippers and non-cereal breakfast consumers, adolescents who are at great risk of not meeting nutrient targets for key nutrients, including calcium and magnesium, had the highest prevalence of breakfast skipping, and the lowest prevalence of breakfast cereal consumption. [28,6]

Overview of the Oates (*Avena sativa*)

Oat remains an important cereal crop in the developing world and the most popularly cultivated species is *Avena sativa*. which is trivially known as the common covered white oat [43,82] Oats require lesser amounts of nutrients (N- Sodium, P-Phosphorus, K-Potassium) to cultivate than that required for wheat or maize. Oat grows in cool and moist climates. [60,61] Oat consumption in human diets has increased because of health benefits associated with dietary fibers such as B-glucan, functional proteins, lipids, starch components, and phytochemicals present in the oat grain. [76,57]

In recent years, public attention is especially paid to inhabitant health and well-being and healthy lifestyle food including functional food. Oat is a well-known annual crop in temperature climates. [34,57] It is recognized as a healthy food containing significant amounts of soluble dietetic fiber, beta-glucans, fat-soluble vitamin E, and polyunsaturated fatty acids in the acids oats are a very rich source of protein [78] Oats have a well-balanced nutritional composition. it is a good source of carbohydrates and quality protein with a good amino acid balance. [57,78,76]

Antioxidants such as vitamin E are known to protect the body from damaging free radicals and play an important role in the prevention of diseases such as cancer. [55] Oat germ has a high level of tocopherol (a and c isomers). Whereas tocopherols are mainly concentrated in endosperm but, are absent in germ.[55]

Oat is a good source of phenolic compounds. [63] Those compounds may contribute to the functional and nutritional properties of the grain.[74] Cereals account for phenolic compounds derived mainly from hydroxybenzoic and hydroxycinnamic acids. The major phenolic acids in oats are ferulic, P-coumaric, caffeic, vanillic, hydroxybenzoic acid and their derivatives. [73,15,49]

Overview of Mung beans (*Vigna radiata*)

Processing mung bean into flour could increase its shelf life and economic value. [48] Pretreatment of mung bean should be done to eliminate unpleasant odors in mung bean flour.[48] Mostly food processing involved heating processes using high temperatures such as roasting, steaming, and boiling. Folate is a compound that is not stable at high temperatures. [45,46]

Folate lost during the cooking process is a result of vitamin thermal degradation in the cooking water and heat damage. [48]

The mung bean is rich in polyphenolics.[25] The major phenolic constituents in the mung bean are phenolic acids (1.81–5.97 mg rutin equivalent/g), flavonoids (1.49–1.78 mg catechin equivalent/g), and tannins (1.00–5.75 mg/g). [25]

The seeds, sprouts, and hulls of mung beans contain an enormous amount of macro (protein, polypeptides, oligo, and polysaccharides) and micronutrients (flavonoids, phenolic acids, organic acids, sterols, triterpenes, aldehydes), which exerts potent antioxidant properties. Germination generally causes an increase in micronutrients, including secondary metabolites (phenolics, flavonoids, -tocopherol, and vitamin C), through aerobic respiration and biochemical metabolism. [45,46,41] These phenolic compounds and vitamins are notably beneficial as antioxidants. [71]

Overview of Maize (*Zea mays*)

Corn is the cereal with the highest production worldwide and is used for human consumption, livestock feed, and fuel. Various food technologies are currently used for processing industrially produced maize flour and corn meals in different parts of the world to obtain precooked refined maize flour, dehydrated nixtamalized flour, fermented maize flour, and other maize products. [1,34,35]

Carbohydrates and water are the main chemical substances in corn. The carbohydrate content in corn is close to 75% and carbohydrates content in sweet corn takes accounts for nearly 18%. The water content in corn is about 10% and the water content in sweet corn is about 75%. Corn and sweet corn provide a wide variety of vitamins (carotenoids, thiamine, riboflavin, niacin, pyridoxine, folate, ascorbic acid, vitamin E, and vitamin K), minerals (calcium, magnesium, phosphorus, potassium, sodium, and zinc) and resistant starches. [2,66,67]

Maize is an essential source of various major phytochemicals such as carotenoids, phenolic compounds, and phytosterols [68] They are commonly categorized as phenolic acids, flavonoids, stilbenes, coumarins, and tannins. Among these phenolics, flavonoids and phenolic acids are the major compounds found in corn. [66,48,52]

II. OBJECTIVES

This research was conducted to introduce a cereal-based breakfast powder for a ready-to-eat concept which has filled with various nutritional properties and secondly to select the best formulation using organoleptic parameters and to evaluate the physio-chemical parameters of the selected formula and self-life evaluation of the selected product

III. METHODOLOGY

Study area and location

This study was conducted in the Food Processing Laboratory, Food Analysis Laboratory, and Food Microbiology Laboratory of the University of Vocational Technology, Ratmalana.

Selection of raw materials

Powder particles of Oates, maize, and mung beans would be prepared and brown sugar & salts would be purchased from the domestic market. Purchased Mung Beans used to grind and dehydrate in order to prepare the Mung Beans flour

Sample preparation

A-	Oates Flour
B-	Maize Flour
C-	Mung Beans Flour
S-	Sugar
T-	Salt

(Sugar 4% and salt 2% are constant in every sample as per the food act in Srilanka)

A	A ₀ =40g(Low)		
	A ₁ = 60g(High)		
B	B ₀ = 15g (Low)	C ₀ =10g (Low)	
	B ₁ =25g(High)	C ₁ =20g(High)	

Figure 1: Experimental design

2³ Design

1	A ₀ B ₀ C ₀ + S + T
A	A ₁ B ₀ C ₀ + S + T
B	A ₀ B ₁ C ₀ + S + T
C	A ₀ B ₀ C ₁ + S + T
AB	A ₁ B ₁ C ₀ + S + T
AC	A ₁ B ₀ C ₁ + S + T
BC	A ₀ B ₁ C ₁ + S + T

TABLE 1: EXPERIMENTAL DESIGN

Treatment	Name	Design	Oates Flour	Maize Flour	Mung Beans Flour	Flour Mix (g)	Sugar 4% (g)	Salt 2% (g)
T1	1	A ₀ B ₀ C ₀ + S + T	40	15	10	65	2.6	1.3
T2	A	A ₁ B ₀ C ₀ + S + T	60	15	10	85	3.4	1.7
T3	B	A ₀ B ₁ C ₀ + S + T	40	25	10	75	3	1.5
T4	C	A ₀ B ₀ C ₁ + S + T	40	15	20	75	3	1.5
T5	AB	A ₁ B ₁ C ₀ + S + T	60	25	10	85	3.4	1.7
T6	AC	A ₁ B ₀ C ₁ + S + T	60	15	20	95	3.8	1.9
T7	BC	A ₀ B ₁ C ₁ + S + T	40	25	20	85	3.4	1.7
T8	ABC	A ₁ B ₁ C ₁ + S + T	60	25	20	105	4.2	2.1

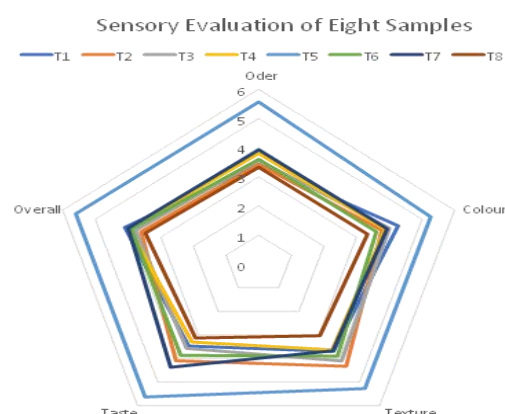


Figure 2: Sensory Evaluation Radar Chart

Selection of the best formula

The best formula will be selected by preparing the above ratios and serving with hot water or milk then conducting a sensory evaluation and selecting the best formula.

Organoleptic Evaluation (Sensory evaluation) Determination of Physio-Chemical Parameters done by ISO standards and microbiological analysis done by SIS standards.

RESULTS & DISCUSSION

To discover the optimum temperature range preliminary experiments were held using a three-time temperature combination.

250 OC 20 Min All the samples were burnt and rejected

250 OC 15 Min All the samples were burnt and rejected

150 OC 20 Min Samples were roasted too much and rejected

Sensory attributes were failed 150 OC 25 Min Samples were roasted and sensory attributes were identified according to the requirements and accepted. According to Keying Q. et.al., 2009 findings, the best and optimum time-temperature combination to roast oats flour was discovered as 150 OC – 15 Min. [39] With the findings of Keying Q. et.al., 2009 the preliminary experiments for the best roasting time-temperature combination for the other two ingredients (mung beans and Maize) were discovered.[39]

Sensory Evaluation

561 - T1, 321 - T2, 132 - T3, 225 - T4, 532 - T5, 165 - T6, 325 - T7, 135 - T8 all the eight samples were named T1-T8 and represent three-digits numbers as mentioned and the sensory evaluation radar chart

TABLE 3: TURKEY COMPARISON TEST RESULTS

Sample N	Mean Grouping
532 T5 30	5.70000 A
325 T7 30	4.36667 B
321 T2 30	4.13333 B
165 T6 30	3.73333 B
132 T3 30	3.53333 B
561 T1 30	3.43333 B
225 T4 30	3.36667 B
135 T8 30	3.20000 B

TABLE 4: DESCRIPTIVE ANALYSIS OF EIGHT SAMPLE

Sample	N	Median	Sum of Ranks
132 T3	30	3.07813	112.5
135 T8	30	3.07813	111.0
165 T6	30	3.26563	128.5
225 T4	30	3.14063	113.0
321 T2	30	3.76563	145.5
325 T7	30	4.01563	152.0
532 T5	30	5.20313	201.5
561 T1	30	3.07813	116.0
Overall	240	3.57813	

Selected Sample from Sensory Evaluation

60 g Oats	25 g Mung Beans	10 g Maize	95 g Weight of the flour Mixture
--------------	--------------------	---------------	--



The sample which is selected from the sensory evaluation was sent for proximate analysis and microbiology analysis. Previously in the experimental design the sugar and salt were added according to the ratios and in the sensory evaluation, the added required amount of sugar and salt according to the food act Sri Lanka was not enough. Therefore, the opportunity to add the preferable amount of sugar and salt is given to the customer.

TABLE 5: PROXIMATE ANALYSIS RESULTS FOR T5

Test parameter	Test method	Results
Fat percentage by dry mass ISO 11085:2015 Solvent extraction	MCL CF- SOP - 01	7.8
Protein, percent by dry mass ISO 59832:2009 Digestion & distillation	MCL CF- SOP - 02	17.5
Crude fiber, percent by dry mass ISO 5498:1981 Gravimetric	MCL CF- SOP - 03	2.8
Ash percentage	SLS standards	9.8
Moisture percentage, dry basis, oven dry method	SLS standards	3.2

TABLE 6: MICROBIOLOGY ANALYSIS

Sample	Dilution factor	TPC	Coliform	E.coli	Yeast	Mold
Extraction(finished good)Boiled	10 ⁰	4.16*10 ²	negative	negative	negative	neget
	10 ¹	12.96*10 ³	-----	-----	-----	-----
	10 ²	4.0*10 ⁴	-----	-----	-----	-----
Mixture preparation(ratio)	10 ⁰	8.80*10 ³	negative	negative	20	90
	10 ¹	3.08*10 ⁴	-----	-----	-----	20
	10 ²	7.60*10 ⁴	-----	-----	-----	-----
Mixture composite samples	10 ⁰	1.114*10 ⁴	negative	negative	40	130
	10 ¹	8.20*10 ⁴	-----	-----	-----	50
	10 ²	5.88*10 ⁵	-----	-----	-----	5
Oats	10 ⁰	2.5*10 ²	negative	negative	10	70
	10 ¹	3*10 ²	-----	-----	-----	10
	10 ²		-----	-----	-----	-----
Mungbeans	10 ⁰	6.28 *10 ³	negative	negative	30	120
	10 ¹	3.96*10 ⁴	-----	-----	-----	-----
	10 ²	4.4*10 ⁴	-----	-----	-----	-----
Maize	10 ⁰	7.08*10 ³	negative	negative	20	270
	10 ¹	6.08*10 ⁴	-----	-----	-----	130
	10 ²	1.02*10 ⁶	-----	-----	-----	80

The results show that, coliform and E. coli are absent in the sample, and yeast and mold are present in the acceptance level.

CONCLUSION

Sample 532-T4 has been identified as the optimal specimen, along with the most favorable ratio, employing the Tukey comparison method and the one-way ANOVA approach through both Minitab and SPSS software analyses. Concurrently, as per the outcomes derived from sensory evaluation tests, sample 532-T5 has been designated as the superior specimen, displaying the most desirable ratio. The data were subjected to thorough examination using SPSS and MINITAB software applications.

Sample T5 demonstrates the most favorable sensory attributes as ascertained through the examination of mean values, suggesting avenues for potential refinement. Remarkably, the protein content was quantified at 17.5 units, signifying its stature as a robust protein source with minimal fat content. This aligns with the prevailing trend wherein individuals are progressively opting for low-fat and low-carbohydrate cereal-based breakfast options, while concurrently expressing a proclivity for heightened protein consumption. Such dietary preferences stem from a desire to foster physical well-being, combat various ailments, and effectively manage health amidst the bustling contemporary lifestyle.

REFERENCES

- [1] Kopsell, D.A., Armel, G.R., Mueller, T.C., Sams, C.E., Deyton, D.E., McElroy, J.S. and Kopsell, D.E., 2009. Increase in nutritionally important sweet corn kernel carotenoids following mesotrione and atrazine applications. *Journal of agricultural and food chemistry*, 57(14), pp.6362-6368.
- [2] Liu S, Stamofer M.G, Rimm E., Manson J. E., Willett, W.C. 1999. whole grain consumption and risk of coronary artery disease. *Am. J. Clin. Nutr.*, 70, 412-419.
- [3] AACC. 2001. *Report of the dietary fibre definition*. American association of cereal chemists.
- [4] Anderson, J.A. 1979. High carbohydrate, high fiber diets for insulin men with diabetes mellitus. *Am. J. Clin. Nutr.*, 32, 2312-2321.
- [5] Arakelyan, H. 2019, May. *Corn Nutrition and Health Benefits*. Retrieved from http://www.researchgate.net/publication/333021434_Corn_Nutrition_and_Health_Benefits
- [6] Arashdeep Singh, Savita Sharma. 2015. Bioactive Components and Functional Properties of Biologically Activated Cereal Grains. *Critical Reviews in Food Science and Nutrition* 27 October 2015.
- [7] Association, A. D. 1994. Nutrition recommendation and principles for people with diabetes mellitus. *J. Am. Diet. Assoc.*, 94, 504-506.
- [8] Balunkeswar Nayak 1, Rui Hai Liu, Juming Tang. 2015. Effect of processing on phenolic antioxidants of fruits, vegetables, and grains--a review. *Crit Rev Food Sci Nutr*, 57(7), 887-919.
- [9] Barbieri R., Casiraghi EM. 2007. Production of Food grade flour from defatted corn germ meal. *International Journal of food science dan Technology*, 18, 35-41.
- [10] Blandino AL., Al Aseeri ME., Pandiella SS. 2003. Cereal Based Food and Beverages. *Food Res. Int.*, 36, 527-543.
- [11] Bode S, Gudmand Hoyer E. 1996. Symptoms and haematological features in consecutive adult celiac patients. *Scand. J. Gastroenterol*, 31, 54-60.
- [12] Bradshaw. 2005. Development of semolina milling. *Grain Feed Mill Tech.*, 14-17.
- [13] Brand J. C., Colagiuri, S., Allen, A., Sassull, M. A., Dilawari, J 1991. Low-glycemic index foods improve longterm glycemic control in NIDDM. *Diabetes Care*, 14, 95-101.
- [14] Bremer, J.M., Scott, R.S., 1991. Oat bran and cholesterol reduction: evidence against specific effect. *Aust. N.Z. J. Med*, 21, 422-426.
- [15] Briel, W, Bobko, K Masiorowski, R. 2009. Chemical composition and nutritive value of husked and naked oats grain. *Journal of cereal science*, 49, 413-418.
- [16] Brochu M., Poehlman E.T., Ades P.A. 2000. Obesity, body fat distribution and coronary artery disease. *Cardiolium Rehabil*, 20, 96-108.
- [17] Caton P.W; Potheary MR; Lees DM; Khan NQ; Wood EG; Shoji T; Kanda T; Rull G. (n.d.). Regulation of vascular endothelial function by procyanidin-rich foods and beverages. *J. Agric food chemistry*, 58, 4008-4113.
- [18] Cenkowski S. Anemes N., Muir WE. 2006. Infrared Processing of Oat Groats in a laboratory scale micronizer. *Can. Biosyst Eng.*, 48, 3.17-3.25.
- [19] Chavan JK., Kadam SS. 1989. Nutritional improvement of cereals by fermentation. *Crit. Rev. Food Sci. Nutr.*, 28, 349-400.
- [20] CRA. 2006. *Corn Oil*. Washington DC: Corn Refiners Association.
- [21] Curtis, T. R. 1989. Ready -to-eat cereals: role in a balanced diet. *cereal foods world*, 34(5), 387-90.
- [22] Patel D.V., Sawant M.G., G. Kaur, 2015. Evaluation of anti-osteoarthritic activity of vigna mungo in papain induced osteoarthritis model. *indian journal of pharmacol*, 47, 59-67.
- [23] David L Katz, et al. 2001. A scientific review of the health benefits of oats.
- [24] De groot, A.P., Luyken, Pikaar, N.A. 1963. cholesterol lowering effect of rolled oats. *Lancet*, 1, 303-304.
- [25] Dianzhi hou, Laraib Yousaf, Yong Xue, Jinrong Hu. 2015. Mung Bean (*Vigna radiata* L.): Bioactive Polyphenols, Polysaccharides, Peptides, and Health Benefits. *Nutrients.*, 11(6), 1238.
- [26] Brounus F., B. Kettlitz, E. Arrigoni. 2002. Resistant starch and "the butyrate revolution". *Trends in Food Science and Technology*, 13, 251-261.
- [27] Sosulski F.W., K.J. Dabrowski. 1984. composition of free and hydrolyzable phenolic acids in the flours and hulls of ten legume species. *agric. food chem.*, 32, 131-133.
- [28] Flavia Fayet-Moore, Andrew McConnell, Kate Tuck, Peter Petocz. 2017. Breakfast and Breakfast cereal choice and its impact on nutrient and sugar intakes and anthropometric measures among a nationally representative sample of Australian children and adolescents. *Nutrients*, 9(21 september 2017), 1045-1061.
- [29] Flodin, N. 1986. Artherosclerosis: an insulin -dependent disease? . *J. Am. Coll. Ntr.*, 5, 417-427.
- [30] Gambus H., Gambus F., Sabat R. 2002. the research on quality improvement of gluten free bread by amaranthus flour addition. *Zywnosc*, 9, 9-112.
- [31] Ganssmann W., Vorwerek K. 1995. Oat milling, Oat processing and storage. *The oat crop: Production and Utilization*, (pp. 369-408). Chapman and Hall, London.
- [32] Ghosh and Konishi. 2007. Anthocyanin and anthocyanin rich extracts: role in diabetes and eye function . *Asia Pasific Journal of Clinical Nutrition*, 16, 200-208.
- [33] Green P.H., Rostami, K. Marsh M.N. 2005. Diagnosis of celiac disease. *Best Pract. Res. Clin. Gastroenterol*, 19, 389-400.
- [34] Grundy, S. 1997. Lipid abnormalities and coronary heart disease. *clinical symposium*, 49, pp. 1-33.
- [35] Hendriks H.F., Weststrate J.A., T. Van, G.W. Meijer. 1999. Spreads enriched with three difference oil sterols and the degree of cholesterol lowering in normocholesterolaemic and mildly hypercholesterolaemic subjects. *Europe Journal of clinical Nutrition*, 53, 319-327.
- [36] Harsah D.W., Lin P.H. 1999. Dietary approach to stop Hypertension: A summary of study results. 99(8).
- [37] Head, D., Cenkowski, S., Arntfield, S. and Henderson, K., 2011. Storage stability of oat groats processed commercially and with superheated steam. *LWT-Food Science and Technology*, 44(1), pp. 261-268.
- [38] Higgins. 2004. Metabolic effects and Potential Health Benefits. *Journal of AOAC*, 87, 761-768.
- [39] Jeffrey A. Gwirtz, and Maria Nieves, Garcia-Casal. 2013. Processing Maize Flour and corn meal. *Ann. N.Y. Acad. Sci.*, 66-75.
- [40] Jiang. 2010. *Resistant starch formation in high amylose maize starch*. Iowa State University Ames.
- [41] Jiang Y.Z., and Wong. 2005. Phytosterols in cereal by-products. *Journal of the American Oil Chemists' Association*, 82, 439-444.
- [42] Johnson RK, Smicikles-Wright H, Crouter AC, Willits FK. 1992. *Maternity employment and the quality of young children's diets: empirical based on the 1987-1988 Nationalwide Food Consumption Survey* (Vol. 90).
- [43] Keenan, J. 1998. Cardiovascular health and soluble fiber from oats. *Philippine Journal of Nutr.*, 45, 1-7.
- [44] Keying Q. 2009. An investigation on pretreatments for inactivation of lipase in naked oat kernel using microwave heating . *J. Food Eng.*, 95, 280-284.
- [45] Klensporf D., Jelen H.H. 2008. Effects of Heat treatments on the flavour of Oat flakes. *Journal of Cereal Science*, 48, 656-661.
- [46] Kumar D, Jaliya N.A . 2013. Nutritional medicinal and economical importance of corn. *Research Journal of Pharmaceutical Sciences*, 2, 7-8.
- [47] Kumar Ganesan, Baojun Xu. 2017. A critical review on phytochemical profile and health promoting effects of mung bean. *Food Science and Human Wellness*.
- [48] Letizia Saturni, Gianna Ferretti, Tiziana Bacchetti. 2010. The Gluten Free Diet: Safety Nutritional Quality. *Nutrients*, 2, 16-34.
- [49] Liu, R. 2007. Whole grain phytochemicals and health . *Journal of cereal science*, 46, 207-209.
- [50] Liu, R. 2013. Dietary bioactive compounds and their health implication . *Journal of Food Science*, 72, 1828.
- [51] Ludwig, D.S., Pereira, M.A., Van Horn, Jacobs, D.R. 1999. Dietary fiber, weight gain and cardiovascular disease risk factors in young adults. *J.A.M.A.*, 282, 1539-1546.

- [52] Michaud. 2000. INtake of specific carotenoids and risk of lung cancer . *American journal of Clinical Nutrition*, 72, 990-997.
- [53] Miftakhussolikah, M. Kurniadi, A. Frediansyah. 2015. folate content of mung beans flour by various heat treatments. *international symposium on food and agro biodiversity* , 3, 69-73.
- [54] N Tapola I, H Karvonen, L Niskanen, M Mikola, E Sarkkinen. 2005, August. Glycemic responses of oat bran products in type 2 diabetic patients. *Nutritional, Metabolism & cardiovascular diseases*, 14, 25561.
- [55] Ostlund 2002. Phytosterol that are naturally present in commercial corn oil significantly reduce cholesterol absorption in human. *American Journal of Clinical Nutrition* , 75, 1000-1004.
- [56] Sing P.N., Fraser G.E., 1998. Dietary risk factors for colon cancer in a low risk population . *American Journal of Epidemiol*, 148, 761-774.
- [57] Lin, P.Y. Lai H.M.2006. Bioactive compounds in legumes and their germinated products. *Agric. and Food Chem.*, 54, 3807-3814.
- [58] Packer. 1991, april 4. Protective role of vitamin E in biological systems. *The American Journal of Clinical Nutrition*, 53(4), 1050S-1055S.
- [59] Plotnic, G. C. (n.d.). Effect of antioxidant vitamins on the transient impairment of endothelium dependent brachial artery vasoactivity following a single high -fat meal. *J.A.M.A.*, 278, 1682-1686.
- [60] Prasad Rasane. 2013. *nutritional advantages of oats and opportunities for its processing as value added foods*. Association of food scientists & technologists.
- [61] Prasad Rasane, Alok Jha, Latha Sabikhi, Aravind Kumar. 2015. Nutritional advantages of oats and opportunities for its processing as value added foods. *J. Food Sci.Tech.*, 2, 662-675.
- [62] Campose Vega R., Loarca Pina G., Oamah B.D. 2010. Minor components of pulses and their potential impact on human health. *Food Research International* , 43, 461-582.
- [63] Liu, R.H., 2004. Potential synergy of phytochemicals in cancer prevention: mechanism of action. *The Journal of nutrition*, 134(12), pp.3479S-3485S.
- [64] Rampersaud, G. C.2009. Benefits of breakfast for children and adolescents: update and recommendations for practitioners. *lifestyle med*, 3(2), 86-103.
- [65] Robert 1985. Characterization of oat residual protein. *Cereal Chemistry*, 62(4), 276-279.
- [66] Ramos, S., 2008. Cancer chemoprevention and chemotherapy: dietary polyphenols and signalling pathways. *Molecular nutrition & food research*, 52(5), pp.507-526..
- [67] Chandrasiri S.D., Liyanage R., Vidanarachchi J.K, P. Wethasinghe. 2016. Does Processing have a considerable effect on the nutritional and functional properties of mung bean. *Procedia Food Science*, 6, 352-355.
- [68] Sanchez.A., Horning, M.C., Wingleth D.C.1983. *Plasma amino acids in humans fed plant proteins*.
- [69] Saxena M. , Saxena J., Nerma , R. , Gupta A. . 2013. Phytochemistry of medicinal plants. *Journal of Pharmacognosy and Phytochemistry*, 1, 168-182.
- [70] Shan L. 2002. Structural Basis for gluten intolerance in celiac sprue. *Science*, 297, 2275-2279.
- [71] Siyuan Sheng, Tong Li, Rui Hai Liu. 2008. Corn phytochemicals and their benefits. *Food science and Human Wellness*.
- [72] Sylvanus D.P., Paul K. Malumba, Yves Beckers. 2015. impact of drying and heat treatment on the feeding value of corn. *Biotechnol.Agron.Soc.Enviro.*, 19(3), 301-312.
- [73] Tajamul Rouf Shah, Kamlesh Prasad & Pradyuman Kumar. 2016. Maize A potential source of human nutrition and health: A review. *Cogent food and agriculture*, 2(1).
- [74] Tappy L., Gugolz E., Wursch P.1996. Effect of breakfast cereals containing various amounts of glucan
- [75] fibers on plasma glucose and insulin responses in NIDDM subjects. *Diabetes Care*, 19, 831-833.
- [76] Thompson, T. 1999. Thiamin, riboflavin and niacin contents of the gluten free diet: is there cause for concern? . *J. American Dietetic Assoc.*, 99, 858-862.
- [77] Turnbull, A.S. and Reeds, A.R. 1989. The effect of rolled oats and a reduced fat modified diet on apolipoprotein AI and B. *J. Clin Nutr. Gastroenterol*, 1, 15-19.
- [78] Zhou, M., Robards, K., Glennie-Holmes, M. Oat lipids. *J Amer Oil Chem Soc* 76, 159-169 1999.
- [79] Van horn, L.1988. serum lipid responses to a fat-modified oatmeal enhanced diet. *Prev.Medicine*, 17, 377-386.
- [80] Vasanthan T., Gaosong J., Yeung J. 2002. Dietary fibre profile of barley flour as affected by extension cooking . *Food Chem.*, 77, 35-40.
- [81] Vita Sterna, Sanit Zute, Linda Brunava. 2016. "Oat grain composition and its nutritional benefits" Agriculture and Agricultural Science Procedia. *florence" Sustainability of well-being International Forum*, 8, 252-256.
- [82] White.1995. Structure and development of oats. *The oat crop production and utilization*, 88-119. Chapman and hall, London UK.
- [83] Williams, P. G. 2014. The benefits of breakfast cereal consumption: A systematic review of the evidence base. *advances in Nutrition*, 5, 636S-673S.
- [84] Wood, P.J., Braaten, J.T. , Scott F. W., Riedel D., Collins M.W.1994. Effect of dose and modification of viscous properties of oat gum on plasma glucose and insulin following and oral glucose load. *Br. J. Nutr*, 72, 731-743.
- [85] Ye X.Y., Wang H.X., T.B. Ng.2000. Structurally dissimilar proteins with antiviral and antifungal potency from cowpea seeds. *Life Science* , 67, 3199-3207.
- [86] Zhang X, Shang P, Qin F, Yang H, Shi H, Yu L.2013. chemical composition and antioxidative and antiinflammatory properties of ten commercial mung bean samples. . *food science and technology*, 54, 171-178.
- [87] Zhenxing Shia, Yang Yaoa, Yingying Zhuab, Guixing Rena.2016. Nutritional composition and antioxidant activity of twenty mung bean cultivars in China. *the crop Journal*, 4(5), 398-406.
- [88] Zhou, M, X, Robards, K, Glennie-Holms, M Helliwell S.1999. Oat lipids. *journal of american oil chemistry science*, 79, 585-592.
- [89] Zwer PK et.al.2004. Encyclopedia of grain science. pp.365-375. Waltham, Massachusetts.: Elsevier Academic Press.

The Goodness of Chlorophyll Food, and beyond with Cactus and Hathawariya (Shathavari) – Nutritional advancements with Nature and Technology

B.M.D.S.Piyasena

*Department of Agriculture and food technology
University of Vocational Technology Ratmalana, Sri Lanka
dilangani1995@gmail.com*

K.B.R.G.Jayathilaka

*Department of Agriculture and food technology
University of Vocational Technology
Ratmalana, Sri Lanka
randikagimhani74@gmail.com*

W.M.D.C.Wijekoon

*Department of Agriculture and food technology
University of Vocational Technology Ratmalana, Sri Lanka
dumeshichathuranga@gmail.com*

A S K Warahena

*Department of Manufacturing Technology,
University of Vocational Technology Ratmalana, Sri Lanka
aruna.warahena@gmail.com*

Abstract— Chlorophyll's prospective use in pharmacy as a treatment, diagnostic tool, and photosensitizer are highlighted by a review of its medical usage in contemporary medicine. It has a variety of therapeutic applications and contributes to the modification of genotoxic effects. Objective of this article how to produce nutritional advancements of cactus and hathawariya enriched chlorophyll food in human health. An overview of studies and advancements in the medicinal claims of chlorophyll is given in the review. Medicinal potential of these photosynthetic pigments and their derivatives including antioxidant, antimutagenic, antigenotoxic, anti-cancer, and anti-obesogenic properties.

Keywords— chlorophyll; chlorophyllin; health, immunity, nutrition

I. INTRODUCTION

Plant products are gaining popularity in the hunt for novel nutraceutical components and all-natural remedies for treating disease, and the development of new antibiotics to replace those now in use is a key area of this study because of pathogen resistance. Chlorophyll juice is one example of a plant product that is now being studied in terms of its potential as a drug. This review aims to explore the health and therapeutic benefits of chlorophyll juice/foods. [1].

Hathawariya, also known as *Asparagus racemosus*, is highly regarded for its nutritional and medicinal properties. The leaves are commonly consumed in porridges, earning it the title of the "queen of herbs." In addition to its culinary use, Hathawariya has found its way into the culinary industry in the form of curry powders and herbal supplements like tablets and syrups. Nutritionally, Hathawariya contains vitamins A, B, C, E, and essential minerals such as magnesium (Mg), calcium (Ca), iron (Fe), and phosphorus (P). Its remarkable medicinal properties include antioxidant, antibacterial, antifungal, antihepatotoxic, antitumor, anticarcinogenic, antiulcerogenic, diabetic retinopathy, and reproductive

benefits. In Sri Lanka, Hathawariya is used to make porridge which is eaten in Sri Lankan homes as well as make "Kola Kanda" (herbal soup) that is an herbal drink which is a heavily used drink among Sri Lankans [23].

A cactus is a member of the Cactaceae family of succulent plants (plural: cacti, cactuses, or cactus). Although many of them are also grown as crop plants, they are frequently utilized as decorative plants. Almost all plants from the "new world" are cacti. This indicates that only North America, South America, and the West Indies are home to them. In dry and semi-arid parts of India, cacti are widely cultivated as wild plants. Cacti are a staple food for people in northern Africa, Mexico, the United States, Spain, and Italy. Its young leaves make a nutritious vegetable and salad meal, and the immature fruits are great for producing mock-gherkins. The fresh fruits have exceptional quality and flavor [22].

II. CHLOROPHYLL

Chlorophyll, due to its chemical similarity to hemoglobin, the substance in red blood cells responsible for carrying oxygen, is believed to mimic hemoglobin in our bodies. This mimicry can aid in rebuilding red blood cells, enhancing their capacity to transport oxygen, thereby increasing our energy levels. Green plants contain antioxidants that have shown potential in preventing certain types of cancers. Research has indicated that chlorophyll, a prominent antioxidant, can influence the balance of oxidants and antioxidants within pancreatic cancer cells.

The technology used to make chlorophyll juice from wheatgrass and other leafy greens typically involves juicing or blending the greens and then using specialized equipment like cold-press juicers or centrifugal juicers to extract the liquid. This process helps retain the nutrients and chlorophyll content. Some companies also use freeze-drying or other preservation methods to create powdered chlorophyll supplements. It's important to note that the

specific technologies and processes may vary among manufacturers.

Every plant has at least one kind of chlorophyll. Both of these substances are fat-soluble and possess antioxidant qualities. Chlorophyll enters the body and travels about in micelles, which are fatty molecular groups. While the exact minimal quantity of fat required to metabolize chlorophyll has not been determined by studies, it is believed that tiny quantities of good fats can aid the body in processing chlorophyll during meals [2]

Being water soluble and non-fat soluble, chlorophyllin is semi-synthetic and frequently added to medications or food coloring. Chlorophyllin is a supplement that is taken with meals, whereas chlorophyll is a naturally occurring substance in plants. [2]

a. Medical Values of Chlorophyll Juice and Suppliments

Chlorophyll-based juices and drinks have gained popularity due to their potential health benefits. Chlorophyll is the green pigment in plants that plays a crucial role in photosynthesis. Some proposed benefits of chlorophyll drinks include detoxification, improved digestion, and potential antioxidant effects. However, it's important to note that scientific research on the specific health effects of chlorophyll consumption in humans is still limited [1]. While chlorophyll itself is considered safe for consumption, some commercial chlorophyll drinks might also contain added ingredients, flavors, and sugars. But balanced diet rich in fruits, vegetables, and a variety of nutrients is essential for overall health, and relying solely on chlorophyll drinks may not provide all the necessary nutrients your body needs. [1] Chlorophyll supplements are often promoted for their potential health benefits, including detoxification and antioxidant effects. However, the scientific evidence [3] supporting these claims is limited and mixed. While chlorophyll is an essential molecule for photosynthesis in plants, its effects on human health are not as well- established. [1]

Enhance blood health: chlorophyll's resemblance to the hemoglobin aids in restoring red blood cells. Enzymes in chlorophyll purify blood, improving oxygen-carrying capacity and combination anemia. [4]

Cancer protection: acting as a chemo protective agent, chlorophyll's anti mutagenic properties prevent toxin absorption in the intestines, potentially reducing cancer risks. It also safeguards the liver from harmful agents. [5]

Powerful antioxidant: chlorophyll's free radical scavenging ability, coupled with its vitamin content, bolsters the body's defense against pathogens and oxidative stress, thereby preventing diseases. [6]

Anti-inflammatory: chlorophyll's similarity to hemoglobin enables efficient detoxification by increasing blood flow, binding to toxins, and eliminating heavy metals and drug residues. [1]

Anti-aging support: as an antioxidant, chlorophyll aids in anti-aging efforts by scavenging free radicals. It promotes

healthy tissue retention, stimulates anti-aging enzymes, and rejuvenates skin while improving adrenal gland function. [7]

Digestive health: Chlorophyll helps prevent constipation, alleviate gastritis discomfort, maintain intestinal flora, stimulate bowel movements, renew wounded bowel tissues, and facilitate colon cleansing by inhibiting cytotoxicity and colonocyte proliferation. [8]

Anti-microbial properties: An alkaline material called chlorophyll has been demonstrated to be very useful in treating *Candida albicans*, a yeast infection brought on by an overabundance of candida in the human body. [9]

Immune Support and Healing: Chlorophyll, due to its resemblance to hemoglobin, can assist in rebuilding red blood cells, enhancing oxygen transportation, boosting energy levels, and promoting healing processes. [10]

Deodorizing properties: Chlorophyll has deodorizing properties, making it effective for combating bad breath. It helps eliminate mouth and throat odors, stimulates digestive health by cleansing the colon and blood stream, and is administered to individuals with colostomies and metabolic disorders to reduce fecal and urinary odors. [11]

Kidney stones: Chlorophyll contains essential vitamins, including vitamin K, which contributes to the formation of compounds in urine. These compounds aid in reducing the growth of calcium oxalate crystals, potentially preventing kidney stones. [12]

Hormonal balance: Chlorophyll plays a role in maintaining hormonal balance in both males and females, primarily due to its vitamin content. Vitamin E in chlorophyll stimulates the production of testosterone in males and estrogen in females, contributing to overall hormonal health.

Oral health: Chlorophyll finds application in maintaining oral health, particularly in the treatment of dental issues such as pyorrhea. It is used to address oral infections, soothe inflamed and bleeding gums, and support overall oral hygiene [13]

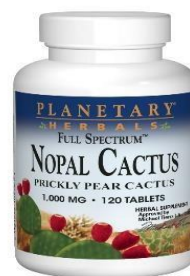


Fig 1: Cactus chlorophyll supplement (vitamingrocer.com)

III. TECHNOLOGY OF MANUFACTURING CHLOROPHYLL JUICE/DRINKS

The technology used to make chlorophyll juice from wheatgrass and other leafy greens typically involves juicing or blending the greens and then using specialized equipment like cold-press juicers or centrifugal juicers to extract the liquid. This process helps retain the nutrients and chlorophyll content. Some companies also use freeze-drying or other preservation methods to create powdered chlorophyll supplements. It's important to note that the specific technologies and processes may vary among manufacturers. [1] In the search for novel nutraceutical components, natural remedies for disease treatment, and antibiotic replacements, plant products are becoming increasingly important. Chlorophyll juice is one example of a plant product that is currently being studied in terms of its potential as a medicine. [1]

a. chlorophyll Food Products

Define abbreviations and acronyms the first time they are used in the text, even after they have been defined in the abstract. Abbreviations such as IEEE, SI, MKS, CGS, sc, dc, and rms do not have to be defined. Do not use abbreviations in the title or heads unless they are unavoidable. Nowadays, humans are more inclined to add healthy natural ingredients to our diet. Chlorophyll can be called as the most popular food among them. The green color in plants called chlorophyll. It has many healing benefits due to its antioxidant properties. Foods contained in green foods. Chlorophyll is sometimes added as a dietary supplement or to products such as juices, smoothies, and powders. By consuming foods rich in chlorophyll, the body can obtain large amounts of nutrients such as iron and dietary fiber. Some examples of foods containing chlorophyll can be seen below. [14]

- ✓ Spinach
- ✓ Collard greens
- ✓ Mustard leaves
- ✓ Alfalfa
- ✓ Parsley
- ✓ Broccoli
- ✓ Green cabbage
- ✓ Asparagus
- ✓ Green beans and peas
- ✓ Matcha green tea

Naturally, we can identify chlorophyll by its appearance, as **chlorophyll-a** and **chlorophyll-b**. There are a few minor differences between these. Chlorophyll is a natural ingredient and there is a synthetically made liquid chlorophyll called chlorophyllin. It is sold in the market as



Fig 2: Cactus juice/drinks (stylecrase.com)

supplements for that. It is used as a treatment for skin, body odor, food related problems. This supplement has been found to help neutralize oxidants. Research has found that it effectively reduces damage caused by agents such as chemical carcinogens, UV light exposure, and radiation. [14]

IV. HEALTH BENEFITS

a. Cactus Plant as a Chlorophyll Supplement as well as Immunity and Other Health Benefits

Cactus plants offer health benefits as they can help improve indoor air quality by absorbing pollutants. Additionally, some varieties of cactus, like prickly pear, have edible fruits that are rich in vitamins, antioxidants, and fiber, which can be good for your overall health. Just be cautious of thorns and potential allergies when handling cacti. [15] Cactus water, particularly derived from the prickly pear cactus (*Opuntia* species), has gained recognition for its potential health advantages. Here are some of the health benefits associated with consuming cactus water:

1. **Hydration:** Cactus water is a naturally hydrating beverage due to its high water content, supporting essential bodily functions such as digestion, circulation, and temperature regulation.
2. **Low Calories and Sugar:** Cactus water typically contains fewer calories and less sugar compared to many other fruit juices and sugary beverages. This can make it a suitable option for those looking to manage their calorie and sugar intake.
3. **Rich in Antioxidants:** Cactus water provides antioxidants like vitamin C and betalains, which combat harmful free radicals in the body, contributing to cellular health and immune system support.
4. **Electrolyte Balance:** Natural electrolytes in cactus water, including potassium, magnesium, and calcium, play a crucial role in maintaining fluid balance, nerve function, and muscle contractions.
5. **Anti-Inflammatory Properties:** Some studies suggest that compounds found in prickly pear cactus, such as betalains, have anti-inflammatory properties. These properties may be beneficial for managing inflammation-related conditions.
6. **Digestive Health:** Soluble fiber in cactus water supports digestive health by promoting regular bowel movements and aiding in waste removal from the body.
7. **Blood Sugar Regulation:** Some research suggests that cactus water may help regulate blood sugar levels due to its potential to slow down the absorption of sugars in the digestive tract. However, more studies are needed to confirm this effect.

8. **Cholesterol Management:** Some studies have indicated that consuming cactus extract might contribute to reducing LDL ("bad") cholesterol levels. Again, more research is needed to fully understand this potential benefit.
9. **Skin Health:** The antioxidants in cactus water

may contribute to skin health by combating oxidative stress and promoting collagen production. Some skincare products include cactus-based ingredients for their potential moisturizing and anti-aging effects.

Cactus-based drinks, primarily made from prickly pear cactus, are believed to offer numerous health benefits, including reducing inflammation, supporting digestion, and aiding in blood sugar management due to their rich content of antioxidants, vitamins, and minerals. [2] [15]

b. Hathawariya (Shatavari) a Locally Available Green Plant Variety Enriched with Chlorophyll and Nutrients, for drinks and Juices for Unparalleled Wellbeing:

Shatavari (*Asparagus racemosus*) is a medicinal plant that has been traditionally used in Ayurvedic medicine for its various potential health benefits. It is often referred to as the "Queen of Herbs" due to its nourishing and rejuvenating properties. While research on Shatavari is ongoing, here are some of the potential medical benefits that have been attributed to the plant. [16] [17]

1. **Hormonal Balance:** Shatavari is often used to support hormonal balance in women. It is believed to have adaptogenic properties that may help regulate hormone levels and alleviate symptoms of hormonal imbalances, such as irregular menstrual cycles, premenstrual syndrome (PMS), and menopausal discomfort.
2. **Reproductive Health:** In Ayurvedic medicine, Shatavari is considered a tonic for the female reproductive system. It is used to support fertility, enhance libido, and promote healthy lactation in breastfeeding mothers.
3. **Digestive Health:** Shatavari is believed to have digestive benefits. It may help soothe the digestive tract, reduce inflammation, and support the body's natural digestive processes.
4. **Immune Support:** Shatavari is thought to have immune-boosting properties that may help the body defend against infections and promote overall immune system health.
5. **Anti-inflammatory:** The plant contains bioactive compounds that exhibit anti-inflammatory properties, which may help reduce inflammation and alleviate associated symptoms.
6. **Stress and Anxiety Relief:** help the body adapt to stress and reduce the negative effects of stress on the body. It may have a calming and anxietyreducing effect.
7. **Antioxidant Properties:** Shatavari contains antioxidants that help protect cells from oxidative

damage, which is associated with various chronic diseases and the aging process.

8. **Urinary Health:** Shatavari has been used to support urinary health, including helping with urinary tract infections and promoting healthy urine flow.
9. **Anti-diabetic Potential:** Some studies suggest that Shatavari may have a role in managing blood sugar levels and improving insulin sensitivity, potentially benefiting individuals with diabetes.
10. **Anti-cancer Effects:** Preliminary research has indicated that Shatavari may have certain compounds with potential anti-cancer properties, although further studies are needed to fully understand its effects. [17]

More scientific studies are needed to fully establish its safety and efficacy for various health conditions. As with any herbal remedy, advisable to qualified before using Shatavari or any other herbal supplement, especially if you have underlying health conditions or are taking medications.

V. CONCLUSION

The primary element that gives the leaves their green hue is chlorophyll. But chlorophyll also has various therapeutic benefits. The alkaline composition and antioxidant capacity of chlorophyll are responsible for many of its therapeutic benefits. To obtain the functional advantages, it is advised to incorporate chlorophyll as the primary component in a daily diet.

REFERENCES

- [1] G. Sreeraj, V. Karthik and G. Robin, "A short review on the medicinal properties of chlorophyll juice," *Asian journal of pharmaceutical Technology & innovation*, vol. 2, no. 9, pp. 89-94, 2014.
- [2] L. Tesoriere, M. Allegra, D. Butera, M. A. Livrea and C. Scaccini, "Absorption, excretion, and distribution of dietary antioxidant betalains in LDLs: potential health effects of betalains in humans," *American Journal of Clinical Nutrition*, vol. 4, no. 80, pp. 941-945, 2004.
- [3] Tanya, "Stylecraze," 22 10 2023. [Online]. Available: <http://www.stylecraze.com>.
- [4] Granick, "'Structural and Functional Relationships between Heme and Chlorophyll,'" *The Harvey Lectures*, pp. 1943-1949.
- [5] R. Yazan and A. Fiasal, "'The Role of Some Plants on Colon Cancer: A Review,'" *Pakistan Journal of Nutrition*, pp. 798-805, 2012.
- [6] Hsu, Y, P. Chao, Y, S. Hu, P, Y. C and M, "The Antioxidant and Free Radical Scavenging Activities of Chlorophylls and Pheophytins".
- [7] Rhoads, "'The Relation of Vitamin K to the Hemorrhagic Tendency in Obstructive Jaundice,'" *Journal of Medicine*, p. 112, 1939.
- [8] Cheny, "Antiseptic Ulcer Dietary Factor," *The Journal of the American Dietetic Association*, pp. 26-668, 1950.
- [9] Ammona and Wolf, "Does Chlorophyll have Bactericidal and Bacteriostatic Activity?," pp. 312-14, 1995.
- [10] O'Brien, Didit and Succeeded, "Wheatgrass Therapy and its Effects on Drug Deposits vs. Immune," *The journal of Perservance*, pp. 777- 333, 2001.

- [11] Kutcher and Chilton, "Clinical Use of Chlorophyll Dentifrice," *Journal of the American Dental*, pp. 420-22, 1953.
- [12] Sonsky, "Vitamin K Influence of Preventative Prenatal Administration," *Ceskolovenska Gyneakologia*, p. 197, 1947.
- [13] [Online]. Available: <https://draxe.com/nutrition/chlorophyllbenefits/>.
- [14] Stintzing, C and R. Carle, "Cactus stems (*Opuntia* spp.): A review on their chemistry, technology, and uses.," *Molecular Nutrition & Food Research*, vol. 2, no. 49, pp. 175-194, 2005.
- [15] P. Kamble, N, S. Giri, P, R. Mane, S and Tiwana, ". Estimation of chlorophyll content in young and adult leaves of some selected plants," *Universal journal of environmental research and technology*, vol. 5, no. 6, pp. 306-310, 2015.
- [16] R. Sharma and H. Singh, "Alteration in biochemical constituents and nutrients partitioning of *Asparagus racemosus* in response to elevated atmospheric CO₂ concentration," *Environmental Science and Pollution Research*, pp. 1-10, 2022.
- [17] [Online]. Available: <https://www.webmd.com/diet/health-benefitschlorophyll>.
- [18] Singh, V. Srivastava, K, A. Shukla, S. Parashar and V. Upadhyay, "Phytochemical Analysis and Antimicrobial Activity of Various Indigenous Plant Species".
- [19] Endang, N. Aida, R, N. Dan, G, A and P, "Chlorophyll extraction methods review and chlorophyll stability of katuk leaves(*sauropus androgynous*)," *journal of physics:conference series*, p. 8, 2021.
- [20] Gitelson, A, M. Merzlyak and N, "Remote estimation of chlorophyll content in higher plant leaves.," *International journal of remote sensing*, vol. 12, no. 18, pp. 2691-2697, 1997.
- [21] Anoop, Shetty, M. Rana, K, S. Preetham and P, "Cactus: a medicinal food," *National library of medicine*, 16 October 2012. [Online]. Available: <https://www.ncbi.nlm.nih.gov>.
- [22] Dr. Lalith, "Hathawariya - Queen of herb - valuable medicinal plant," 16 December 2015. [Online]. Available: <https://srilankatwo.wordpress.com>.

Development of Artichoke (*Goeppertia allouia*) and Sweet Potato (*Ipomoea batatas*) Based Instant Cream Soup

P.U.A.Senanayake

Department of Agriculture & Food Technology
University of Vocational Technology
Ratmalana, Sri Lanka
udanianupamap@gmail.com

M. Thenabadu

Department of Agriculture and Food Technology
University of Vocational technology
Ratmalana, Sri Lanka
mal.thenabadu@gmail.com

Abstract—With the growing population, people increasingly move away from home for study and work, the demand for Ready-to-Eat, Ready-to-Cook, and Ready-to-Serve foods has increased. Today's health-conscious consumers demand processed food products that are convenient, of high quality, shelf-stable, and packed with nutrients, such as instant soup, to maintain their well-being. The aim of research work is to formulate instant cream soup with natural Artichoke Yam, Sweet potato, Purple yam and Oyster mushroom. Sweet potato, Artichoke, and purple yam are chosen in this study for their nutritional richness, making them ideal ingredients to meet the demands of a balanced and nutrient-enriched diet. Four samples of Instant cream soup (Sample IS001, IS002, IS003, IS004 were made With Artichoke flour 20%, 30%, 20% and 30% respectively, Sweet potatoes flour 22%, 22%, 35% and 35% respectively and Purple yam flour 21% constantly) were prepared and Initial sensory evaluation was done using Thirty non trained panelists and best sample was selected. The second phase of the sensory evaluation involved a comparative analysis between the selected sample and a control sample. Proximate and physicochemical properties were analyzed by using AOAC methods. Data were analyzed with MINITAB-19 version at 0.01 significance level. The Instant cream soup sample underwent proximate analysis, assessing moisture (4.76%), protein (12.7%), fat (2.4%), ash (1.54%), total sugar (6.08%), and pH value (6.5). Sample IS002 received the highest consumer acceptance. Coliform, Yeast, and mould, along with total plate count, was within acceptable limits. Considering sensory, Proximate, and microbial analyses, Artichoke and Sweet potato-based instant cream soup show potential for widespread consumption due to high acceptability and health benefits.

Keywords— Artichoke, Purple yam, Sweet Potato, Instant cream soup

I. INTRODUCTION

Today's health-conscious consumers seek convenient and health-promoting products. They have high expectations for convenience, shelf stability, and ready-to-use processed foods. Meeting these demands can be achieved by providing easy-to-prepare, nutrient-enriched options, like instant soups [1]. This requirement could be fulfilled by supplying nutrient-enriched foods such as instant soup [2].

The choice of sweet potato, artichoke, and purple yam as ingredients is based on their nutritional richness, making them ideal for a well-rounded and nutritious addition to one's regular diet. Artichoke or Leren (*Calathea allouia*) is

an indigenous tuberous crop in the Caribbean and South America. *Calathea allouia* is rarely used as the primary starchy staple in a meal, but it is frequently served as a side dish. Tubers are typically prepared by boiling. It contains 0.3% of fat, 1.5% of proteins, amylose content 39.2% and 21.4% of carbohydrates and 94.3% of calories (Kinupp & Lorenzi, 2014). *Calathea allouia* has prebiotic properties, and the high concentration of resistant starches [3].

The sweet potato (*Ipomoea batatas* (L) Lam), a perennial plant with tuberous roots from the Convolvulaceae or morning glory family, serves as an affordable alternative to starchy staples. It is rich in starch, soluble sugar, vitamins, minerals, and various nutrients [4]. Sweet potatoes offer numerous health benefits, such as antioxidant, liver-protective, anti-inflammatory, anti-tumor, anti-diabetic, anti-microbial, anti-obesity, and anti-aging effects [5].

Purple yam (*Dioscorea alata*), commonly found in tropical regions, features a vibrant purple to red flesh and is classified under the species *Dioscorea alata* L. [7]. Within yam tubers, you can find diverse functional components, including mucin, dioscin, dioscorin, allantoin, choline, polyphenols, polyphenolases, vitamins and essential amino acids [8]. Notably, purple yams are rich in phenolic compounds, particularly anthocyanins, known for their antioxidant, anticancer apoptosis-inducing, anti-diabetes, anti-obesity, and DNA damage prevention activities properties [9].

The formulation and development of complementary foods using locally available raw materials have garnered significant attention. The current research project is focused on creating an instant soup mixture using ingredients like artichoke powder, sweet potato powder, and other components.

Considering above facts, the objective of my research is to produce instant soup mixtures with Artichoke powder, Sweet potato powder and other ingredients.

A. Instant Soup

Soup is a tasty and nutritious liquid food typically enjoyed at the start of a meal or as a snack [10]. It's made by blending vegetables with stock and various thickeners [11]. Soups come in two main categories: thick soups and clear soups [12]. Dry soup mixes, in particular, offer protection against enzymatic and oxidative spoilage and maintain flavor stability when stored at room temperature for an extended duration. They don't necessitate the use of preservatives or refrigeration for preservation. Additionally, they boast high nutritive value due to their richness in fiber and vitamin C [13].

B. Artichoke yam (*Calathea allouia*):

a. Artichoke or Leren (*Calathea allouia*) is an indigenous tuberous crop in the Caribbean and South America. Extended from the stem rhizomes by single strands of root are clusters of tubers [14]. Tubers are cylindrical in shape, measuring 5–18 cm length and 2–4 cm diameter [15]. The *Calathea allouia* has high fat, proteins, amylose content, carbohydrates and calories (Kinupp & Lorenzi, 2014). It finds application in diverse medications including adhesives, binders, and film-formers, serving as gelling agents, thickeners, retardant retainers, and retarders of retrogradation in certain food products [16].

C. Sweet potato (*Ipomoea batatas* (L) Lam):

Sweet potato (*Ipomoea batatas* (L.) Lam.), is a long-term species in a warm and hot climate zone and an annual plant in temperate zone. [17]. The edible tuberous root is either long and tapered, ovoid or round. And its skin colour is ranging from white, brown, purple or red and the flesh colour ranging from white, pale cream, orange or purple [10]. The sweet potato is rich in various nutrients such as protein, carbohydrates, minerals (calcium, iron, and potassium), carotenoids, dietary fiber, vitamins (especially C, folate, and B6), minimal fat, and sodium. [10]. In certain nations, a variety of sweet potato is consumed in its raw form as a remedy for anemia, hypertension, and diabetes. [18].

D. Purple Yams (*Dioscorea alata* L.):

b. It usually produce one to three tubers, which may be of any shape i.e. globular, cylindrical, elongated, branched or lobed [19]. The presence of carbohydrates, proteins, fats, vitamins and minerals increases the nutritional acceptability of purple yam [20]. Polyphenolic compounds, including anthocyanins and phenolic acids, are the primary functional constituents of purple yam. [21]. The yam extracts exhibit a range of bioactivities and health advantages, including antioxidant capacity, immunomodulatory activity, antihypertensive activity, antimicrobial activity, estrogenic effect, and antitumor effect. [22]. Many value-added products like spreads, jams, chips, dehydrated slices, flour, pickles, etc. can be made from using it [19].

A. Preparation of sample

Preparation of the Artichoke Flour and Sweet Potato Flour:

Both Artichoke and sweet potato tubers were cleaned with filtered tap water and peeled using sharp stainless steel knives. Tubers were cut into 2 mm thick slices. Slices were blanched by 90°C hot water for 6 minutes and dehydrated in a tray drier at 60°C for 4hr. Dried slices were ground by electrical grinder. A 60mm-mesh sieve was used to sieve the flour [23].

Preparation of the Purple Yam Flour

Purple yam tuber was washed with filtered tap water and peeled using sharp stainless steel knives. The peeled Purple yam tubers were cleaned in filter tap water and sliced into 2 mm thick slices with a stainless-steel knife. Raw purple yam was blanched by 100°C hot water for 5 minutes. Slices of Purple yam were dehydrated in a tray drier at 65°C for 4hr. Then dried tubers ground by electrical grinder. A 60mm-mesh sieve was used to sieve the flour [24].

i. Preparation of Soup Mix

ii. The Artichoke and Sweet potato based instant soup formulation was made by mixing different ingredients: Artichoke flour, Sweet potato flour, Purple yam flour, Oyster mushroom flour, pepper, citric acid and salt. The ingredients were carefully and accurately weighted. All ingredients were mixed and stored in LDPE bag for further use.

TABLE 1: FORMULATION OF THE ARTICHOKE AND SWEET POTATO BASED INSTANT SOUP SAMPLES

Ingredients, g	IS001 (%)	IS002 (%)	IS003 (%)	IS004 (%)
Artichoke flour	20	30	20	30
Sweet potato flour	22	22	35	35
Purple yam flour	21	21	21	21
Oyster mushroom	11	11	11	11
Pepper	2	2	2	2
Citric acid	1	1	1	1

B. Sensory Analysis

Sensory evaluation was conducted for four Instant soup samples (i.e., IS001, IS002, IS003, IS004) prepared by three different composite formulas with 30 semi trained panellists as described by Amerine et al on 5-point hedonic scale (Curi et al., 2019).

C. Proximate Analysis

Proximate composition (moisture%, fat%, protein%, ash%, total sugar% and pH value) of selected Instant soup sample was determined according to the AOAC methods.

D. Shelf life of the Composite Flour

The shelf life of the selected best Instant soup sample was evaluated for moisture content, Total colony count, Coliform, yeast and mould.

IV. RESULT AND DISCUSSION

A. Result of Sensory Evaluation

The IS002 sample was selected as the best one with respect to all attributes of the sensory analysis (Figure 1).

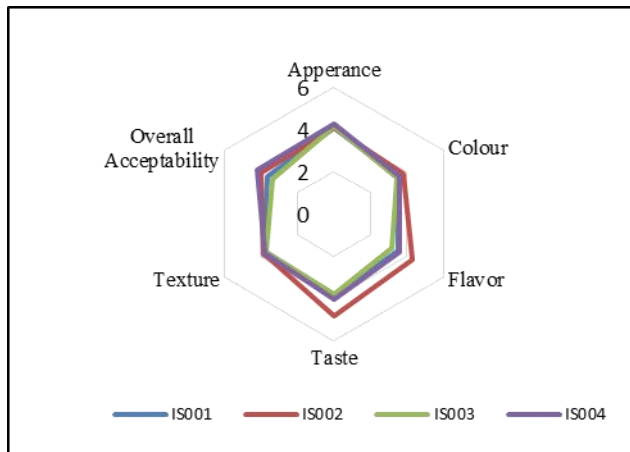


Figure 1: web diagram of sensory evaluation of Instant soup sample

General comments by the panellists regarding sensory attributes were also evaluated. The result indicated that the sample number IS002 had the highest mean value which contained 30g of Artichoke flour and 22g of Sweet potato flour for appearance, colour, flavour, taste, texture, and overall acceptability. Compared other sensory attribute there is no significant statistical difference of texture and taste has most significant statistical difference.

For further the validation of the outcome of sensory evaluation of Instant soup sample with control sample were drawn using web diagram shown in figure 2.

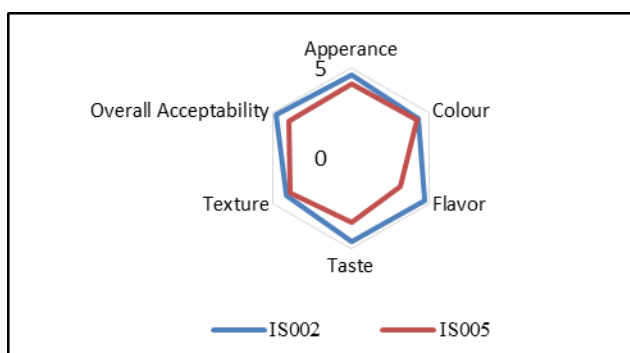


Figure 2: web diagram of comparison of sensory properties with Instant soup sample and control sample

Second part of sensory evaluation was carried out for evaluation of sensory characteristics of selected sample IS002 which had highest mean values for flavour, taste and overall acceptability to compare with the control sample (Control sample was made with purple yam 21%, mushroom powder 11% pepper 2% and citric acid 1%). There is no significant statistical difference for appearance

and colour between sample number IS002 and control sample. But there is a significant statistical difference for Taste and flavour and overall acceptability between two samples. The sample number IS002 which prepared using 30g Artichoke flour and 22g Sweet potato had the highest mean values for taste and flavour and overall acceptability when compared with control sample.

B. Result of Proximate Analysis

The proximate analysis (Table 2) revealed that IS002 contained higher moisture (4.76 ± 0.01 g/100g dry basis), crude protein (12.7 ± 0.15 g/100g dry basis), crude fat (2.4 ± 0.01 g/100g dry basis), total sugar (6.08 ± 0.02 g/100g dry basis), total ash (1.54 ± 0.01 g/100g dry basis), and lower pH value (5.94 ± 0.02) than the control sample.

TABLE 2: THE PROXIMATE COMPOSITION OF THE INSTANT SOUP SAMPLE

Proximate value	Amount(g/100g dry basis)		
	IS002 sample	Control sample	P value
Moisture	4.76 ± 0.01	4.23 ± 0.02	0.000
Crude Protein	12.7 ± 0.15	6.84 ± 0.15	0.003
Crude Fat	2.4 ± 0.01	1.29 ± 0.02	0.000
Total Sugar	6.08 ± 0.02	2.97 ± 0.01	0.000
Total Ash	1.54 ± 0.01	0.98 ± 0.01	0.000
pH Value	5.94 ± 0.02	6.52 ± 0.01	0.000

C. Result of Microbial Analysis

Microbial analysis demonstrated negative results for Coliform and yeast and mold in both instant soup mix samples at a 10—1 dilution. The total plate count was 2.9×10^3 cfu/g, well below the acceptable limit (5×10^4 cfu/g) (SLSISDs), ensuring the safety of the developed instant soup.

D. Shelf life Study

The shelf life study indicated no significant difference in moisture content over two months of storage at room temperature ($28 \pm 2^\circ\text{C}$) in high-density polyethylene packaging.

V. CONCLUSION

Based on the organoleptic evaluation, IS002, containing 30g of Artichoke flour and 22g of Sweet potato, showed the highest consumer acceptance. Sensory analysis confirmed the superiority of Artichoke and Sweet Potato Based Instant Cream Soup over the control sample in terms of taste, flavor, and overall acceptability. Its nutritional profile, characterized by higher protein, fat, sugar, and ash content, along with a lower pH value, further enhances its appeal. Consequently, Artichoke and Sweet Potato Based Instant Cream Soup can be considered a favorable option due to its high consumer acceptability.

VI. RECOMMENDATIONS

Recommendations and future research should focus on several key aspects to enhance Artichoke and Sweet Potato Based Instant Cream Soup. Firstly, conducting market acceptability studies through consumer surveys and taste tests will provide valuable insights into preferences and potential demand, facilitating effective marketing strategies. Secondly, a comprehensive cost analysis is essential to determine economic feasibility and potential profitability, considering ingredient costs, production expenses, and pricing strategies. Thirdly, nutritional studies should be undertaken to highlight the soup's health benefits, appealing to health-conscious consumers. Additionally, exploring shelf-life extension techniques, eco-friendly packaging options, process optimization, and health impact evaluations will further improve the soup's market position and desirability.

REFERENCES

- [1] N. Joshi, K. Bains, and H. Kaur, "Evaluation of Antioxidant Activity of Developed Instant Soup Mixes using VegetaJoshi, N., Bains, K., & Kaur, H. (2020). Evaluation of Antioxidant Activity of Developed Instant Soup Mixes using Vegetable Leaf Powders from Unconventional Greens. Internation," *Int. J. Curr. Microbiol. Appl. Sci.*, vol. 9, no. 1, pp. 711–721, 2020, doi: 10.20546/ijcmas.2020.901.077.
- [2] R. C. Kokani, S. Mokashi, and Y. Pandurang Shelar, "Studies on Development and Standardization of Moringa Leaves Instant Soup Mix Powder Incorporated With Garden Cress Seeds," *Int. J. Res. Rev. Vol.*, vol. 6, no. 10, pp. 242–246, 2019, [Online]. Available: www.ijrrjournal.com
- [3] A. P. M. G. Carvalho *et al.*, "Dielectric barrier atmospheric cold plasma applied to the modification of Ariá (*Goeppertia allouia*) starch: Effect of plasma generation voltage," *Int. J. Biol. Macromol.*, vol. 182, pp. 1618–1627, 2021, doi: 10.1016/j.ijbiomac.2021.05.165.
- [4] S. S. Ranaweera KKDS, "Formulation of Vegetable Soup Mixture Using Physically Modified Sweet Potato Starch as a Thickener," *J. Food Process. Technol.*, vol. 05, no. 04, pp. 1–5, 2014, doi: 10.4172/2157-7110.1000313.
- [5] S. Wang, S. Nie, and F. Zhu, "Chemical constituents and health effects of sweet potato," *Food Res. Int.*, vol. 89, pp. 90–116, 2016, doi: 10.1016/j.foodres.2016.08.032.
- [6] C. Moriya *et al.*, "New acylated anthocyanins from purple yam and their antioxidant activity," *Biosci. Biotechnol. Biochem.*, vol. 79, no. 9, pp. 1484–1492, 2015, doi: 10.1080/09168451.2015.1027652.
- [7] Z. Fang, D. Wu, D. Yü, X. Ye, D. Liu, and J. Chen, "Phenolic compounds in Chinese purple yam and changes during vacuum frying," *Food Chem.*, vol. 128, no. 4, pp. 943–948, 2011, doi: 10.1016/j.foodchem.2011.03.123.
- [8] X. Liu, K. Lu, J. Yu, L. Copeland, S. Wang, and S. Wang, "Effect of purple yam flour substitution for wheat flour on in vitro starch digestibility of wheat bread," *Food Chem.*, vol. 284, pp. 118–124, 2019, doi: 10.1016/j.foodchem.2019.01.025.
- [9] S. Ochoa, M. M. Durango-Zuleta, and J. Felipe Osorio-Tobón, "Techno-economic evaluation of the extraction of anthocyanins from purple yam (*Dioscorea alata*) using ultrasound-assisted extraction and conventional extraction processes," *Food Bioprod. Process.*, vol. 122, pp. 111–123, 2020, doi: 10.1016/j.fbp.2020.04.007.
- [10] J. Fernández-López *et al.*, "Vegetable soups and creams: Raw materials, processing, health benefits, and innovation trends," *Plants*, vol. 9, no. 12, pp. 1–33, 2020, doi: 10.3390/plants9121769.
- [11] R. M. Lolge *et al.*, "The Pharma Innovation Journal 2022; 11(12): 676-681 Technology development for preparation of Instant soup mix powder from yam, drumstick leaves and roselle calyces," vol. 11, no. 12, pp. 676–681, 2022, [Online]. Available: www.thepharmajournal.com
- [12] M. Islam *et al.*, "Development and Quality Analysis of Protein Enriched Instant Soup Mix," *Food Nutr. Sci.*, vol. 09, no. 06, pp. 663–675, 2018, doi: 10.4236/fns.2018.96050.
- [13] S. M. Sudarsan, G. Santhanam, and V. Visalachi, "Development and formulation of instant soup mix from sprouted horse gram and radish leaves," ~ 346 ~ *Int. J. Home Sci.*, vol. 3, no. 1, pp. 346–349, 2017, [Online]. Available: www.homesciencejournal.com
- [14] C. L. Yost, "The *Calathea allouia* (Marantaceae) and Commelinaceae conundrum: the search for diagnostic phytoliths," vol. 60, no. September 2011, pp. 300–310, 2018.
- [15] M. de J. C. Varejão, M. N. de S. Ribeiro, and C. R. Bueno, "Composição mineral do ariá (*Calathea allouia* (Aubl.) Lindl," *Acta Amaz.*, vol. 18, no. suppl 1-2, pp. 477–480, 1988, doi: 10.1590/1809-43921988185480.
- [16] MIFTAHUL RESKI PUTRA NASJUM, "No 主観的健康感を中心とした在宅高齢者における健康関連指標に関する共分散構造分析Title," *Kaos GL Derg.*, vol. 8, no. 75, pp. 147–154, 2020, [Online]. Available: <https://doi.org/10.1016/j.jnc.2020.125798%0Ahttps://doi.org/10.1016/j.smr.2020.02.002%0Ahttp://www.ncbi.nlm.nih.gov/pubmed/810049%0Ahttp://doi.wiley.com/10.1002/anie.197505391%0Ahttp://www.sciencedirect.com/science/article/pii/B9780857090409500205%0Ahttp://www.innspub.net>
- [17] B. Sawicka, J. Shupski, B. Krochmal-Marczak, J. Supski, T. Cebulak, and K. Paradowska, "Nutrition value of the sweet potato (*Ipomoea batatas* (L.) Lam) cultivated in south-eastern Polish conditions The nutritional value of the potato View project Wellness View project Nutrition value of the sweet potato (*Ipomoea batatas* (L.) Lam) cultivated i," *Int. J. Agron. Agric. Res.*, vol. 4, no. 4, pp. 169–178, 2014, [Online]. Available: <http://www.innspub.net>
- [18] R. Mohanraj and S. Sivasankar, "Sweet potato (*Ipomoea batatas* [L.] Lam) - A valuable medicinal food: A review," *J. Med. Food*, vol. 17, no. 7, pp. 733–741, 2014, doi: 10.1089/jmf.2013.2818.
- [19] P. Singh, "Bioactive components, food applications and health benefits of yam (*Dioscorea* spp.): A review Pranav Singh and Twinkle," ~ 2092 ~ *Pharma Innov. J.*, vol. 11, no. 6, pp. 2092–2102, 2022, [Online]. Available: www.thepharmajournal.com
- [20] P. H. Li, C. C. Huang, M. Y. Yang, and C. C. R. Wang, "Textural and sensory properties of salted noodles containing purple yam flour," *Food Res. Int.*, vol. 47, no. 2, pp. 223–228, 2012, doi: 10.1016/j.foodres.2011.06.035.
- [21] J. Zhang *et al.*, "A novel method: ionic liquid-based ultrasound-assisted extraction of polyphenols from Chinese purple yam," *Nat. Prod. Res.*, vol. 32, no. 7, pp. 863–866, 2018, doi: 10.1080/14786419.2017.1361955.
- [22] S. Srivichai and P. Hongsprabhas, "Profiling Anthocyanins in Thai Purple Yams (*Dioscorea alata* L.)," *Int. J. Food Sci.*, vol. 2020, 2020, doi: 10.1155/2020/1594291.
- [23] F. Haile, S. Admassu, and A. Fisseha, "Effects of pre-treatments and drying methods on chemical composition, microbial and sensory qualities of orange-fleshed sweet potato flour and porridge," *Am. J. Food Sci. Technol.*, vol. 3, no. 3, pp. 82–88, 2015, doi: 10.12691/ajfst-3-3-5.
- [24] U. D.E., O. G.C., M. B.C., O. S.O, I. V.S., and O. U.B., "Effect of cocoyam and water yam flour blends on the chemical and mineral composition of dry soup mix," *Int. J. Res. Sci. Innov.*, vol. 09, no. 07, pp. 54–65, 2022, doi: 10.51244/ijrsi.2022.9705.

Microbiology Quality Evaluation of Selected Cow Milk Products Collected from Small Scale Farmers in the Ratmalana Area, Sri Lanka

M.G.N.C.B Meegahakotuwa
Department of Agricultural and Food Technology
University of Vocational Technology
Rathmalana, Sri Lanka
chathurnb@gmail.com

Sagara Kamal Edirisinghe
Department of Agricultural and Food Technology
University of Vocational Technology
Rathmalana, Sri Lanka
sagarak@uovt.ac.lk

Abstract— In the Sri Lankan context, the production of milk and dairy products is hampered using poor milking and processing processes, which results in microbial spoiling of milk, particularly in small-scale processing plants. The aim of this survey was to identify potential hazards and evaluate the microbial contamination of milk and dairy products in a small-scale dairy processing unit located in Ratmalana Area, Sri Lanka. A total of eight samples were analyzed, including ice cream, yoghurt, and curd samples from various processing units from small-scale processing plants in Ratmalana area Sri Lanka. Total plate count (TPC) and Total Coliform Count (TCC) were determined for the samples. Also, for yeast and mold. For milk product samples, the range of and TPC & coliform was 6.9×10^5 to 1×10^5 cfu/ml and 16×10^6 to 6.9×10^5 cfu/ml respectively. Preventive and corrective measures for milking and processing phases (thermal treatment, packaging, and storage) were defined based on microbiological outcomes and milk production flow characterization, with a focus on training of farmers and dairy employees to improve the hygiene of the local milk and dairy production chain.

Keywords—microbiological quality, milk products, microbial contamination, food safety, food inspection

I. INTRODUCTION

It is critical to ensure the microbiological purity of milk products in order to ensure their safety for consumption. Microbial contamination can result in product spoiling, pathogenic illnesses, and deterioration. This review of the literature highlights critical considerations for evaluating the microbiological quality of milk products. To maintain microbiological safety in milk products, strict hygiene standards must be followed throughout the production and processing chain. Reference [1] found that applying Good Manufacturing Practices (GMP) and Hazard Analysis and Critical Control Points (HACCP) systems is critical for preventing microbiological contamination and ensuring product safety [1].

Milk and dairy products are important components of Sri Lankan cuisine culture and nutrition. It is critical to

ensure the microbiological quality of these items in order to protect public health and retain consumer trust. The following overview of the literature addresses major research findings concerning the microbiological quality of milk products in Sri Lanka. In Sri Lanka, microbial contamination of milk products has prompted worries regarding foodborne illnesses. Reference [2] found dangerous microbes such as Salmonella and Escherichia coli in locally produced milk and dairy products, underlining the importance of severe quality control procedures [2]. Reference [3] found that sanitary measures during milk production, processing, and distribution are critical for preserving the microbiological quality of dairy products. The study emphasizes the importance of education and awareness among stakeholders in order to improve the overall quality of milk products [3]. In Sri Lanka, the impact of various processing processes on the microbiological quality of milk products has been investigated. Reference [4] explores the efficacy of heat treatment strategies in lowering microbial load and improving dairy product safety [4]. In Sri Lanka, efforts to improve the microbiological quality of milk products include the adoption of microbial testing and quality control procedures. Reference [5] conducted research on the influence of such activities on the decrease of microbiological contamination in dairy products [5].

No prior studies have been conducted focusing on the products of small-scale dairy manufacturers in the Ratmalana area. Therefore, this research centers on the microbiological assessment of dairy products manufactured and distributed within the Ratmalana area and its neighbouring areas. All samples were collected directly from the factory level to accurately gauge the microbiological quality of the products. This approach was adopted to eliminate potential research discrepancies arising from transportation and storage conditions prevalent in the market.

Total of 8 samples were analyzed in the microbiology laboratory at the University of Vocational Technology

Ratmalana and compared with SLS 516 quality standards for microbiological quality of the milk products.

II. METHODOLOGY

a. Collection of samples

Milk product samples were collected from the four listed factories using sterile aseptic containers and ice for preservation. These samples were then transported to the laboratory in separate ice crates to maintain isolation. In total, eight samples were analyzed.

1. C### ice cream
2. R### yoghurt
3. W### ice cream
4. N### curd

b. Total Coliform count

Total coliform count was measured by plate count agar medium. The sample (0.1ml) of each dilution was taken onto each sterile Petridis and poured plate count agar medium. The plates were then incubated at 37°C for 24 hours. Total bacterial count was measured in colony forming unit per gram (cfu/ml). The Coliform count was done using MacConkey agar medium. Typical pink colonies were counted for determination of Total Coliform after incubation of plates at 37°C for 24 hours.

c. Total Aerobic Plate count

Total plate Count was measured by plate count agar medium. The sample (0.1ml) of each dilution was taken onto each sterile Petridis and poured plate count agar medium. The plates were then incubated at 37°C for 48 hours. Total bacterial count was measured in colony forming unit per gram (cfu/ml).

d. Yeast and Molds

PDA (Potato Dextrose Agar) was used as the growth medium, with 0.1% peptone water serving as the diluent. Each sterile Petri dish received a 0.1ml sample from various dilutions, which was subsequently poured onto PDA agar medium. The plates were incubated at 25°C for 72 hours to determine the yeast and mold count in colony forming units per gram (cfu/ml).

III. RESULTS AND DISCUSSION

a. Total Coliform Count

Three milk products successfully passed the coliform test, namely C#### ice cream, R### yoghurt, and N### curd, while W### ice cream did not meet the criteria. As per SLS 516 regulations, 75% of the tested items are expected to pass the coliform test. The permissible coliform limit stands at 1×10^2 cfu/g.

RESULTS OF TCC

HYGIENIC MICRO-ORGANISM	COLIFORM		
sample dilution	10	1000	10000
product Name			
C### ice cream			
(sample 01)	0	0	0
(sample 02)	0	0	0
Standard Deviation	0	0	0
R### yoghurt			
(sample 01)	0	0	0
(sample 02)	0	0	0
Standard Deviation	0	0	0
W### ice cream			
(sample 01)	uncountable	690000.00	18000000
(sample 02)		740000	16000000
Standard Deviation		392020	9338094
N### curd			
(sample 01)	0	0	0
(sample 02)	0	0	0
Standard Deviation	0	0	0

b. Total Plate Count

The total number of products allowed under SLS 516 (total plate count TPC) was one. R### yoghurt accounted for only 25% of the evaluated items. The permitted maximum for ice cream, according to SLS 516, is 2×10^5 cfu/ml.

RESULTS OF TPC

HYGIENIC MICRO-ORGANISM	TOTAL PLATE COUNT		
sample dilution	10	1000	10000
product Name			
C### ice cream			
(sample 01)	uncountable	650000	1600000
(sample 02)	uncountable	690000	900000
Standard Deviation		28284	494974
R### yoghurt			
(sample 01)	0	0	0
(sample 02)	0	0	0
Standard Deviation	0	0	0
W### ice cream			
(sample 01)	uncountable	6000000	900000
(sample 02)	uncountable	7100000	700000
Standard Deviation		3608600	443846
N### curd			
(sample 01)	131000000	9000000	100000
(sample 02)	1220000000	3000000	0
Standard Deviation	770039284	4242640	70710

c. Yeast and Mold Count

The allowable limits for yoghurt SLS 516 are 2×10^5 cfu/g. It is 1×10^2 cfu/g for curd. It should be 0 for ice cream. All products tested for yeast and mold were rejected according to SLS 516 restrictions. 100% genuine items

RESULTS OF YEAST AND MOLD

HYGIENIC MICRO-ORGANISM	YEAST AND MOLD			
sample dilution	10	1000	10000	100000
product Name				
C### ice cream				
(sample 01)	uncountable	21000000	200000	0
(sample 02)	uncountable	16000000	100000	0
Standard Deviation		3535534	70711	0
R### yoghurt				
(sample 01)	1000000	200000	900000	0
(sample 02)	1000000	100000	0	0
Standard Deviation	0	70711	636396	0
W### ice cream				
(sample 01)	115000000	21000000	100000	0
(sample 02)	0	18000000	200000	300000
Standard Deviation	81317280	10665885	384230	134164
N### curd				
(sample 01)	114000000	8000000	300000	100000
(sample 02)	105000000	7500000	300000	120000
Standard Deviation	6363961	353553	0	14142

d. Results Summary

The table indicates whether the products met SLS 516 quality standards in the three hygienic micro-organisms tests.

RESULTS SUMMARY

PRODUCT NAME	COLIFORM TEST	TOTAL PLAT COUNT	YEAST & MOLDS
C### Ice Cream	Accepted	Rejected	Rejected
R### Yoghurt	Accepted	Accepted	Rejected
W### Ice Cream	Rejected	Rejected	Rejected
N### Curd	Accepted	Rejected	Rejected

IV. CONCLUSION AND RECOMMENDATION

The total coliform count was used to assess the microbial quality of selected dairy products from Ratmalana area, Sri Lanka. The presence of coliforms in general and E. coli in particular implies fecal contamination. The presence of nonfecal coliforms also suggests the presence of additional harmful bacteria. The health of the dairy herd, milking, and pre-storage conditions as well as transport conditions to the factory all have an impact on milk quality. The presence of coliform in processed food indicates unsanitary conditions throughout the manufacturing and post-manufacturing stages.

According to the findings of this study, the microbiological quality of most milk product samples obtained from Ratmalana areas was not sufficient, as evidenced by their high bacterial loads. As a result, milk products must be handled with prudence. More research is required to set standards for small-scale milk product producers.

In accordance with the outcomes of this investigation, an educational training program was conducted with the objective of enhancing awareness regarding microbiological food safety in dairy production. The program specifically targeted factory personnel and production supervisors within the chosen four factories situated in the Ratmalana region.

Ensuring the adherence to Good Agricultural Practices (GAP) at the farm level and maintaining rigorous Good Manufacturing Practices (GMP) at the factory level are pivotal in ensuring the safety of the food supply chain from farm to table. Thus, conducting comprehensive training and educational programs for small-scale dairy product manufacturers, coupled with continuous product sample analysis and factory inspections, plays a critical role in identifying and rectifying unsanitary production procedures.

To ensure the safety of milk products, it is advised that all milk product samples be tested in a qualified laboratory and that reports be submitted with the trade license application

for annual renewal in the Dehivala-Mount Lavinia municipal council region.

REFERENCES

- [1] Doyle, M. P., 2015. Microbiological hazards of dairy products.. In: Dairy Microbiology Handbook . s.l.:John Wiley & Sons., pp. 187-198
- [2] Silva, .A. D. N. S., Thilakarathne , B. M. J. K. & Kumari, M., 2019. "Microbiological quality of raw milk used for production of dairy products in the Kurunegala district of Sri Lanka." Sri Lanka Journal of Food and Agriculture, 5(2), pp. 61-68.
- [3] Wickramasinghe, I. Rajapaksha, R. & Kothalawala, S. M., 2017. "Microbial quality and safety of selected dairy products sold in Sri Lankan market.", Journal of the National Science Foundation of Sri Lanka, 45(4), pp. 365-373. (references)
- [4] Fernando, S. A. V. Kumari, M. & Manthi, W., 2018. "Assessment of the microbial quality of milk and dairy products processed using different methods in Sri Lanka". , Journal of Food Safety, 38(5).
- [5] Hettiarachchi, D. Nandasena, Y. L. & Tissera, G., 2015. "Impact of a microbial testing and quality control programme on the microbiological quality of milk in Sri Lanka". , Food Control, Volume 50, pp. 781-785.
- [6] Anon., n.d. Department of Agriculture. [Online] Available at: <https://www.doa.gov.lk/FCRDC/index.php/en/2015-09-22-05-59-43/62-pineapple-e>
- [7] Barbano, D. M., Rasmussen, R. R. & Lynch, J. M., 1991. "Influence of milk somatic cell count and milk age on cheese yield.", Journal of Dairy Science, 74(2), p. 369–388.
- [8] Bayemi, et al., 2005. "Participatory rural appraisal of dairy farms in the North West Province of Cameroon." Livestock Research for Rural Development.
- [9] Chandan, R. C., Kilara, A. & Shan, N. P., 2008. Dairy Processing and Quality Assurance,. Ames, IA, USA: Wiley-Blackwell.
- [10] European Food Safety Authority, 2015. The European Union summary report on trends and sources of zoonoses, zoonotic agents and food-borne outbreaks in 2013., s.l.: s.n.
- [11] Jamali, H. et al., 2015. "Prevalence and antimicrobial resistance of Listeria, Salmonella, and Yersinia species isolates in ducks and geese.", 94(8), pp. 1697-1703..
- [12] Micha, R., 2014. Milk consumption and risk of mortality and fractures in women and men: cohort studies. BMJ.
- [13] Mocanu, D. G., Andronoiu, D., botez, e. & Nistor, . O. V., 2011. "Quality control of raw cow milk from Galati county", Journal of Agroalimentary Processes and Technologies, 17(03), p. 303–307.
- [14] Oliver , S. P., Murinda, S. E. & Jayarao, B. M., 2015. "Impact of antibiotic use in adult dairy cows on antimicrobial resistance of veterinary and human pathogens: a comprehensive review.", Foodborne Pathogens and Disease, 12(5), pp. 365-372.
- [15] Shashidhar, S. & Malleshi, N. G., 2014. Finger millet polyphenols: characterization and their nutraceutical potential.", American Journal of Food Technology , 9(4), pp. 181-191.
- [16] Tamime, A. Y. & Robinson, R. K., 2007. Yogurt science and technology. s.l.:Woodhead Publishing.
- [17] Vithanage, N. R., Bhagya, D. M. & Welgama, C., 2020. ,"Application of modern molecular techniques in monitoring microbiological quality of dairy products. In: Modern Techniques in Dairy Processing and Milk Products ", s.l.:Academic Press., pp. 145-164.
- [18] Wells, J. G., Shipman, L. D. & Greene, K. D., 1991. "Isolation of Escherichia coli serotype O157: H7 and other Shiga-like-toxin-producing E. coli from dairy cattle.", Journal of Clinical Microbiology, 29(5), p. 985–989.

Investigation of The Medicinal Plant, *Aporosa Lindleyana* (Wight) Baill. For Their Biochemical Composition and Proximate Analysis

S.S.I. Jayarathne
Quality control department
Sands Active Pvt Ltd
Ekala, Sri Lanka
jayarathnewns@gmail.com

E.M.C.K. Ekanayake
Division of Science and Technology
University College of Ratmalana, University of Vocational
Technology
Ratmalana, Sri Lanka
ekanayakeemcke@gmail.com

Abstract— *Aporosa lindleyana* (Wight) Baill. (Sri Lankan name: Kebella) is a widely used herbal plant in the treatment of Diabetes in Ayurveda, Traditional and Alternative Medicine in Sri Lanka. Globally, very few studies are available on the *Aporosa lindleyana*. Therefore, the present study was carried out to investigate the medicinal plant *Aporosa lindleyana* (Wight) Baill extract with other biochemical compositions and proximate analysis. Steam and Simple distillations were carried out to isolate the Volatile oil from fresh plant leaves and isolated oil samples were analyzed using GC-MS. Maceration using methanol followed by phytochemical screening was done for air-dried samples. Alkaloids, Glycosides, Saponins, Phytosterols, Triterpenes, Diterpenes, and Flavones were present in *A. lindleyana* extract. Thin-layer Chromatography was carried out to separate the both macerated aqueous and methanolic extracts. The proximate analyses (moisture, ash, crude fats, proteins) of the samples were determined. *A. lindleyana* showed moisture = 2.30%, ash = 13.22% and crude fat = 2.85%. Results of the present study revealed that *A. lindleyana* is rich in secondary metabolites. As this study planned to investigate the Biochemical composition and antioxidant activity of *A. lindleyana* extracts, this will support the investigation of the medicinal values of *A. lindleyana* and it will help the community to select better solutions for their diabetic matter.

Keywords— Diabetes, Kebella, Herbal Plant, Biochemical

I. INTRODUCTION

Sri Lanka is rich with a vast diversity of medicinal plants which include several endemic species with a wide array of pharmacological and other health-beneficial interests. Currently, Non-communicable diseases (NCDs) such as Diabetes Mellitus are highly prevalent among society in every part of the world. The high content of diverse specific secondary metabolites, phenolic, and flavonoids in medicinal plants have been associated with their antioxidant activities that play a role in the prevention of the development of NCDs and age-related diseases, particularly caused by oxidative stress.

Diabetes is a defect associated with the difficulty in the body to convert glucose (sugar) to energy. In Sri Lanka, many herbal preparations are widely used in the treatment of Diabetes and it has a rich history of using different herbs for the treatment of Diabetes and NCDs.

Aporosa lindleyana (Wight) Baill is a tree that is used for several diseases. In traditional medicine, ayurveda and alternative medicine are used as herbal medicine.

Taxonomy

Kingdom: Plantae

Phylum: Tracheophyta

Class : Equisetopsida C. Agardh

Order : Malpighiales Juss. ex Bercht. & J. Presl

Family: Phyllanthaceae

Genus: *Aporosa*

Species : *Aporosa cardiosperma* (Gaertn.) Merr. /
Aporosa lindleyana



Figure 01: *Aporosa lindleyana* (Wight) Baill.

II. MATERIALS AND METHODS

Live steam distillation was carried out to isolate the volatile oil from fresh plant leaves and separation was done with fresh diethyl ether. Then simple distillation was carried out to evaporate the excess diethyl ether and oil samples were isolated and analyzed. Maceration using methanol was done for 4 days and a rotary evaporator (HS 2005-S-) was used to evaporate the excess solvent, followed by phytochemical screening for air-dried samples. Tests for

alkaloids, Glycosides, Saponins, Phytosterols, Diterpenes, and Flavonoids were Carried out.

Phytochemical Screening of methanolic crude extract was conducted as follows. Screening of alkaloids,

About 200 mg of methanolic crude extract was mixed with 5 mL of 2N HCl solution. The solution was heated in a steam bath for 5 minutes. It was allowed to cool to room temperature and the solution was filtered using a filter paper (Whatmann No.1). The filtrate was subjected to the following tests.

Mayer's test

A few drops of Mayer's reagent were added into 1 mL of the filtrate and observed for the turbidity.

Wagner's test

A few drops of Wagner's reagent were added into 1 mL of the filtrate and observed for the precipitate.

Dragendroff's test

A few drops of Dragendroff's reagent were added into 1 mL of the filtrate and observed for the turbidity.

Screening for Saponins

A fourth test was carried out.

About 200 mg of methanolic crude extract was shaken with 2 mL of distilled water. If persistent froth forms for more than 3 minutes test was considered as positive.

Screening of tannins and phenols

About 100 mg of methanolic crude extract was shaken with 2 mL of 5 % FeCl₃ solution. If blue-green or green-black coloration indicates the presence of tannins and phenols.

Screening for flavonoids

About 100 mg of methanolic crude extract was defatted with petroleum ether. It was dissolved in 2 mL of 95% ethanol. A few pieces of Mg turnings were added into the test tube and a few drops of conc.HCl was added. The color of the solution was determined.

Orange-red	Flavones
Red crimson	Flavonols
Crimson-magenta	Flavanones

Screening for Glycosides

Kellar-Killiani test

About 100 mg of methanolic crude extract was dissolved in 2 mL of glacial acetic acid and 6 drops of 5% FeCl₃ solution were added. The mixture was poured slowly along the wall of the test tube containing 2 mL of conc.H₂SO₄. The formation of a brown ring at the interface was observed.

Screening for diterpenes

About 200 mg of methanolic crude extract was dissolved in distilled water. A few drops of Cu (CH₃COO)₂ solution was added. The formation of an emerald green color indicates the presence of diterpenes.

Screening of phytosterols and triterpenes

About 200 mg of methanolic crude extract was shaken with 5 mL of pet ether and pet ether solution was discarded. 10 mL of chloroform was added and shaken. The following tests were carried out for the chloroform layer.

Libermann-Burchardt test

About 2 mL of chloroform extract was obtained into a test tube. 0.25 mL of acetic anhydride followed by a few drops of conc.H₂SO₄ was added. The appearance of the green color solution is considered positive for the test.

Salkowski test

About 2 mL of chloroform layer was obtained into a test tube. Few drops of conc. H₂SO₄ was added to it. The appearance of the yellow color solution is considered positive for the test.

To separate the samples, Thin layer chromatography was done for both aqueous and methanolic extracts using the Hexane: Ethyl acetate solvent system and spots were visualized by using a UV lamp. The parameters determined for proximate analyses include ash, moisture, crude protein, and fat, All of these were carried out using the methods described by (AOAC, 2010).

Moisture content was determined gravimetrically by drying the samples in an oven at 100 °C to a constant weight. Crude protein content (N × 6.25) was determined by the Kjeldahl method (Method No. 978.04) (AOAC 2010). Crude fat was determined by the Soxhlet extract method using petroleum ether as the extracting agent (60–80 °C) (Method No. 930.09) (AOAC 2010). Ash content was assayed by incinerating the samples in a muffle furnace at 550 °C (Method No. 930.05) (AOAC 2010).

III. RESULTS AND DISCUSSION

Phytochemical Studies

Phytochemical Studies of the plant extract confirmed the presence of a large array of plant constituents such as alkaloids, saponins, flavonoids, glycosides, steroids, tannins, and terpenoids, all of which may be potential sources of phyto-anti-inflammatory agents.

TABLE 1: RESULTS OF PHYTOCHEMICAL STUDIES

Phytochemical	Availability
Alkaloids	Available
Glycosides	Available
Saponins	Available
Phytosterols	Available
Triterpenes	Available
Diterpenes	Available
Flavones	Available

According to observed results, Alkaloids, Glycosides, Saponins, Phytosterols, tyrpenes, Diterpenes, and Flavones were present in *A. lindleyana* extract.

Thin Layer Chromatography

Thin-layer Chromatography was carried out on macerated aqueous and methanolic extracts. For methanolic extract, there were four separate samples for *Aporosa lindleyana* and two separate samples for aqueous extract.

TABLE 2: RESULTS OF THIN LAYER CHROMATOGRAPHY

Sample Spot	R _f Value
Spot 01 (R _{f1})	0.56
Spot 02 (R _{f2})	0.88

The proximate analysis

The Proximate analysis is a quantitative analysis of a mixture to determine the percentage of components. The following Parameters were analyzed.

TABLE 3. RESULTS OF PROXIMATE ANALYSIS

Parameter	Results
Moisture	2.30%,
Ash	13.22%
Crude fat	2.85%.

IV. CONCLUSION

Steam and Simple distillations were carried out to isolate the Volatile oil from fresh plant leaves and isolated oil samples were analyzed using GC-MS. Maceration using methanol followed by phytochemical screening was done for air-dried samples. Alkaloids, Glycosides, Saponins, Phytosterols, Triterpenes, Diterpenes, and Flavones were present in *A. lindleyana* extract. Thin-layer Chromatography was carried out to separate the both macerated aqueous and methanolic extracts. The proximate analyses (moisture, ash, crude fats, proteins) of the samples were determined. *A. lindleyana* showed moisture = 2.30%,

ash = 13.22% and crude fat = 2.85%. Results of the present study revealed that *A. lindleyana* is rich in secondary metabolites. Results of the present study revealed that *Aporosa lindleyana* (Wight) Baill. is rich in secondary metabolites. It is very useful for enhancing immunity. This study further planned to develop a new antidiabetic drug using *Aporosa lindleyana* (Wight) Baill. extracts with other medicinal values will support the community in selecting the best drug for their diabetic matter. It will lead to a reduction the Diabetic and other diseases among the population.

REFERENCES

- Hapuarachchi, S.D.; Suresh, T.S.; SLJIM. 2011, 1 (01), 1.50.
- Grunert, J. Side Effects of Herbal Medicine <http://herbs.love to know.com/Side Effects of Herbal Medicine> (Accessed Jan 28, 2018)
- Christophe, T.; Bieke, D.; Anal.Chim. Acta.2011, 690, 148-161.
- Zhebg, L.; Ruichao, L.; Zhongzei, Q.; Anal.Chim.Acta.2006, 555, 217-224.
- Nawaneri, C.; Webmedcentral. 2015, 1-28.
- Grazia, T.; Alberto, E.; Diabetes Metab. 2013, 4, 4-8.
- Vinay, K.; Shahid, U. S.;Journal of Herbs, Spices & Medicinal Plants.2008,14(1-2).
- Bhushan Patwardhan; Interdisciplinary School of Health Sciences, University of Pune, Pune 411007, India, Accepted 6 June 2005.
- Dinesh, k.B., Analava, M., Manjunatha, M., Azadirachtolide: an anti-diabetic and hypolipidemic effects from Azadirachtaindica leaves. Pharmacognosy Communication1.2011 (78-84).
- Shah, J.G., Patel, M.S., Patel, K.V., Gandhi, T.R., Evaluation of anti-diabetic and antioxidant activity of *Centratherum anthelmintica* in STZ-induced diabetes in rats. The International Internet Journal of Pharmacology, 2008 (6:1-10).
- Li, W.L., Zheng, H.C., Bukuru, J., De Kimpe, N., Natural medicines used in the traditional Chinese medical system for therapy of diabetes mellitus. Journal of Ethnopharmacology, 2004 (92:1-21).
- Tolman, K.G., Chandramouli, J., Hepatotoxicity of the thiazolidinediones. Clinics in Liver Disease, 2003 (7: 369-379).
- DeFronzo RA.; Pharmacologic therapy for type 2 diabetes mellitus. Annals Inter Med. 1999; (131: 281- 303).
- Brown JB., Nichols GA., Perry A.; The burden of treatment failure in type 2 diabetes. Diabetes Cr. 2004; (27: 1535-1540).
- Reddy MB., Reddy KR., Reddy MN.; A survey of plant crude drugs of Anantapur district, Andhra Pradesh, India. Int J Crude Drug Res.1989; (3: 145-155).
- Ravikant, Abhay, K.; Priyanka, S.; European journal of pharmaceutical and medicinal research. 2016,3(1), 415-420.
- Shrishailappa Badami, Sujay R. Rai, B. Suresh.; Antioxidant activity of *Aporosa lindleyana* root. Journal of Ethnopharmacology 101 (2005) 180-184.
- B.L.C. Samanmali, Mangala Gunatilake, Ranil D. Guneratne and T.R.K. Perera.; Hypoglycaemic effect of the methanolic extract of *Aporosa lindleyana* leaves on rats. J.Natn.Sci.Foundation Sri Lanka. 2014, 42 (2): 129-135.
- Kathirgamanathar, S.,Abeysekera W.P.K.M.,Weerasinghe, D.M.K.P.,Ranasinghe, P., Binduhewa, A.M.C.U. Antioxidant, anti-amylase, and lipid-lowering potential of leaves of *aporosa lindleyana* baill. Sri Lankan J. Biol. 2018, 3 (1): 1-10.
- M. B. Narkhede, , P. V. Ajimire., In vitro antidiabetic activity of *Caesalpinia digyna* (R.) methanol root extract. Asian Journal of Plant Science and Research, 2011, 1 (2): 101-106.
- Susanna Phoboo, Kalidas Shetty., In Vitro Assays of Anti-Diabetic and Anti-Hypertensive Potential of Some Traditional Edible Plants of Qatar, Human Nutrition Program, Department of Health Sciences, Qatar University, Doha, Qatar; June 7, 2015

Assessment of Knowledge of Pregnant Mothers on Maternal Nutrition and Associated Factors: Udubaddawa Divisional Secretariat, Kurunegala, Sri Lanka

A.D.M.P. Dissanayake
Department of Agriculture & Food Technology
University of Vocational Technology
Rathmalana, Sri Lanka
fpt18b121@uovt.ac.lk

Malkanthi Thenabadu
Department of Agriculture & Food Technology
University of Vocational Technology
Rathmalana, Sri Lanka
mal.thenabadu@gmail.com

Abstract— This study investigates the knowledge, attitudes, and practices of pregnant mothers regarding maternal nutrition within the Udubaddawa Divisional Secretariat, Kurunegala, Sri Lanka. Employing a quantitative research approach, the research explores demographic characteristics, nutritional knowledge, attitudes, practices, and their correlations among study variables. Demographic profiles reveal a diverse representation of participants across various categories. Notably, nutritional knowledge displays varying levels of understanding, with specific areas well grasped while others require improvement. Attitudes towards nutrition show mixed positive inclinations and uncertainties, shaping dietary behaviors. While responsible practices such as awareness of alcohol and smoking risks during pregnancy are evident, areas like daily iron supplementation and animal product consumption suggest opportunities for enhancement. Correlational analysis underscores the influential role of maternal education in shaping attitudes and practices ($r = -0.113$, $p < 0.05$), highlighting its significance. Recommendations for further research encompass longitudinal studies to assess long-term effects, exploration of cultural influences on dietary practices, and tailored nutrition education interventions. Strategies involving healthcare providers, digital platforms, partner engagement, and socioeconomic factors are suggested. Comparative studies across regions could provide broader insights. Additionally, exploring links between maternal nutrition and child development is suggested. The study contributes insights into maternal nutrition dynamics, offering pathways to enhance maternal and infant health outcomes through informed interventions and policy actions. This research provides valuable context for advancing maternal care and underscores the pivotal role of education in promoting healthier behaviors during pregnancy.

Keywords— maternal nutrition, pregnant mothers, knowledge, attitudes, practices, Sri Lanka

I. INTRODUCTION

Nutrition is a fundamental pillar of human life, health and development throughout life. Proper diet and good nutrition are essential for survival, physical development, mental development, performance and productivity, health and well-being [1]. However, nutritional requirements vary with physiological changes such as age, gender, and pregnancy. Pregnancy is a crucial time in a woman's life, unhealthy nutrition or inability to meet the nutritional needs of the mother during this period causes several health

problems for both the mother and the baby [2]. Problems such as anemia, osteomalacia and gestational poisoning increase the risk of pregnancy and stillbirth, premature birth, cognitive abnormalities and dementia in infants due to inadequate and unbalanced nutrition. In addition, low maternal food quality can lead to misalignment of fetal development [3]. This leads to permanent structural, physiological and metabolic changes and is prone to cardiovascular, metabolic and endocrine diseases in adulthood [4]. The effects of nutrition during pregnancy affect the short- and long-term health of the mother, fetus, and infant, and that pregnant women are more likely to suffer from malnutrition and unbalanced nutrition [5]. The main reasons for inadequate and unbalanced nutrition of pregnant women are not getting the necessary nutritional supplements for increasing pregnancy and lactation needs, not purchasing the right nutrients according to the nutritional content due to economic weakness, and choosing the wrong nutrients [6].

Maternal knowledge about nutrition is an important link to good pregnancy outcomes and is a critical skill in improving the nutritional status of children [7]. Evidence of maternal knowledge and attitudes about nutrition during pregnancy and their association with dietary diversity practices can never be obtained [8]. Existing studies have reported a link between maternal awareness levels or some pregnancy outcomes but a decrease explanation on how awareness levels during pregnancy are linked to attitudes and dietary practices. Therefore, in this study, aimed to assess the level of maternal knowledge about nutrition and attitudes towards nutrition [9].

II. OBJECTIVES

The general objective of the study is to assess the knowledge of pregnant mothers on maternal nutrition and associated factors in Udubaddawa Divisional Secretariat, Kurunegala, Sri Lanka. Further, this study aimed to describe socio-demographic attributes of pregnant mothers, evaluate their knowledge on nutrition and explore their various dietary behaviors and practices. Further this study will ascertain the potential influence of socio-demographic variables on their nutritional awareness.

III. METHODOLOGY

The research employs a quantitative approach involving a cross-sectional descriptive framework. The primary aim is to comprehensively assess maternal nutrition and its associated factors among pregnant women. The study was conducted between March and August 2022 within the Udubaddawa divisional secretariat in Kurunegala, Sri Lanka. The cross-sectional design utilized a cluster sampling technique to gather data from a representative community sample of pregnant mothers registered under the Udubaddawa divisional secretariat. Participants were selected among those seeking antenatal care at health centers and posts during the specified period in 2022.

a. Sample Size Determination

The sample size is determining by the assumption that 95% of the pregnant mothers were knowledgeable on maternal nutrition during pregnancy with 5% marginal error and 95% CI and a none response rate of 20%. Based on this assumption, the actual sample size for the study is determine using the formula for single population proportion.

$$n = \frac{(Z \alpha/2)^2 p q}{d^2}$$

Where n = Sample size

$Z \alpha/2$ = Z value corresponding to a 95% level of significance = 1.96

p = expected proportion of practices of mothers on nutrition during pregnancy = 95% = 0.95

q = (1 - p) = (1 - 0.95) = 0.05

d = absolute precision (5%)

None response rate = 20%

n = 73 + 20 = 93

This number was made up to 100 to increase the statistical power.

B. Data collection procedures

Systematic sampling was applied to select study subjects from each antenatal care unit. The semi-structured questionnaire, translated from English to Sinhala, was pre-tested in the health center's antenatal care unit on 5% of the sample. Data collection involved multiple visits to the study area's MOH clinic. The dependent variable focused on pregnant mothers' nutritional knowledge, assessed through a 10-question quantitative study. Respondents answered questions about supplements, health risks, causes of malnutrition, and more. Answers were scored, and the nutrition knowledge variables were calculated out of 100. Independent variables included socio-demographic characteristics and nutrition information. Data quality was ensured through pre-testing, translation, daily checks, and oral recording. Statistical analysis using SPSS included descriptive statistics and correlational analysis, while ethical considerations prioritized informed consent and data confidentiality.

IV. RESULTS AND DISCUSSION

a. Demographic Characteristics of Respondents

The demographic characteristics of the study participants were distributed across various categories. The age groups showed representation of 18.0%, 51.0%, 28.0%,

and 3.0% for 15-24, 25-34, 35-44, and above 44 years, respectively. All participants were married. Regarding religion, 62.0% were Buddhists, 20.0% Catholics, and 18.0% Muslims. The ethnicity composition included 79.0% Sinhala, 17.0% Muslim, and 4.0% Tamil. Maternal occupations encompassed 15.0% government employees, 21.0% house servants, 56.0% housewives, and 8.0% private employees. Husband's occupations ranged from 22.0% business, 48.0% farmers, 15.0% government employees, 8.0% merchants, to 7.0% private employees. Maternal education levels were 81.0% with secondary education (9-12) and 19.0% with a diploma or above. Similarly, 67.0% of husbands had secondary education, 22.0% had a diploma or above, and 11.0% had primary education. Family sizes consisted of 26.0%, 57.0%, and 17.0% for less than 3, 3-5, and more than 5 members, respectively. Gestational weight gain percentages were 31.0%, 44.0%, and 25.0% for 40-50, 50-60, and 60-70, respectively. Gestational age in weeks displayed percentages of 31.0%, 47.0%, and 22.0% for less than 20 weeks, 20-40 weeks, and more than 40 weeks, correspondingly. Monthly income categories were 56.0%, 41.0%, and 3.0% for less than 10,000, 10,000-50,000, and more than 50,000, respectively.

DEMOGRAPHIC CHARACTERISTICS AMONG RESPONDENTS

Demographic Characteristic	Category	Frequency	%
Age Group	15 - 24	18	18.0%
	25 - 34	51	51.0%
	35 - 44	28	28.0%
	More than 44	3	3.0%
Marital Status	Married	100	100.0%
Religion	Buddhism	62	62.0%
	Catholic	20	20.0%
	Islam	18	18.0%
Ethnicity	Sinhala	79	79.0%
	Muslim	17	17.0%
	Tamil	4	4.0%
Maternal Occupation	Government Employee	15	15.0%
	House Servant	21	21.0%
	Housewife	56	56.0%
	Private Employee	8	8.0%
Husband's Occupation	Business	22	22.0%
	Farmer	48	48.0%
	Government Employee	15	15.0%
Maternal Education	Merchant	8	8.0%
	Private Employee	7	7.0%
	Secondary (9-12)	81	81.0%
Husband's Education	Diploma and above	19	19.0%
	Primary (1 - 8)	11	11.0%
	Secondary (9 - 12)	67	67.0%
Family Size	Diploma and above	22	22.0%
	Less than 3	26	26.0%
	3 - 5	57	57.0%
Number of Births	More than 5	17	17.0%
	1 - 2	66	66.0%
	2 - 4	34	34.0%
Inter-pregnancy Interval	Less than a year	8	8.0%
	1 - 2 years	34	34.0%
	More than 2 years	58	58.0%
Total Gestational Weight Gain	40 to 50	31	31.0%
	50 to 60	47	44.0%
	60 to 70	2	25.0%

Demographic Characteristic	Category	Frequency	%
<i>Gestational Age in Weeks</i>	<i>Less than 20 weeks</i>	31	31.0%
	<i>20 - 40 weeks</i>	47	47.0%
	<i>More than 40 weeks</i>	22	22.0%
<i>Monthly Income</i>	<i>Less than 10,000</i>	56	56.0%
	<i>10,000 - 50,000</i>	41	41.0%
	<i>More than 50,000</i>	3	3.0%

b. Nutritional knowledge of pregnant mothers

Comprehension of maternal and infant nutrition during pregnancy was assessed through a set of questions. Notably, around 40% accurately recognized causes of malnutrition, identified anemia, and understood necessary supplements for pregnant women. Additionally, 38% comprehended the health risks linked to insufficient iron intake in maternal diets, while 48% identified risks for infants. Moreover, participants displayed sound awareness (44%) of preventive measures for anemia, iron-rich foods, and substances affecting iron absorption. The mean knowledge score was 45.1, indicating a moderate overall understanding. The results underline variable familiarity across different topics, highlighting areas for potential improvement through targeted education. These findings emphasize the significance of enhancing knowledge to facilitate better maternal and infant nutritional practices during pregnancy.

NUTRITIONAL KNOWLEDGE

Question	%Correct answers
1. What do you think are the causes of malnutrition?	40%
2. What supplements do you think pregnant women need during pregnancy?	44%
3. How do you identify anemia?	40%
4. What are the health risks when pregnant women's diet lacks iron?	38%
5. What are the health risks when infants' diet lacks iron?	48%
6. What do you think are the prevention measures of anemia?	44%
7. What are iron-rich foods?	51%
8. What enhances iron absorption when taken with meals?	44%
9. Which beverages inhibit iron absorption when taken with meals?	44%
10. Who/what is your source for nutritional information?	58%
Mean score of the participants based on the knowledge	45.1

c. Attitude towards Nutrition

Table III outline the maternal attitudes towards nutrition during pregnancy within the Udubaddawa division. It depicts responses to various statements concerning dietary practices. Notably, 52% of participants expressed a positive attitude towards consuming more food during pregnancy, while 48% were uncertain about this notion. Regarding carbohydrate intake, 23% believed it should be increased, contrasting with 35% who disagreed, and 42% who were unsure. An overwhelming 90% acknowledged the importance of increasing protein or legume consumption during pregnancy. Similarly, 63% recognized the need for more milk and dairy products during this period. Encouragingly, 97% acknowledged the significance of incorporating iron-rich foods into their meals, such as beef, chicken, or liver. Participants also indicated positive inclinations towards good-tasting omega-3-rich foods (48%), milk and dairy products (75%), and iodized salt use in meal preparation (48%).

MOTHERS ATTITUDE TOWARDS NUTRITION IN PREGNANCY

Question	Good	Not good	Not sure
<i>Eat more food during pregnancy?</i>	52	48	0
<i>Eat more carbohydrate than non-pregnancy</i>	23	35	42
<i>Eat more proteins or beans during pregnancy?</i>	90	10	0
<i>Have more milk and its products during Pregnancy?</i>	63	37	0
<i>Meals with iron-rich foods such as beef, chicken or liver?</i>	97	3	0
<i>Good taste of omega 3 rich foods</i>	48	48	4
<i>Good taste of milk and milk products?</i>	75	25	0
<i>Prepare meals with iodized salt?</i>	48	40	12

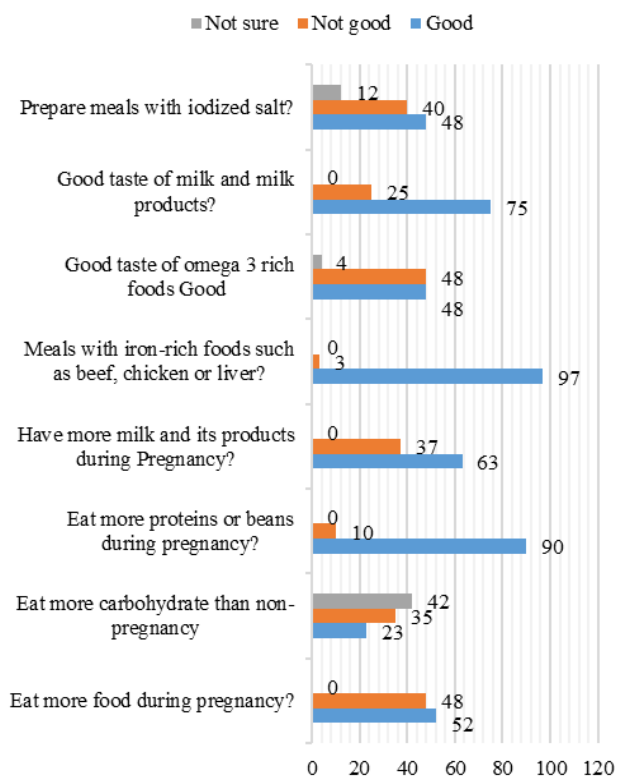


Fig.1. - Mothers attitude towards nutrition in pregnancy

d. Nutritional practices of pregnant mothers

The table IV highlights the nutritional practices of pregnant mothers within the Udubaddawa division. The study assessed these practices through a series of questions, and the responses shed light on various aspects of dietary behavior. Encouragingly, the participants exhibited sound understanding and responsible behavior in certain areas, with 100% acknowledging the risks of alcohol and smoking during pregnancy. However, only 33% reported daily iron supplementation, suggesting a need for improvement in this crucial aspect. Similarly, while 41% consumed animal products daily, there is potential for increased intake considering their nutritional significance. On a positive note, 76% included dark green leafy vegetables daily, signifying awareness of their benefits. Daily meal consumption was generally high, with breakfast (82%), lunch (100%), and dinner (92%) being consistently consumed. Citrus fruit addition to dark green leafy vegetables was practiced by 72%, often attributed to its nutritional benefits (88%). Coffee/tea consumption (34%) and its timing (52%) during pregnancy were also addressed. The mean count and score reflected overall satisfactory nutritional practices, although specific areas like iron supplementation and optimal food variety could be addressed for enhanced maternal nutrition

NUTRITION PRACTICE OF THE PREGNANT MOTHERS

Question	Percentage of correct answers
1.Alcohol consumption during pregnancy	100%
2.Smoking during pregnancy	100%

3.Daily use of iron supplementation	33%
4.Consumption of animal products at least once a day	41%
5.Consumption of dark green leafy vegetable at least once a day	76%
6.More food consumed during pregnancy as compared to before getting pregnant	97%
7.Daily breakfast consumption	82%
8.Daily lunch consumption	100%
9.Daily dinner consumption	92%
10.Add citrus fruits to dark green leafy vegetables	72%
11.Reason for adding citrus fruit to dark green leafy vegetables	88%
12.Coffee/tea consumption during pregnancy	34%
13.Timing of coffee/tea consumption during pregnancy	52%
Mean count	7.67

e. Correlational Analysis

RELATIONSHIP OF DEMOGRAPHIC FACTORS AGAINST KNOWLEDGE ,NUTRITION PRACTICE AND ATTITUDES

Correlations	Knowledge	Nutrition Practice	Attitude
Age group	0.041 (0.686)	0.087 (0.390)	-0.033 (0.747)
Maternal occupation	0.020 (0.842)	0.005 (0.962)	-0.010 (0.919)
Husband occupation	-0.100 (0.320)	-0.037 (0.715)	0.135 (0.179)
Maternal education	-0.085 (0.399)	-0.113** (0.264)	-0.170** (0.090)
Husband education	-0.138 (0.170)	0.087 (0.392)	-0.069 (0.498)
Number of births	-0.002 (0.981)	-0.089 (0.381)	0.085 (0.400)
Monthly income	0.062 (0.539)	0.073 (0.470)	-0.010 (0.923)

**Correlation is significant at the 0.05 level (2-tailed).

The significant correlations between maternal education and nutrition practices (-0.113) and attitudes (-0.170) are denoted by ** and signify their meaningful impact on shaping these aspects. Other correlations indicated weak associations without statistical significance. These findings underscore the pivotal role of maternal education in influencing nutritional behaviors and attitudes, highlighting its significance in promoting healthier practices during pregnancy[10].

V. CONCLUSION

In conclusion, this study delved into the knowledge, attitudes, and practices of pregnant mothers regarding maternal nutrition within the Udubaddawa Divisional Secretariat, Kurunegala, Sri Lanka. Employing a mixed-method approach, the research uncovered a diverse demographic profile among participants, offering context for understanding their perspectives. Notably, the study revealed varying levels of nutritional knowledge among pregnant mothers, with some areas well understood while

others showed room for improvement. Attitudes towards nutrition exhibited a mix of positive inclinations and uncertainties, shaping dietary behaviors. While certain practices, such as awareness about the risks of alcohol and smoking during pregnancy, were commendable, opportunities for enhancement were identified, especially in aspects like daily iron supplementation and animal product consumption. Correlational analysis highlighted the influential role of maternal education in shaping both attitudes and practices, underscoring the significance of education in promoting healthier behaviors during pregnancy.

Overall, the study emphasized the need for targeted educational interventions to bolster maternal nutrition understanding and practices. By addressing specific areas of knowledge and behavior, particularly among those with lower education levels, the potential to enhance maternal and infant health outcomes becomes evident. The findings underscore the importance of a holistic approach to maternal care, integrating knowledge dissemination, attitude refinement, and practice improvement. Ultimately, these insights contribute to the broader goal of advancing maternal and child health in the Udubaddawa Divisional Secretariat, Kurunegala, Sri Lanka.

VI. FURTHER RESERCAH AND RECOMMENDATIONS

To build upon the insights gained from this study, several avenues for further research and recommendations emerge. Firstly, a longitudinal study could provide a comprehensive understanding of the long-term impact of improved maternal nutrition knowledge and practices on maternal and infant health outcomes. Efforts could focus on designing and implementing targeted nutrition education interventions, leveraging healthcare providers' roles, and creating accessible digital education platforms. Investigating the interplay of socioeconomic factors and partner engagement in influencing maternal nutrition practices would provide a holistic view. Comparing findings

across regions would broaden perspectives on influencing factors.

Collaborating with policymakers to translate research into impactful policies can lead to sustainable improvements in maternal and child health outcomes. In essence, by exploring these directions, we can refine interventions, enhance maternal nutrition, and contribute to healthier communities.

REFERENCES

- [1] J. Blundell, 'women zyxwvutsr zyxwvu zyxwvu zyxwvuts zyxwvuts'.
- [2] R. Nagi, S. Sahu, and R. Nagaraju, 'Oral health, nutritional knowledge, and practices among pregnant women and their awareness relating to adverse pregnancy outcomes', *J. Indian Acad. Oral Med. Radiol.*, vol. 28, no. 4, pp. 396–402, 2016, doi: 10.4103/jiaomr.JIAOMR_246_15.
- [3] S. C. Asia, 'Global malnutrition', no. Table 4, 2000.
- [4] L. J. Picton, 'Health and nutrition', *Br. Med. J.*, vol. 1, no. 4346, p. 568, 1944, doi: 10.1136/bmj.1.4346.568-b.
- [5] G. D. Fekadu Beyene, 'Assessment of Knowledge of Pregnant Mothers on Maternal Nutrition and Associated Factors in Guto Gida Woreda, East Wollega Zone, Ethiopia', *J. Nutr. Food Sci.*, vol. 03, no. 06, 2013, doi: 10.4172/2155-9600.1000235.
- [6] G. Daba, F. Beyene, W. Garoma, and H. Fekadu, 'Assessment of Nutritional Practices of Pregnant Mothers on Maternal Nutrition and Associated Factors in Guto Gida Woreda, East Wollega Zone, Ethiopia', *Sci. Technol. Arts Res. J.*, vol. 2, no. 3, p. 105, 2013, doi: 10.4314/star.v2i3.98748.
- [7] A. Suh NchangMugyia, A. Nguti Kien Tanya, P. Nana Njotang, and P. Koki Ndombo, 'Knowledge and attitudes of pregnant mothers towards maternal dietary practices at Etug Ebe Knowledge and Attitudes of Pregnant Mothers towards Maternal Dietary Practices During Pregnancy at the Etoug-Ebe Baptist Hospital Yaounde', *Heal. Sci. Dis.*, vol. 17, no. 2, pp. 24–29, 2016.
- [8] H. Yeatman and M. J. Williamson, 'a cross sectional survey of nutrition knowledge , attitudes , and confidence', 2016.
- [9] A. Zelalem, M. Endeshaw, M. Ayenew, S. Shiferaw, and R. Yirgu, 'Effect of Nutrition Education on Pregnancy Specific Nutrition Knowledge and Healthy Dietary Practice among Pregnant Women in Addis Ababa', *Clin. Mother Child Heal.*, vol. 14, no. 3, 2017, doi: 10.4172/2090-7214.1000265.
- [10] D. Gehrke, M. Avenue, and L. Beach, 'Determinants of Successful Website Design : Relative Importance and Recommendations for Effectiveness Efraim Turban', vol. 00, no. c, pp. 1–8, 1999.

Detecting The Diseases of Potato Based On Leaves Using SVM And XG-Boost Classifiers

Anushka Parajuli
Software Engineering
Gandaki College of Engineering and
Science
Pokhara, Nepal
parajulianushka1213@gmail.com

Bidur Devkota
Software Engineering
Gandaki College of Engineering and
Science
Pokhara, Nepal
<https://orcid.org/0000-0001-5901-3971>

Pratikshya Shrestha
Software Engineering
Gandaki College of Engineering and
Science
Pokhara, Nepal
pratikshyashrestha@gces.edu.np

Ashok Raj Parajuli
Software Engineering
Gandaki College of Engineering and
Science
Pokhara, Nepal
ahokparajuli@gmail.com

Abstract—Potato, known for the superior food crop in Nepal, has been affected by microorganisms like the fungus *Alternaria* and the oomycete *Phytophthora*, causing early blight and late blight, profound diseases of potato leaf. To overcome the traditional disease detection technique in the leaves of potato, an accelerated approach is needed. The proposed paper focuses on identifying disease in potato leaves using SVM and XG-Boost classifiers. A balanced dataset of 1500 leaf images of potatoes are used in this study to classify three different classes, namely early blight, late blight and healthy leaves. The performance achieved using the SVM classifier and XG-Boost classifier are 0.9933 and 0.9866 respectively.

Keywords—image classification, potato disease detection, svm, xg-boost

I. INTRODUCTION

Potato, the major vegetable crop, is widely known as the superior staple food crop in the agricultural country, Nepal. Potato occupies fifth, fourth and first in area coverage, total production and productivity respectively. Potato contributes its role in cash generation and food production unit areas for smallholder farmers. [1]

Since days in the past years and continuing in the present too, farmers follow the same traditional mechanism to detect the diseases in the crops, through their naked eyes. Thus, a traditional mechanism makes one decide if the crop is healthy or not. If not, he has to decide the disease through visual inspection and makes them confused about which preventive measures to adopt. Detailed knowledge and study about the diseases of crops and a lot of expertise is required for the prediction of the actual disease detection. During the visual inspection of the leaves, diseases may appear almost similar to farmers', often leaving farmers full of doubts and confusion. When one makes false predictions and the wrong type and inaccurate quantity of fertilizers are applied, adverse effects can be seen in the crops, thus leading to an unfavorable situation for both the plant and ferment.

The presence of infections caused by various microorganisms in potato leaves is a critical aspect of plant pathology and agricultural research. Understanding the types of microorganisms involved, their pathogenic mechanisms, and their impact on potato plants is essential for efficient disease management and sustainable crop production. Early and late blight are two profound diseases found in potatoes which belong to the Solanaceae family. While the early blight is caused by the fungus *Alternaria Solani*, which thrives relatively in warmer temperatures, late blight is caused by the oomycete *Phytophthora Infestans*, which flourishes relatively in cooler temperatures.

Traditional mechanisms for classifying diseases on the leaves of potatoes have often been time-consuming, labor-intensive, and reliant on human resources to manually classify the potato leaves. Consequently, there's an utmost requirement for a more accelerated and efficient approach required in the potato leaf disease detection system. Thus, this paper targets a computerized detection system of potato leaves through machine learning and computer vision.

The patterns that are present on the leaves will be identified using different image processing techniques. The acquired patterns are compared to the patterns corresponding to different diseases and thus, which influence the precise identification of different diseases among various classes, or obtaining a particular pattern corresponding to a disease which creates an impact on the identification of various diseases. Thus, the obtained features or patterns will be compared with the historical data, and we are able to classify the disease, which can be done by various machine learning methodologies. So, the symbiosis of machine learning and image processing is very efficient in the detection and classification of diseases.

This paper is structured into 4 sections. Section 1 introduces potato diseases and the importance of early identification of diseases. Section 2 demonstrates literature review, Section 3 depicts Materials and Method, Section 4

depicts Results and Discussion and followed by Section 5 which concludes the paper.

II. LITERATURE REVIEW

Different researchers have presented their views from the detailed study regarding the Potato disease detection based on leaves.

Anushka Bangal, Neha Pande, Dhiraj Pagar, Neha Pande conducted Potato Leaf disease detection and classification using the deep learning approach, CNN to classify potato leaves among early blight, late blight and healthy leaves. An 1150 image dataset having 500 leaves belonging to each class was used in this paper and thus 91.41% validation accuracy was achieved. [2]

Dr. S. Satheesh and Dr. P. Ashok Babu conducted leaf disease detection using SVM, XG-Boost and Texture XG-Boost Classifier on the leaves of Bell Pepper, Potato and Tomato. Concerning potatoes, the performance of the potato leaves from the Plant Village Dataset using the SVM classifier was 0.812, the XG-Boost classifier was 0.849. [3]

Rahul Sharma, Amar Singh, Vishnu Sharma presented a CNN model that used a 1500 image dataset having 500 leaves belonging to each class and was used in their research. The CNN models automatically learn the features from the raw images and are able to classify the images with 94.4% accuracy. [4]

Amar Singh, Rahul Sharma, Mehedi Masud, Kavita, N.Z Jhanjhi, Sahil Verma and Emed Sami Jaha conducted Rice and Potato leaf diseases using classifiers CNN, SVM, KNN, Decision Tree and Random Forest. An accuracy of 97.66% was achieved using the deep learning-based CNN model to detect the disease of potato based on the leaf. The deep learning-based CNN model was able to detect potato leaf disease with an accuracy of 97.66%. 1500 images of infected and healthy leaves of potato crops were used. [5]

Thus, the proposed research paper has better performance than the related works which are mentioned in Section 2. Our proposed paper has got a better performance level in comparison to Paper 1, which uses the CNN model with 1150 dataset collection. Our proposed methodology achieved a better performance level with both SVM and XG-boost classifiers than Paper 2, which also used SVM and XGboost classifiers. The proposed research paper got better performance in comparison to Paper 3 using the same dataset. Since Paper 3 used CNN methodology, which is a heavy deep learning model, we got better performance compared to Paper 4 using the SVM classifier. One contribution of the proposed paper to Paper 4 is improved performance by optimization of the hyper-parameters.

III. MATERIALS AND METHOD

This section of the paper represents the proposed methodology for detecting and classifying the profound diseases in the leaves of the potato. The methodology of the proposed research paper framework is depicted in the bloc diagram below.

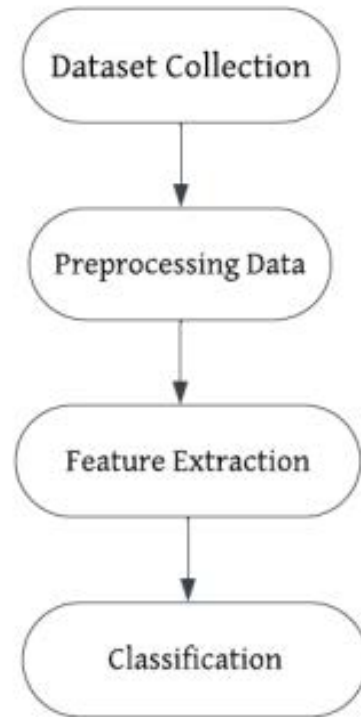


Fig.1. Methodology of proposed paper

a. Dataset Collection

Acquisition of the data from Plant Village Dataset [6] was done in the first phase of the methodology. This dataset consists of 1500 images, which are divided into three distinct classes, specifically late blight, healthy and early blight. Detailed information about the dataset used is depicted in the following table:

TABLE I. DATASET

Categories	Total Data
Early Blight	500
Late Blight	500
Healthy	500

Each image of different categories of the dataset is as follows:

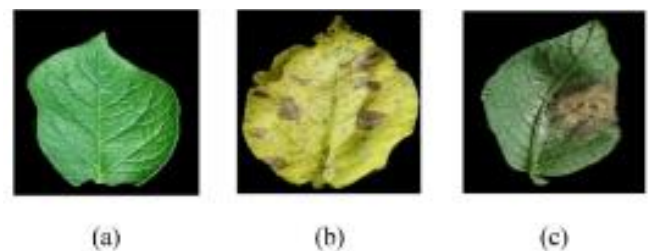


Fig.2. Potato leaves [7]

Labels a, b and c in the above figure depict healthy leaf, early blight leaf and late blight leaf of potato respectively.

b. Preprocessing Data

Preprocessing phase, a vital step in the methodology, targets image denoising, image enhancement and maintenance of the images at a standard size, so that a better result can be achieved. Prefetching of the images is done so that it reduces the computational time. Different images from the dataset are resized into dimensions with size (256, 256).

c. Feature Extraction

A process where high-dimensional and raw data is transfigured into a meaningful illustration, in which the essential patterns and characteristics of the data are captured, is called feature extraction. The features, which are the transformed representation, are used as the input to machine learning algorithms for classification. For the feature extraction process, Visual Geometry Group-16 (VGG-16) [8], a deep CNN architecture is used. VGG-16 consists of 13 convolutional layers and 3 fully connected layers, which sums up 16 layers in total. The fully connected layers can be removed, and the convolutional layers are used for the extraction of features. Low-level features like colors, edges and textures are extracted from the first few layers of the convolutional layer while the complex patterns are recognized from the deeper layers of the convolutional layer. Max-pooling layers are used in between some convolutional layers which are used to retain the key insights within the area.

d. Classification

This phase of the research methodology is all about classifying the data into one of the three classes, specifically early blight, healthy and late blight. Two classifiers were used in this paper, namely Support Vector Machine [6] and XG-Boost [9].

Support Vector Machine, one of the supervised machine learning techniques which performs even better with smaller datasets and is also capable of inferring the output label. A hyperplane maximizing the margins is output by SVM. The kernel method is employed by SVM for the purpose of classification of non-linear data. $y = mx + c$ is the standard equation of the separator hyperplane is given by $Di = \frac{|wx_i + b|}{||w||}$.

Maximization of the classification distance Di is aimed by SVM and thus can be achieved by the minimization of $\frac{1}{2} ||w||^2$ with the constraint $\{\frac{\min_{i=1,2} ||w||^2}{2}\}$. Training and Validation accuracy were evaluated with respect to parameters kernel, C and random_state. [10]

In the evaluation process, the difference in training accuracy and validation accuracy is minimal as the kernel is set to sigmoid and C is set to 3.0. Thus, C = 3.0, kernel = sigmoid and the default random_state are chosen for evaluation of the performance of SVM.

An ensemble learning algorithm, XG-Boost, is used for purposes like classification and regression. XG-Boost is

based on the gradient boosting framework. A collection of weak learners is decision trees and is built in a sequential manner in which the errors made by previous learners are corrected by each new learner. The predictions of multiple weak learners are often combined to form a robust learner.

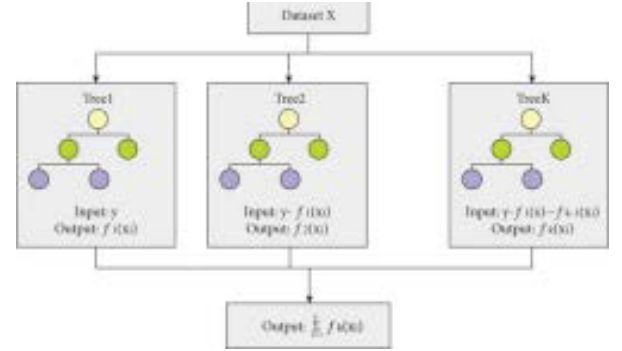


Fig.3. Framework of XG-boost [11]

The representation of the output final prediction is depicted below:

$$y_i = \varphi(x_i) = \sum_{k=1}^K f_k(x_i), f_k = F$$

where, training set and their corresponding class labels are represented by x_i and y_i respectively.

f_k is the leaf score for the kth tree and the set of all regression trees are represented by f_k and F respectively. [12]

The ability to handle large datasets effectively and missing data is one of the crucial elements of using XG-Boost. A number of hyperparameters in XG-Boost can be tuned to improve the performance level of the model. Parameters like n_estimators and learning_rate are set to 250 and 0.1 respectively. Different values of the parameter tree_method, namely 'gpu_hist', 'hist', 'approx', were also implemented [13].

But the performance of the XG-Boost classifier in this study was better with learning_rate and n_estimators than in addition to tree_hist.

IV. RESULTS AND DISCUSSION

Profound classifiers like SVM and XG-boost were used in this proposed study for the classification of potato leaf disease detection. Two of the emerging classifiers, SVM and XG Boost, were used to detect one of the three classes: Early blight, Late blight and Healthy. For evaluating SVM classification, parameters like C, kernel and random_state were used, whereas for XG-boost classification, n_estimators and learning rate were used.

The performance achieved to detect the disease on potato leaves of SVM is 0.9933 and that of XG-Boost is 0.9866. Evaluation of the classifiers using evaluation metrics like Accuracy, Precision, Recall and F1-score is depicted in the table below:

TABLE II.PERFORMANCE OF THE CLASSIFIERS

Classifiers	Accuracy	Precision	Recall	F1-Score
SVM	0.9933	0.9934	0.9933	0.9933
XG-Boost	0.9866	0.9867	0.9866	0.9866

SVM achieved better results with smaller datasets due to the different kernel functions and different values of the parameter C. Due to which, the computational time is reduced, thus achieving a better performance level.

The performance achieved can also be evaluated using a confusion matrix. The prediction summary which is represented in a matrix form is called a confusion matrix. Through a confused matrix, the total number of correct and incorrect predictions per class is depicted. Figure 4 and Figure 5 depict the confused matrix of the SVM classifier and XG boost classifier applied for predicting potato lead diseases.

True Labels	Potato Late Blight	100	0	0
	Potato Healthy	0	100	0
	Potato Early Blight	0	2	98
		Potato Late Blight	Potato Healthy	Potato Early Blight
		Predicted Labels		

Fig 4. Confusion Matrix obtained using SVM classifier

True Labels	Potato Late Blight	100	0	0
	Potato Healthy	2	97	1
	Potato Early Blight	0	1	99
		Potato Late Blight	Potato Healthy	Potato Early Blight
		Predicted Labels		

Fig. 5. Confusion Matrix obtained using XG-Boost classifier

True Positives (TP) are the diagonal values of the confused matrix. The values in the corresponding row items are added, ignoring the true positive values, to obtain false negatives. 2 % of misclassified data over the three classes has been observed in the confusion matrix of SVM while 4% of misclassified data over the classes has been observed in the confusion matrix of XG-Boost.

V. CONCLUSIONS AND FUTURE SCOPE

This paper is concerned with the detection of diseases on potatoes based on their leaves. 1500 data from the Plant Village Dataset were used in this machine learning approach. Two of the emerging classifiers, SVM and XG-Boost, were used to detect one of the three classes: late blight, healthy and early blight. The performance achieved to detect the disease on the leaves of potatoes using classifiers SVM and XG Boost are 0.9933 and 0.9866 respectively.

Integrating mobile applications with this machine learning approach is one of the improvements to be made in the future so that farmers can easily detect if the potato is healthy or not with their handy mobile devices. Adding more datasets to optimize the performance and accuracy of the machine learning approach is also one of the improvements to be made in the future.

REFERENCES

- T.L. Lama, B.B. Khatri, and S. P. Dhakal, "Status and prospects of potato research and development in Nepal," Horticulture in last Six Decades 1 pp. 145-156, 2016J. Clerk Maxwell, A Treatise on Electricity and Magnetism, 3rd ed., vol. 2. Oxford: Clarendon, 1892, pp.68–73.
- A. Bangal, D. Pagar, H. Patil and N. Pande, "Potato Leaf Disease Detection and Classification Using CNN," Int. J. Res. Publ. Rev. J. homepage www. ijpr. com, 3(5), pp.1510-1515, 2022.
- D. S. Satheesh and D. P. A. Babu, "Plant Leaf Detection using Texture Features and XG-Boost Classifier," March 201M. Young, The Technical Writer's Handbook. Mill Valley, CA: University Science, 1989.
- R. Sharma, A. Singh and V. Sharma, "Potato Leaf Diseases Identification using CNN," J. Emerg. Technol. Innov. Res, 5(12), pp.519-527, 2018
- R. Sharma, A. Singh, N.Z. Jhanjhi, M. Masud, E.S. Jaha, and S. Verma, "Plant Disease Diagnosis and Image Classification Using Deep Learning," Computers, Materials & Continua, 71(2), 2022.
- M. A. Putra, "Potato Leaf Disease Dataset," Kaggle, September, 2022
- T.Y. Lee, I.A. Lin, J.Y. Yu, J.M. Yang, and Y.C. Chang, "High efficiency disease detection for potato leaf with convolutional neural network," SN Computer Science, 2(4), p.297, 2021
- S. L. Sahu and R. Chintala Bhargavi, "Prediction of Diseases in Potato Plant using Pre-trained and Traditional Machine Learning Models," 2023 4th International Conference for Emerging Technology (INCET), Belgaum, India, pp. 1-8, 2023.
- Liu, J.J. and Liu, J.C., "Permeability predictions for tight sandstone reservoir using explainable machine learning and particle swarm optimization. Geofluids, pp.1-15, 2022.
- S.I. Amari and S. Wu, "Improving support vector machine classifiers by modifying kernel functions" *Neural Networks*, 12(6), pp.783-789, 1999.
- A. Gupta, S. Sharma, S. Goyal, and M. Rashid, "Novel xgboost tuned machine learning model for software bug prediction," In 2020 international conference on intelligent engineering and management (ICIEM) (pp. 376-380). IEEE, June, 2020.
- T. Chen, and C. Guestrin, Xgboost: A scalable tree boosting system. In Proceedings of the 22nd acm sigkdd international conference on knowledge discovery and data mining .pp. 785-794, August, 2016.
- S.M. Hassan, M. Jasinski, Z. Leonowicz, E. Jasinska and A.K. Maji, "Plant disease identification using shallow convolutional neural network," *Agronomy*, 11(12), p.2388, 2021.

Exploring a Versatile Carboxymethyl Cellulose Coating for Enhancing Passion Fruit Quality and Shelf Life

A.D.M.P.Dissanayake
Department of Agriculture & Food
Technology
University of Vocational Technology
Rathmalana, Sri Lanka
fpt18b121@uovt.ac.lk

Dr.Erandya Jayawardena
Department of Agriculture & Food
Technology
University of Vocational Technology
Rathmalana, Sri Lanka
erandya.jayawardena@uovt.ac.lk

Dr.Kamal Edirisinghe
Department of Agriculture & Food
Technology
University of Vocational Technology
Rathmalana, Sri Lanka
sagarakamal@gmail.com

Abstract— Approximately one-third of all fruit is lost during the agricultural and post-harvest phases before it reaches consumers. This research focused on addressing the issue of spoilage, especially in the case of highly perishable fruits like passion fruit, which have a limited shelf life due to dehydration and microbial growth. This limitation hampers their storage, transportation, and marketability. The study aimed to evaluate the impact of a protective coating on the shelf life and overall quality of passion fruit (*Passiflora edulis*) during storage. The investigation monitored chemical changes associated with weight loss, decay, and ripening over a four-week period under ambient conditions (20-25°C and 70-85% Relative Humidity). The results revealed that passion fruit treated with a 3% CMC coating solution exhibited a significant reduction in weight loss, shrinkage index, and an extension of shelf life by 15 days. These findings demonstrate the effectiveness of the CMC coating solution in preventing oxidation, reducing water loss, and delaying the ripening of passion fruit. This research underscores the importance of passion fruit preservation, highlighting its potential for enhanced quality and economic benefits.

¹ **Keywords—** Passion fruit, Carboxymethyl cellulose, coating, shelf life, quality

I. INTRODUCTION

Passiflora edulis, commonly known as passion fruit, has gained significant recognition in modern society thanks to its well-documented medicinal properties, impressive nutritional profile, and associated health benefits, which include cancer prevention, blood pressure control, and the management of hyperlipidemia [1]. In addition to its health advantages, passion fruit's delightful flavor has led to a substantial increase in demand for both fresh and processed passion fruit products in domestic and international markets over the past few years. This fruit is cultivated in various countries, including Australia, New Zealand, Kenya, South Africa, South America, Hawaii, India, and Sri Lanka [2]. Presently, South America stands as the world's leading producer of passion fruit, with a global annual production of approximately 0.8 million metric tons [3].

In recent times, an increasing number of individuals in Sri Lanka are drawn to passion fruit cultivation due to the region's favorable climate conditions, temperature, and the appealing market demand for this fruit. Sri Lanka features two distinct varieties of passion fruit [4]. One variety is yellowish (*Passiflora edulis* flavicarpa), while the other is purplish (*Passiflora edulis*). Especially, the yellowish passion fruit variety, which possesses a tangier flavor, is widely cultivated in Sri Lanka. Passion fruit cultivation is particularly popular in districts such as Kalutara, Gampaha, Ratnapura, and Kurunegala. Sri Lanka's annual passion fruit production averages around 500 metric tons [1].

Although passion fruit is highly sought after, its tropical characteristics pose challenges for its commercialization as a fresh product. These challenges include issues like fruit quality degradation, reduced market appeal, moisture loss, diminished fruit size, cell wall deterioration, a wilted appearance, and eventual senescence [5]. Both domestically sold and exported passion fruit face a significant issue where their unsightly appearance renders them unmarketable. Consequently, there is a pressing demand for preservation methods for passion fruit [6]. Under typical tropical conditions, passion fruit experiences rapid moisture loss, leading to excessive shriveling, a reduction in fruit size, cell wall deterioration, a withered appearance, and eventual senescence. In some cases, the pulp can undergo fermentation within just 7-10 days of harvest [7]. Given that passion fruit is often an impulse purchase, its shriveled appearance can discourage potential customers from buying it. However, by storing it at temperatures between 6.5°C and 7.0°C and maintaining a relative humidity of 85%-90%, the marketable shelf life of passion fruit can be extended to 4 to 5 weeks. Lower temperatures may lead to disorders and make the fruit more susceptible to fungal attacks, while higher temperatures can result in increased moisture loss and susceptibility to fungal infestation [8].

Shriveling represents a significant physiological issue affecting both passion fruit sold domestically and those intended for export. This condition makes the fruit

unsuitable for sale due to its unattractive appearance. Consequently, there is a critical need for preservation methods to prolong the shelf life of passion fruit [9]. Coatings serve various essential functions, including acting as a protective barrier to minimize product interaction with the environment. Additionally, they can alter the food's functional characteristics and aid in managing surface moisture to prevent clumping, adhesion, or disintegration [10]. These coatings establish a modified atmosphere around the product, preserving its freshness by reducing gas exchange (CO_2 and O_2) and forming a semi-permeable membrane around the fruit. This helps minimize alterations during the fruit's maturation or ripening processes [6]. CMC (Carboxymethyl cellulose), stands as a vital derivative in fruit coating applications. Coatings composed of CMC have found use in enhancing fruits and vegetables by creating barriers to oxygen, oil, or moisture transfer, as well as improving batter adhesion[11]. CMC is the predominant choice for fruit coatings, contributing to the retention of the fruits' original firmness and crispness. Furthermore, it aids in preserving the essential flavor components of various fresh fruits and vegetables while also curbing oxygen intake without elevating carbon dioxide levels within the coated environment [12]. The general objective of the study is to reduce dehydration and oxidation as well as the resulting undesirable changes in external appearance & also to preserve freshness and maintain quality standards often associated with appearances that consumers have come to expect and further investigated the CMC and thus the quality maintenance of passion fruit during storage and ascertain protect the shrinkage level and extend the shelf life.

II. MATERIAL AND METHOD

According to the maturity index,[13]. (Figure 1) passion fruits at the time of maturation were used for this study.

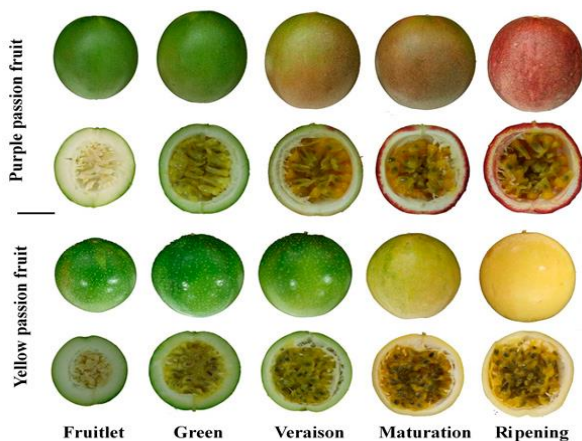


Fig 1: Lateral and transverse sections of both purple and yellow passion fruits at various developmental stages.

After harvested passion fruits study was conducted in the laboratory. The selected Passion fruits were washed and cleaned well.

Solution preparation: Make the solution with different percentages (1%,3%,5%).Then the best one was selected

considering the thickness.The required amount of CMC was measured (3g) and the solution was prepared(CMC 3% solution).The prepared solution was mixed well under 1000 rpm.

a. Passion Fruits storage Quality

To assess the storage quality of passion fruits, a dip-coating method was employed for applying the fruit coating. The gathered passion fruits were initially rinsed with tap water and subsequently divided randomly into two groups, each include five fruits for replication. One of these groups withstand a soaking process in the coating solution for five minutes and was then allowed to air dry (referred to as the "coated group"). The second group, serving as the control, received no treatment. Following the drying process, both groups were stored at room temperature (20-25°C, 70-85% relative humidity) and subjected to daily evaluations over a 25-day period..

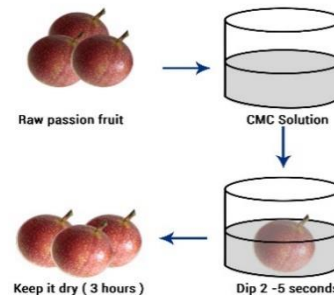


Fig 2. Coating apply procedure for passion fruit.

b. The Weight loss

Each day, the weight of both the control sample (without coating) and the coated sample of passion fruit was measured and recorded using an electronic balance. The weight loss was then determined using the following formula.

$$\text{weight loss (\%)} = (W_o - W_t) / W_t \times 100\%$$

where: W_o - Initial weight
 W_t - tested day weight respectively.

c. The Shrinkage index

The shrinkage index was evaluated by 0 points: no shrinkage; 0-1: 0%-10% shrinkage; 1-2: 10% - 20% shrinkage; 2-3: 20%-30% shrinkage; 3-4: 30%-40% shrinkage; 4-5: 40%-50% shrinkage; 5-6: 50%-60% shrinkage; 6-7: 60%-70% shrinkage; 7-8: 70%-80% shrinkage; 8-9: more than 80% shrinkage, respectively.

The calculation for the shrinkage index is as follows.

$$\text{Shrinkage index} = \sum S \times n / N$$

III. RESULTS AND DISCUSSION

In the studies conducted, the applied coating acts as a barrier to external agents on passion fruit. (fig.3). Thus, the basic objectives of the study are fulfilled.

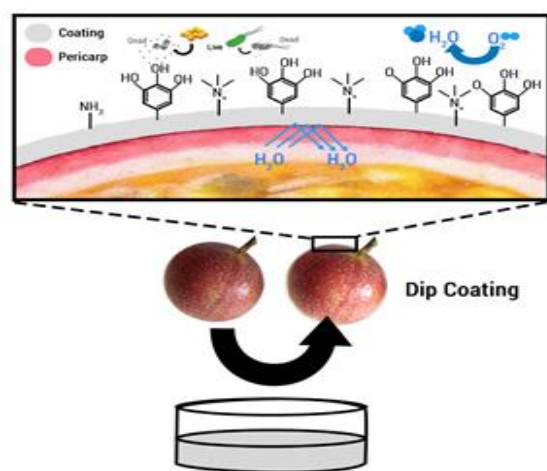


Fig 3. Experimental process and mechanism diagram.

a. Assessing the Storage Quality of Passion Fruits

The coating was prepared and applied to passion fruit using the dip-coating method. The evaluation focused on the coating's ability to maintain the fruit's freshness and minimize shrinkage. Figure 4 illustrates the visible differences in both untreated and coated passion fruit over time when stored at room temperature. Specifically, after five days from harvest, the uncoated fruits began to exhibit signs of shriveling, indicating the progression of changes with time.



Fig 4. images captured of 25 days depicting the changes in both uncoated and coated passion fruits during storage.

External discoloration and dehydration significantly impact the visual appeal and color of passion fruit. In contrast, the coated fruits demonstrated effective control over external appearance changes, even as early as the 10th day, and maintained a consistent appearance at the 15th and 20th day marks. This outcome enhance the efficacy of the CMC coating in prolonging the freshness of passion fruit by preserving its quality for an extended duration. Harvested passion fruit exhibits high respiration rates and permeable post-harvest, resulting in ongoing nutrient consumption and dehydration, leading to weight loss and a short shelf life. To investigate this, the fruits were initially stored at room temperature for 25 days, and the difference between uncoated and coated fruits were observed and compared.

The CMC coating exerts an influence on the permeability of carbon dioxide, oxygen, and water vapor in passion fruit, effectively reducing evaporation. Furthermore, it regulates the water loss through the pores on the fruit's skin, which helps maintain internal pressure and mitigate weight loss[14].

The shrinkage index serves as a crucial indicator for assessing passion fruit quality, affecting its appearance and hastening the aging process. As illustrated in Figure 4, when comparing coated and non-coated passion fruit, it becomes evident that uncoated passion fruit displays a higher tendency for shrinkage. Table 1 illustrates the progression of the shrinkage index during storage. In the control group, there was a substantial increase in the shrinkage index from the 4th day (4th day - 0.48, 5th day - 0.82, 6th day - 1.08, 7th day - 2.80, 9th day - 3.55, 12th day - 4.43, 14th day - 5.00, 16th day - 5.9, 18th day - 6.5, 20th day - 7.0, 22nd day - 7.42, 24th day - 8.3), reaching 8.50 on the 25th day, which corresponds to approximately 85% of the fruit's surface exhibiting signs of shriveling (Table 1). In contrast, the coated group showed a shrinkage index of 5.3 on the 25th day, indicating that only 52.90% of the surface area significantly had shrunk due to the coating. This result was lower than that of the control group. These findings emphasize the effectiveness of CMC coating in preserving passion fruit quality and extending its shelf life. The CMC coatings can effectively delay the aging process, potentially prolonging the fruit's shelf life by postponing anaerobic respiration and fruit metabolism. This enhancement contributes to increasing the appeal of passion fruit to consumers.

Table 1
Shrinkage of passion fruit in both the Control and Coated groups throughout the storage period.

Days	Control		Coated	
	Shrinkage(%)	Shrinkage index	Shrinkage(%)	Shrinkage index
1	0.00	0.00	0.0	0.00
2	0.00	0.00	0.00	0.00
3	1.28	0.15	0.00	0.00
4	4.48	0.48	2.00	0.20
5	8.78	0.82	3.00	0.30
6	10.72	1.08	3.00	0.30
7	19.00	2.80	10.10	1.10
8	33.00	3.30	11.00	1.10
9	35.50	3.55	13.00	1.30
10	43.38	4.34	14.00	1.40
11	43.80	4.38	14.80	1.50
12	44.29	4.43	15.00	1.50
13	45.10	4.51	15.80	1.58
14	50.00	5.00	16.20	1.62
15	56.70	5.67	20.00	2.00
16	58.50	5.90	21.50	2.15
17	60.00	6.00	22.80	2.23
18	65.00	6.50	25.00	2.50
19	68.00	6.80	28.00	2.80
20	70.00	7.00	32.60	3.30
21	72.00	7.20	35.90	3.60
22	74.20	7.42	38.00	3.80
22	76.00	7.60	40.00	4.00
23	80.00	8.00	45.00	4.50
24	82.50	8.30	50.00	5.00
25	85.00	8.50	52.90	5.30

IV. CONCLUSION

In this research, a 3% CMC coating solution emerged as the most effective method for prolonging the post-harvest shelf life of passion fruit, reducing the loss of fresh matter, minimizing shrinkage, and preserving the fruit's edibility over an extended period.

The dip-coating process, the application of this coating on passion fruit surfaces significantly delays both weight loss and softening of the fruit. Furthermore, passion fruits treated with these active ingredients, as compared to untreated ones, can be stored at room temperature for up to 15 days with minimal to no noticeable changes. While these outcomes remain at the laboratory experimentation stage, the simplicity of preparation, ease of application, and eco-friendliness of this coating make it a promising candidate for real-world applications in fruit preservation.

REFERENCES

- [1] N. A. Deshmukh, R. K. Patel, S. Okram, and H. Rymbai, 'Passion fruit (', 1997.
- [2] H. P. Sharma, V. Chaudhary, and M. Kumar, 'Importance of edible coating on fruits and vegetables: A review', ~ 4104 ~ *J. Pharmacogn. Phytochem.*, vol. 8, no. 3, pp. 4104–4110, 2019.
- [3] J. F. Mariani, 'Passion Fruit', *Encycl. Am. Food Drink*, pp. 381–381, 2020, doi: 10.5040/9781635577068-1310.
- [4] R. M. Robles-Sánchez, M. A. Rojas-Graü, I. Odriozola-Serrano, G. González-Aguilar, and O. Martín-Belloso, 'Influence of alginate-based edible coating as carrier of antibrowning agents on bioactive compounds and antioxidant activity in fresh-cut Kent mangoes', *Lwt*, vol. 50, no. 1, pp. 240–246, 2013, doi: 10.1016/j.lwt.2012.05.021.
- [5] R. Rojas, A. A. Vicente, and C. N. Aguilar, 'Advances in preservation of fruits and vegetables with bioactive coatings', *Bol. Cent. Pesqui. Process. Aliment.*, vol. 33, no. 2, pp. 45–58, 2015, doi: 10.5380/cep.v33i2.46231.
- [6] S. Galus, E. A. A. Kibar, M. Gniewosz, and K. Kraśniewska, 'Novel materials in the preparation of edible films and coatings-A review', *Coatings*, vol. 10, no. 7, pp. 1–14, 2020, doi: 10.3390/coatings10070674.
- [7] C. M. P. Freitas, R. C. S. Sousa, M. M. S. Dias, and J. S. R. Coimbra, 'Extraction of Pectin from Passion Fruit Peel', *Food Eng. Rev.*, vol. 12, no. 4, pp. 460–472, 2020, doi: 10.1007/s12393-020-09254-9.
- [8] S. Z. Tesfay, L. S. Magwaza, A. Mditshwa, and N. Mbili, 'Carboxyl methylcellulose (CMC) incorporated with moringa leaf and seed extracts as new postharvest organic edible coating for avocado (*Persea americana* Mill.) fruit', *Acta Hort.*, vol. 1201, no. Cmc, pp. 161–168, 2018, doi: 10.17660/ActaHortic.2018.1201.22.
- [9] I. Kaushik, 'Organogelation: It's Food Application', *MOJ Food Process. Technol.*, vol. 4, no. 2, pp. 58–64, 2017, doi: 10.15406/mojft.2017.04.00088.
- [10] R. K. Dhall, 'Advances in Edible Coatings for Fresh Fruits and Vegetables: A Review', *Crit. Rev. Food Sci. Nutr.*, vol. 53, no. 5, pp. 435–450, 2013, doi: 10.1080/10408398.2010.541568.
- [11] S. M. Mazhari Mousavi, E. Afra, M. Tajvidi, D. W. Bousfield, and M. Dehghani-Firouzabadi, 'Cellulose nanofiber/carboxymethyl cellulose blends as an efficient coating to improve the structure and barrier properties of paperboard', *Cellulose*, vol. 24, no. 7, pp. 3001–3014, 2017, doi: 10.1007/s10570-017-1299-5.
- [12] A. Sarker and T. E. Grift, 'Bioactive properties and potential applications of Aloe vera gel edible coating on fresh and minimally processed fruits and vegetables: a review', *J. Food Meas. Charact.*, vol. 15, no. 2, pp. 2119–2134, 2021, doi: 10.1007/s11694-020-00802-9.
- [13] P. Passiflora *et al.*, 'Yellow (*Passiflora edulis* f. *flavicarpa*) Passion Fruits', 2021.
- [14] R. K. Patel, S. Akath, D. S. Yadav, B. Mousumi, and C. Deka Bidyut, 'Waxing, lining and polyethylene packaging on the shelf-life and juice quality of passion fruit during storage', *J. Food Sci. Technol.*, vol. 46, no. 1, pp. 70–74, 2009.

Introducing a Natural Nutrient Enriched Organic Solid Baby Food to the Sri Lankan Market

L.N.Weerakkody

*Department of Management Studies
University of Vocational Technology
Rathmalana, Sri Lanka
lakmini.n.weerakkody@gmail.com*

H.G.L.L.Padmasiri

*Department of Management Studies
University of Vocational Technology
Rathmalana, Sri Lanka
lakpadmasiri@gmail.com*

J.A.E.C. Jayawardena

*Department of Management Studies
University of Vocational Technology
Rathmalana, Sri Lanka
erandya.jayawardena@uovt.ac.lk*

Abstract – Solid baby foods are defined as weaning food, which is first introduced at the age of 6 months with breastfeeding. In Sri Lanka, it is called “Beribatha” which is enriched with the required nutrients for the baby. However, modern mothers often struggle with time limitations due to work commitments, and the scarcity of 100% organic in reasonable price options further complicates the situation. Therefore the new solid baby food product was introduced to the market enriched in natural nutrients, produced by 100% organic ingredients at an affordable price. Raw materials were selected concerning nutritional value, availability, sensory quality, function, and ability to process under minimal processing conditions. Four types of samples were formulated by considering health guidelines and nutritional composition. The sensory characteristics were evaluated separately using 35 untrained panelists and the best formula (354) was selected. The proximate composition of the selected formula (354) contained 3.3 ± 0.01 % moisture, 8.86 ± 0.05 % crude protein, 2.52 ± 0.02 % Total fat, and 1.45 ± 0.01 % of Ash. A comprehensive shelf life analysis was conducted, revealing that sensory attributes and microbiological counts remained within acceptable levels over a three-month storage period within the laminated metalized wrapper packaging (Material: BOPP 25 Micron + Met CPP 20 Micron). In conclusion, the developed natural nutrient-enriched organic solid baby food exhibits great potential for creating highly consumer accepted infant-based products and it can be introduced as a main meal for babies.

Keywords – solid baby food, organic, nutrient enriched, weaning food

I. INTRODUCTION

Proper nutrient intake from the early stages of infancy is important for the optimal growth and development of a baby. Solid baby foods are defined as weaning, which is first introduced at the age of 6 months with breastfeeding (WHO, 2021). Introducing solid foods at the age of 6 months is the current recommendation of WHO and earlier it was 4 to 6 months according to WHO (WHO, 2021 & WHO, 2011). In Sri Lanka it is called “Beribatha” which is enriched with the required nutrients for the baby. Beribatha is considered one of the most highly-consuming preparations of baby food products and it is one type of high nutrient product. The quality of baby food depends on many factors such as ingredients used for Beribatha preparation, nutrient content of ingredients, and process conditions. Introducing a mix of ingredients to the babies’ food is

important to fulfill the increasing nutritional demand of babies with their age and body weight. Nowadays, it is difficult to find 100% organic foods in the market. According to USDA, organic crops are defined as fresh produce, which is grown on soil without adding any synthetic fertilizer or pesticide. Farm animals who are raised for meat products should be given natural conditions, fed 100% organic feed, and should not be given antibiotics or hormones (USDA,2019) At present, people have a very busy lifestyle as both men, and women work in most families, and some mothers lack knowledge in making baby foods. Therefore, they always look for convenient meals in preparation. When convenience is taken as the priority, preparation time becomes a very important factor. When considering the normal Beribatha making process it takes more than one hour to complete. So that most of them do not tend to make Beribatha at home. Therefore, to protect the nutrients in the raw ingredients, in urban communities, the time devoted to cooking has been shortened by the introduction of increasingly popular "convenience" foods such as solid ready to cook mixes, where most of the work has already been done. It is not simple to replace 100% of functions in Beribatha by using dehydrated ingredients. The functions of the egg, fish, and meat in Beribatha help to gain nutrients for the baby. The newly introduced solid baby food only contains dehydrated plant materials and meat, egg, or fish can be added when preparing the product. The general objective to develop a natural nutrientenriched organic solid baby food (Beribatha) for the infants and specific Objectives are to produce organic raw materials for the solid baby food, to determine the best combination of ingredients to develop the natural nutrient-enriched organic solid baby food and to select the best formulation for the natural nutrient solid baby food.

II. LITERATURE REVIEW

The guidelines outlined by the GMOA emphasize exclusive breastfeeding from birth until 6 months of age, followed by the introduction of complementary foods at 6 months (180 days) while continuing breastfeeding. Findings from the 2010 National Nutrition and Food Security survey (Jayatissa and Hossaine, 2010) revealed that 0.5% of households faced "severe food insecurity," 11.8% experienced "moderate food insecurity," and 87.6% were

classified as "food secure" according to the World Food Program's criteria. Common household consumption patterns indicated widespread use of cereals, roots, tubers, sugar, and coconut. While 78% consumed fish or meat, there were notable disparities based on economic status. The consumption of eggs stood at 35% (IYCF, 2017). The Codex Alimentarius Commission has established Recommended International Standards for infant formula (CAC/RS 72-1976), canned baby foods (CAC/RS 73-1976), and cereal-based foods for infants and children (CAC/RS 74- 1976). In addition, the Commission has issued a Recommended International Code of Hygienic Practice for Food for Infants and Children (CAC/RCP 21-1979).

III. METHODOLOGY

Survey on Consumer Perception The initial phase of this study involved assessing consumer perspectives on ready-to-cook solid baby food product (Beribatha) through a questionnaire. The target demographic for this evaluation was mothers with infants aged 0-36 months. This assessment aimed to gather insights into the market viability of these products in the context of solid baby food development.

Comparative market analysis An analysis of existing baby products in the market was conducted, focusing on key label information such as the intended target group, ingredients, product weight, pricing, and any special information provided on the labels. In this comparative analysis, five prominent products against our newly developed organic solid baby food, "Beribatha" were evaluated.

Raw material selection and preparation According to the health guidelines and WHO guidelines, raw materials were selected to consider the nutritional value, availability, sensory quality, function, and ability to process under minimal processing conditions. The most important thing is that the product is 100% organic. The raw materials were taken from selected organic farmers. For the preparation of solid baby food, Suwadel rice, Dhal, chickpea, Spinach, Carrot, Pumpkin, Potato, and Gotukola leaves were selected to achieve the nutritional requirements. According to the GMP (Good Manufacturing Practices) guidelines, all the processing practices were conducted. The dehydrated raw materials were taken to generate the formulas.

Sample formulation The solid baby food formula was generated considering health guidelines given by the health ministry and general practice of Beribatha preparation method. Different ratios of ingredients were formulated and sample trials were conducted.

TABLE 1: COMPOSITIONAL VARIATION OF THE VARIABLE INGREDIENTS OF SOLID BABY FOOD

Variable Ingredients	Sample_01 (123)	Sample_02 (234)	Sample_03 (345)	Sample_04 (456)
Suwadel Rice	96.6%	96.8%	97.0%	97.5%
Carrot	0.8%	0.7%	0.7%	0.9%
Pumpkin	1.0%	0.6%	0.7%	0.4%
Dhal	0.5%	0.5%	0.5%	0.3%
Potato	0.4%	0.4%	0.4%	0.3%
Chickpea	0.3%	0.3%	0.3%	0.2%
Spinach	0.2%	0.3%	0.2%	0.2%
Gotukola	0.2%	0.4%	0.2%	0.2%

Formulated ingredients were mixed well and prepared for sample trials. The mixture with water is cooked for 40 minutes while it makes a thick mixture. The cooked product samples were taken for the sensory evaluation to select the best formula.

Sensory evaluation Sensory evaluation was conducted to evaluate odour, colour, mouth Feel, taste, and overall acceptability of the developed solid baby food samples. The samples were prepared in uniform sizes. Thirty-five untrained panel members were selected from mothers who have babies 6 to 18 months from Narammala, Avissawella, and Bandaragama areas. The samples were evaluated based on a five point hedonic scale. Sensory data were analyzed using IBM SPSS Statistics 21 software with a 95% confidence interval under the Friedman test.

Selecting suitable packing material The suitable packing material for the developed product selected concerning moisture resistance, light protection, and air barrier properties. The product was first enclosed with a laminated metalized wrapper and a cardboard box was used as the secondary packing material. Packing material combination was BOPP 25 Micron + Met CPP 20 Micron.

Proximate analysis For the proximate analysis total Ash content (AOAC 17th edn official method 923.03), Crude fat content (Using Soxhlet apparatus : AOAC, 922.06), Crude Protein content (Using Kjeldhal apparatus: AOAC 1984b) and total moisture content (AOAC, 2000) of the final sample mixture was analyzed.

Shelf life analysis To determine the shelf life of the final product, the peroxide value and the microbiological analysis including Yeast and mold count (ISO 21527:2008), Presumptive coliform (ISO 4833:2006), and Aerobic plate count (ISO 4833) were analyzed over a 3-month storage duration.

Product price calculation Costing techniques and cost analysis theories used for calculating the price of the final Product price. When deciding the product price, the total cost of materials, labor, depreciation values, electrical, water, bills, and other overheads were considered. After that the profit percentage to the product and margin of the

marketer/ seller were added to get the final retail price of the product.

V. RESULTS AND DISCUSSION

Results of Consumer Perception Survey The sampled participants consisted of mothers with babies aged 0 to 36 months. It was observed that 71% of these mothers encountered challenges while feeding their infants. Conversely, approximately 21% of mothers found baby feeding to be effortless. Impressions about Beribatha's impact on babies varied, with 56% of mothers confirming their babies' satisfaction with the product, while others indicated dissatisfaction. Precisely, 12% of mothers found preparing Beribatha at home to be highly manageable, whereas 17% reported facing difficulties. Meanwhile, 44% held a neutral perspective. The survey findings underscore a prevailing inclination among mothers to take the initiative in preparing Beribatha 3 for their infants and 73% of mothers expressed their willingness to explore novel approaches to Beribatha preparation.

Comparative market analysis The comparative market analysis of baby food products available in the local market and properties were compared with the developed product. All the marketed products are cereal-based foods and can be given as an additional meal to babies, but there is no replacement for the main meal. Unlike the existing products, "Beri batha" stands as a feasible replacement for a primary meal.

Sensory evaluation Formulated ingredients were mixed well and prepared for sample trials. According to the results of sensory evaluation, Sample 4 (formula;456) was the least consumer-preferred sample in all the sensory attributes. Sample 3 (formula;354) can be considered as the most consumer-preferred sample concerning all the sensory parameters.



Figure 1: Formulated sample mixtures for the sample

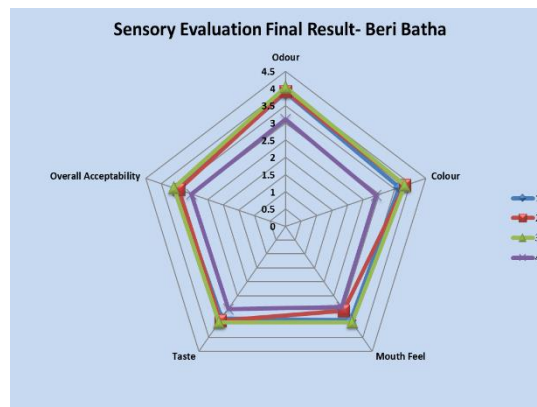


Figure 2 : Descriptive rating chart for sensory evaluation for selection of the best formula for the Solid baby food

Proximate and Shelf-life evaluation According to the results of proximate analysis, the 100 g of the final product contained contained 3.3 ± 0.01 % moisture, 8.86 ± 0.05 % crude protein, 2.52 ± 0.02 % Total fat, and 1.45 ± 0.01 % of Ash.

Microbiological analysis within three months revealed that Aerobic plate count(1.9×10^2 cfu/g), yeast and mold count ($<10^2$ cfu/g), and presumptive coliform count (not detected) were within the acceptable limits, and the peroxide value was negligible within the storage period. After 3 months the sensory attributes of the packaged product (packaged in a laminated metalized wrapper) were evaluated. According to the observation, no changes were shown with previous samples.

Furthermore, in terms of pricing, our newly developed product can be made available at Rs. 490.00 in the retail market. This offering includes 10 servings, with each cup containing 20 grams. Consequently, the cost per cup equates to Rs. 49.00.

V. CONCLUSION

A natural nutrient-enriched organic solid baby food (Beribatha) was successfully developed using dehydrated suwadel rice, Carrot, Pumpkin, Dal, Potato, Chick Pea, Spinach and Gotukola concerning nutritional value, availability, sensory quality, function, and ability to process under minimal processing conditions. Four types of samples were formulated by considering health guidelines and nutritional composition and Sample 3 (formula;354) was selected as the most consumer-preferred sample concerning all the sensory parameters.

The selected formula exhibited a proximate composition including 3.3 ± 0.01 % moisture, 8.86 ± 0.05 % crude protein, 2.52 ± 0.02 % Total fat, and 1.45 ± 0.01 % of Ash. A comprehensive shelf-life analysis was conducted, revealing that sensory attributes and microbiological counts remained within acceptable levels over a three-month storage period.

Recommend to introducing the high-quality and costeffective natural nutrient-enriched organic solid baby food product, "Beribatha," to the market as a primary meal option for infants aged 6-18 months.

REFERENCES

- [1] AACC (1995). Approved Methods of the American Association of Cereal Chemists, 9th edn. Methods 44-15A, 46-12, 08-01, 30-20. St Paul, MN: AACC, Inc, 1995
- [2] AOAC (1980) Official Methods of Analysis, 13th Edn. Association of Official Analytical Chemists, Washington, DC, 1980.
- [3] Commercial foods for infants and young children in the WHO European Region A study of the availability, composition and marketing of baby foods in four European countries; Available from <https://apps.who.int/iris/handle/10665/346581>; 28/08/2021
- [4] Family Health Bureau, Ministry of Health, Nutrition & Indigenous Medicine, National Strategy for Infant and Young Child Feeding Sri Lanka (2015 - 2020), Available from: <https://fhh.health.gov.lk/>
- [5] Feeding your baby: 6–12 months; Available from; <https://www.unicef.org/parenting/food-nutrition/feeding-your-baby6-12-months/>; (28/08/2021)
- [6] Gichau, A.W., Okoth, J.K., Makokha, A. and Wanjala, G.W., 2019. Use of peroxide value and moisture content as a measure of quality for amaranth-sorghum grains-based complementary food. *Nutr Food Technol*, 5, pp.1-5, 2019.
- [7] GMOA, 2013, Complementary feeding 6-12 months, Available from; Available from: <http://www.healthysrilanka.lk/healthy-eating/agerelated-guide/complementaryfeeding>, 2013.
- [8] https://medicine.kln.ac.lk/depts/publichealth/Fixed_Learning/Nutrition. Jayatissa R., Department of Nutrition, Medical Research Institute. 2011
- [9] Improving the nutritional quality of commercial foods for infants and young children of commercial foods for infants and young children in the WHO European Region; available from; <https://www.euro.who.int/en/health-topics/disease-prevention/nutrition/publications/2019/improving-the-nutritional-quality-of-commercial-foods-for-infants-and-young-children-in-the-who-european-region-2019>; 28/08/2021
- [10] Infant and young child feeding practices in Sri Lanka: A desk review and IYCF Practices in Sri Lanka; 2006 – 2017 Sample 1 Sample 2 Sample 3 Sample 4 4
- [11] Infant and young child feeding. Available from; <https://www.who.int/news-room/factsheets/detail/infant-and-youngchild-feeding>; (28/08/2021)
- [12] Infant and Young; Child Feeding Guidelines for Sri Lanka, Faculty of Medicine, University of Kelaniya, Available from:
- [13] Infant and Young; Child Feeding Guidelines for Sri Lanka; Faculty of Medicine, University of Kelaniya; available from; <https://medicine.kln.ac.lk/depts/publichealth/FixedLearning/Nutrition/Guidelines%20on%20Infant%20and%20Young%20Child%20Feeding.pdf>; 28/08/2021
- [14] Kandel, R.F. and Branch, L., 1983. Legislation on Foods for Infants and Small Children. FAO.
- [15] Kuo, A.A., Inkelas, M., Slusser, W.M., Maidenberg, M. and Halfon, N., 2011. Introduction of solid food to young infants. *Maternal and Child Health Journal*, 15(8), pp.1185-1194.
- [16] Maslin, K. and Venter, C., 2017. Nutritional aspects of commercially prepared infant foods in developed countries: a narrative review. *Nutrition research reviews*, 30(1), pp.138-148.
- [17] Nasirpour, A., Scher, J. and Desobry, S., 2006. Baby foods: formulations and interactions (a review). *Critical Reviews in Food Science and Nutrition*, 46(8), pp.665- 681.
- [18] National Strategy for Infant and Young Child Feeding Sri Lanka; Family Health Bureau, Ministry of Health, Nutrition & Indigenous Medicine; 2015 - 2020)
- [19] Nutritional aspects of commercially prepared infant foods in developed countries; Maslin and Venter; 2017
- [20] SLS 1036:2011 Sri Lanka Standard Specification for Processed Cereal Based Products for Infants and Young Children
- [21] Thushara, P.A.N., Godakumbura, P.I. and Prashantha, M.A.B., 2019. Importance, health benefits and bioactivities of Sri Lankan traditional rice (*Oryza sativa* L.) varieties: A review. University of Sri Jayewardenepura, 2019
- [22] Twabi, H.S., Manda, S.O. and Small, D.S., 2021. Evaluating the effect of appropriate complementary feeding practices on child growth in Malawi using cross-sectional data: an application of propensity score matching. *Frontiers in Nutrition*, 8, p.714232, 2021
- [23] World Health Organization, 2017. Guidance on ending the inappropriate promotion of foods for infants and young children: implementation manual.
- [24] World Health Organization. (2021). Infant and young child feeding. Available from; <https://www.who.int/news-room/factsheets/detail/infant-and-young-child-feeding>; (27/08/2021) 69

Development and Sensory Quality Evaluation of Rice Bran Oil Incorporated Ice Cream as a Functional Food

I.G.V.V Gilsinghe

*Department of Agriculture and Food
Technology
University of Vocational Technology
Ratmalana, Sri Lanka
fpt18b113@uovt.ac.lk*

J.A.E.C Jayawardena

*Department of Agriculture and Food
Technology
University of Vocational Technology
Ratmalana, Sri Lanka
erandya.jayawardena.uovt.ac.lk*

Malkanthi Thenabadu

*Department of Agriculture and Food
Technology
University of Vocational Technology
Ratmalana, Sri Lanka
mal.thenabadu@gmail.com*

Abstract— this study is focused on the development of a functional ice cream infused with Rice Bran Oil (RBO). Rice Bran Oil possesses attributes of being odorless, light, and pale yellow, accompanied by a subtle nutty essence. Renowned for its health-enhancing qualities, Rice Bran Oil is commonly referred to as "heart oil" or "healthy oil" due to its well-balanced fatty acid composition, antioxidant content, and bioactive phytochemical constituents. This recognition stems from its capacity to confer physiological benefits, thus positioning Rice Bran Oil as a functional food source. The ice cream formulations created encompassed distinct ratios of ingredients: 50% RBO and 50% Milk Fat (designated as S1), 75% RBO and 25% Milk Fat (S2), and 100% RBO (S3), in addition to a control sample. Following sensory evaluations conducted by an untrained panel comprising 30 individuals, the ice cream variant featuring 100% RBO (S3) garnered the highest preference. Consequently, this chosen formulation was subjected to a comparative analysis against the control sample, encompassing assessments of proximate composition, physical attributes, and physiochemical characteristics. The ice cream variant integrated with 100% RBO displayed a Crude Protein content of $0.83 \pm 0.2\%$ and a Crude Fat content of $11.5 \pm 0.5\%$. Microbiological investigations indicated that parameters such as Total Plate Count, Yeast, and Mold Count, as well as the presence of Coliform bacteria, remained well below the permissible thresholds stipulated by the Sri Lanka Standards (SLS).

Keywords—Rice (*Oryza sativa*), Rice bran, RBO (Rice Bran Oil), Ice cream, Functional food

I INTRODUCTION

Ice cream is a sweetened frozen dairy product preferred as a snack or dessert made of milk and milk products[1]. The number of studies regarding ice cream's functionalization has expanded since people enjoy it enthusiastically and has a convenient structure[2].

Rice (*Oryza sativa*) is the most important staple food for a large part of the world's human population[3]. especially in East and South Asia, the Middle East, Latin America, and the West Indies. For more than half of the global population, particularly in East and South Asia, the Middle East, Latin America, and the West Indies, rice (*Oryza sativa*) is the most important staple food. It is grown in at least 114 countries with a global production of

645 million tons; the share of Asian farmers is about 90% of the total produce[4].

The bran (8–10%) and husk (20%) are separated from rice during the milling process, releasing the 70% starchy endosperm [5].

Among the many byproducts produced during the cultivation of rice, rice bran gets special attention. Because rice bran includes a variety of macronutrients (proteins, lipids, and carbohydrates) along with dietary fibers and the bioactive component. RBO is incredibly nutrient-dense[6]. And rice bran contains carbohydrates (34–62%), lipids (15–20%), protein (11–15%), crude fiber (7–11%) and ash (7–10%). The variety of rice, the environment, and the techniques of processing all affect the composition of rice bran[7]. Due to the increasing worldwide need to provide a food supply and based on its composition, rice bran is considered an inexpensive high-quality lipid and protein source for human consumption[8].

Rice Bran Oil (RBO) can be extracted from rice bran. Considering the oil yield (12%– 18%) and practical refining yield (50%– 70%), RBO is a very precious oil. RBO oil has a slight nutty taste and is odorless and somewhat pale yellow in color[9]. However, the highly active enzyme system found in rice bran is made up of lipoxygenase, peroxidase, and, most importantly, lipase, which is either produced naturally in the bran or as a consequence of microbial activity and activated during grinding. If no stabilizing treatment is done, the bran will decompose naturally and become unsuitable for human consumption in about 6 hours[8].

The main barrier to rice bran's use as a food component is its instability during storage [4]. Therefore, stabilization—an enzyme deactivation process—is frequently used to increase rice bran's shelf life so that we can reintroduce it into our diets[3]. Bran may be a great source of protein, calories, vital fatty acids, and minerals including tocopherols and ferulic acid derivatives if it has stabilized adequately. The most common stabilizing techniques are thermal and chemical treatments.[10].

TABLE 1: FEW METHODS OF RICE BRAN OIL STABILIZATION [10].

Domestic heating methods	Heating conditions	Instruments
Hot air heating	150 ±2 °C, 10 min	Domestic hot air oven (TRIMOND, BO-300D-HT, China)
Roasting	150±2 °C, 10 min	Domestic cooking Pan with a diameter of 60 cm
Steaming	130±2 °C, 60 min	Domestic cooking steamer with a diameter of 60 cm
Microwave heating	150±2 °C, 3 min Power 800 w, frequency 2450 MHz	Domestic microwave oven (Re218H, Sharp, Japan)

Hexane was once the solvent of choice for extracting oils. However, hexane has a significant potential for flammability and toxicity, and when improperly collected, it may potentially pollute the environment. Consequently, a lot of research has gone into developing substitute solvents. These are the short-chain alcohols, and ethanol and isopropanol in particular are very promising because they can be produced from biorenewable sources, have lower toxicity and higher operational safety, can be used to extract high-quality oil, and enhance the defatted meal's functional and sensory characteristics[8].

RBO has a fatty acid composition that is around 0.6 (SFA): 1.1 (MUFA): 1 (PUFA) for saturated (SFA), monounsaturated (MUFA), and polyunsaturated (PUFA) fatty acids. In RBO, palmitic acid makes up the majority of SFA (17.0%–21.5%), whereas myristic and stearic acid are just trace amounts. With around 40% of the total, oleic acid is the primary MUFA, and with about 35%, linoleic acid, an ω -6 PUFA, is the primary PUFA. There is very little ω -3 PUFA linolenic acid present[11]. And Rice bran oil (RBO) has a high concentration of oryzanol, phytosterols, tocopherols, tocotrienols, and other nutrients (proteins, fats, carbohydrates)[6] [12]. Rice bran includes significant amounts of phytosterols, sterolins, and gamma-oryzanol, an antioxidant that may have immune-stiffening properties[13]. It has been shown to modulate cholesterol, hypertension, hyperglycemia, insomnia, and other chronic conditions in a good way. RBO's special properties have made it valuable in a variety of fields, including food, pharmaceuticals, cosmetics, industries, etc. Many people throughout the world are currently interested in expanding the uses of RBO[14].

Since around a century ago, RBO gained popularity in Japan as it is considered a “healthy oil” and is one of the most used vegetable oils in this country. India has also a long tradition of using RBO and, nowadays, the reputation and sale of RBO is rapidly increasing in China, Korea, Thailand, and Vietnam as well[11]. Its calculated as 7% bran obtained from paddy production in 2017 (FAO, 2017) and 20% oil from bran.

TABLE 2: RICE BRAN OIL PRODUCTION, SUPPLY, AND USES IN 2013 (FAOSTAT, 2013) AND MAXIMUM POTENTIAL FOR RBO PRODUCTION)[15][11].

Country	RBO production (KT)	Maximum potential for RBO production (KT) ^a
Sri Lanka	9	35

Consumers are interested in RBO because of its biological properties, nutritional composition, and health benefits, and they hope to see more of it in the future. Many applications, both food and non-food, have grown to rely on the RBO components. Those are, Cooking oil, bakery items, milk, milk-related items, meat products and meat, Emulsifiers, and structured lipids (SLs)[16].

II OBJECTIVES

The principal objective of this study was to develop an ice cream infused with rice bran oil, subsequently assessing its sensory attributes to develop it into a functional food product.

III MATERIALS AND METHODOLOGY

Materials

Rice bran oil mechanically extracted from rice bran by using a mechanical extractor. Ice cream processed by using homogenizer and Ice cream Machine. Ice cream Nutrition analysis carried out by using Kjeldhal machine, Soxhelt extractor. Physiochemical characteristics of ice cream were carried out by using pH meter, Acid base titration and Flow time determination. Microbiology analysis was carried out by using autoclave, laminar floor, incubator, vortex mixture and colonies counter.

Methodology

Selection of raw materials

Rice bran of *Oryza Sativa* - Bg 370 variety used to extract the Rice Bran Oil.

Extraction of rice bran oil

Rice bran oil extracted from rice bran of *Oryza Sativa* - Bg 370 by using a mechanical oil extractor.

Preparation of ice cream incorporating rbo

Different compositions of Rice bran oil used to make ice cream are shown below.

Ice cream fat percentage takes as 12%. Four samples were prepared and named as S1, S2, S3, and Control Sample.

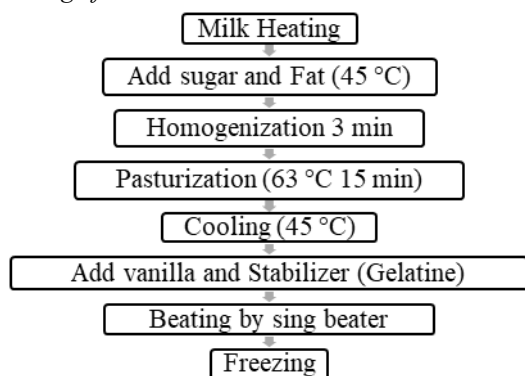
TABLE 3: COMPOSITIONAL VARIATION OF THE PREPARED SAMPLES

List of Ingredients	Amount (500ml of Ice cream mixture)			
	Sample 01 (316)	Sample 02 (423)	Sample 03 (543)	Control Sample (234)
Milk (ml)	310	310	310	310
Sugar (g)	120	120	120	120
Rice Bran Oil (g)	30	45	60	0
Milk Fat (ml)	30	15	0	60
Stabilizers (Cremodan) (g)	8	8	8	8
Vanilla (ml)	2	2	2	2

TABLE 4: Raw Material Composition as a Percentage

Raw material	Percentage (%)
Milk	62
Fat	12
Sugar	24
Stabilizers	1.6
Vanilla	0.4

Processing of Ice cream



Sensory evaluation of RBO incorporated Ice cream

Sensory evaluation was carried out by using sets of samples, with variations in the ingredient's composition and type of the ingredients (Sample 01, Sample 02, Sample 03 and Control Sample). 5 point Hedonic scale test followed for sensory in term of appearance, Odor, Color, Taste, Mouth feel, after taste and Overall acceptability.

In this step, the best treatment from each test will be identified from a sensory panel which consists of 30 untrained panelists by using 5 point hedonic scales. The results were assessed statistically with respect to each sensory stimulus individually. Then the combination that gives the best sensory properties was compared with the control sample and selected.

Proximate analysis of Ice cream

The proximate composition of the selected Ice Cream sample was analyzed for crude protein and crude fat using approved methods of 925.10, 978.04, and 923.03 of the Association of Official Analytical Chemists (AOAC, 2005). Fat content was determined by using Soxhlet apparatus (SER 148, VelpScientifica-Italy,) using petroleum ether as solvent extractor, further followed by evaporation till a constant weight at 103 °C for 30 minutes in the hot air oven. (YCO-010, Gemmy 888, Thaivan). Protein content (N (%) × 6.25) was estimated by the Kjeldahl method (AOAC, 978.04) using a Keldhal digester unit (UDK 139, Velp Scientifica, Italy) and distillation unit (UDK 139, VelpScientifica, Italy). The sample was titrated against 0.2N HCl solutions with the presence of methyl blue and methyl red indicator and the endpoint was recorded.

Physiochemical characteristics

Titrateable Acidity

Titrateable acidity was determined by titrating an ice cream sample and distilled water (2:8) mixture with 0.1N NaOH using a 0.1% Phenolphthalein indicator until a shade of pink color endpoint was observed, the titrateable acidity was finally calculated using the acid factor of lactic acid for each ice cream sample (AOAC,2005).

pH value

The pH was measured after calibration of the pH meter (sensIONTM+PH3, HACH, USA) with standardized pH buffer solutions 4.0, 7.0, and 10.0 before the measurement.

Microbial analysis of ice cream

A microbial study of the RBO-incorporated Ice Cream was carried out by determining Total Plate Count, Yeast and mold count, and Coliforms.

IV RESULTS

Sensory Analysis Results

The best ingredient mix was selected through a sensory evaluation by using 30 untrained panelists from the Department of Agriculture and Food Technology of the University of Vocational Technology - Ratmalana.

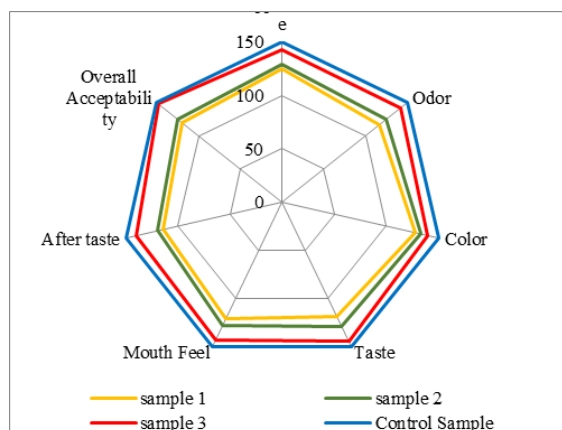


Figure 3: Descriptive rating chart for sensory evaluation for selection of the best formula for the RBO ice cream

As figure shows the sensory evaluation of RBO Incorporated ice cream. The incorporation of 100% rice bran oil (RBO) into the ice cream had a positive effect compared with the control sample on the sensory properties of Ice cream. Sensory analysis data highlighted that the inclusion of the S3 sample resulted in a higher ranking for sensory attributes compared to both Sample 01 and Sample 02.

Proximate Analysis Results

TABLE 5: The fat and protein content of RBO incorporated ice cream and Control Sample.

Properties	Amount (g/100g wet basis)	
	100% Rice bran oil incorporated Ice Cream Sample	Control Sample
Protein (%)	0.83±0.2	1.00±0.2
Fat (%)	11.5±0.5	12±0.5

Microbiology Analysis Results

TABLE 6 : Microbiology analysis results

#	Sample Description	TPC (CFU/g)	Yeast (CFU/g)	Mold (CFU/g)
1	100% RBO incorporated Ice cream	<10	<10	<10
2	Control Sample	<10	<10	<10

#	Sample Description	Coliform
1	100% RBO incorporated Ice cream	Negative
2	Control Sample	Negative



Figure 4: Physical appearance of RBO incorporated ice cream and control sample ice cream

VI. DISCUSSION

As the figure shows the sensory evaluation of RBO-Incorporated ice cream, 100% RBO-incorporated Ice cream (S3 Sample; 543) had a positive effect on the sensory properties of Ice cream. Sensory data revealed that the incorporation of 100% RBO-incorporated Ice cream (S3 sample; 543) leads to a higher rank of all the sensory attributes than other treatments. Physical appearance, odor, color, and mouthfeel were the same in both samples (Control sample and 100% RBO incorporated ice cream). The taste and aftertaste of the 100% RBO-incorporated sample were a little bit different than the control sample and the taste of the 100% RBO-incorporated sample had a mild nutty flavor. According to the proximate analysis Protein content of the 100% RBO incorporated sample was 0.83% ±0.2 and the control sample protein percentage was 1.00% ±0.2. The fat percentage of the 100% RBO-incorporate sample was 11.5% ±0.5. Incorporating 100% rice bran oil (RBO) was a challenge due to its liquid form. The process of integrating RBO into the ice cream mixture required a longer homogenization period than that of the control sample ice cream mixture. The titratable Acidity of the 100% RBO-incorporate sample was 0.14 % ±0.01 and the Titratable Acidity of the Control sample was 0.17 % ±0.01. pH of 100% RBO-incorporate sample was 6.2±0.2 and pH of Control sample was 6.4±0.2. The flow rate of the 100% RBO-incorporate sample was 51±5 and the Control sample was 55±5. The flow rate of the 100% sample little bit lower than the Control sample. TPC, Yeast, and Mold counts of both samples were less than 10 CFU/g and Coliform was negative in both samples. The panelist suggested incorporating different flavors and colors into rice bran oil incorporated Ice cream.

VII. CONCLUSION

Rice bran oil is an underutilized oil in Sri Lanka. RBO uses for many food applications in some Asian Japan, India, China etc. In Japan RBO consider "Hearth oil" "Healthy oil" Due to unique health benefits of RBO. Rice bran oil is a rich source of nutrients and bioactive compounds which are associated with many health benefits. Essential oil, dietary fiber, tocopherol, tocotrienols, and γ-oryzanol are some important nutrients in rice bran with proven health benefits. RBO Associated with several beneficial modulating effects on hypertension, insomnia, cholesterol, hyperglycemia etc.

The study offers a new perspective on the use of Rice Bran Oil incorporated ice cream as a functional food. Sensory

evaluation results showed that different ratios could be used in Rice Bran Oil. And 100% RBO incorporated Ice cream was considered the most organoleptic ally acceptable by the untrained panelists.

Rice bran oil can be successfully used as an alternative for milk fat and vegetable fat. Research regarding functional foods and nutraceuticals must include rice bran and rice bran oil as a major source of bioactive compounds for the development of functional foods. And we should go for this kind of oils to make life healthier.

REFERENCES

- [1] V. Paul, . A., D. C. Rai, S. Pandhi, and A. Seth, "Development of functional ice cream using basil oil microcapsules," *Indian J. Dairy Sci.*, vol. 73, no. 6, pp. 542–548, 2020, doi: 10.33785/ijds.2020.v73i06.005.
- [2] A. Arslaner and M. A. Salik, "Functional Ice Cream Technology," *Akad. Gida*, vol. 18, no. 2, pp. 180–189, 2020, doi: 10.24323/akademik-gida.758835.
- [3] K. Gul, B. Yousuf, A. K. Singh, P. Singh, and A. A. Wani, "Rice bran: Nutritional values and its emerging potential for development of functional food - A review," *Bioact. Carbohydrates Diet. Fibre*, vol. 6, no. 1, pp. 24–30, 2015, doi: 10.1016/j.bcdf.2015.06.002.
- [4] M. K. Sharif, M. S. Butt, F. M. Anjum, and S. H. Khan, "Rice Bran: A Novel Functional Ingredient," *Crit. Rev. Food Sci. Nutr.*, vol. 54, no. 6, pp. 807–816, 2014, doi: 10.1080/10408398.2011.608586.
- [5] J. M. RANDALL *et al.*, "Rice Bran Stabilization by Extrusion Cooking for Extraction of Edible Oil," *J. Food Sci.*, vol. 50, no. 2, pp. 361–364, 1985, doi: 10.1111/j.1365-2621.1985.tb13402.x.
- [6] S. Fraterrigo Garofalo, T. Tommasi, and D. Fino, "A short review of green extraction technologies for rice bran oil," *Biomass Convers. Biorefinery*, vol. 11, no. 2, pp. 569–587, 2021, doi: 10.1007/s13399-020-00846-3.
- [7] M. Alauddin, J. Islam, H. Shirakawa, T. Koseki, Ardiansyah, and M. Komai, "Rice Bran as a Functional Food: An Overview of the Conversion of Rice Bran into a Superfood/Functional Food," *Superfood Funct. Food - An Overv. Their Process. Util.*, 2017, doi: 10.5772/66298.
- [8] M. C. Capellini, V. Giacomini, M. S. Cuevas, and C. E. C. Rodrigues, "Rice bran oil extraction using alcoholic solvents: Physicochemical characterization of oil and protein fraction functionality," *Ind. Crops Prod.*, vol. 104, no. April, pp. 133–143, 2017, doi: 10.1016/j.indcrop.2017.04.017.
- [9] S. Punia, M. Kumar, K. S. Sandhu, and W. S. Whiteside, "Rice-bran oil: An emerging source of functional oil," *Journal of Food Processing and Preservation*, vol. 45, no. 4, Blackwell Publishing Ltd, Apr. 01, 2021, doi: 10.1111/jfpp.15318.
- [10] A. Thanonkaew, S. Wongyai, D. J. McClements, and E. A. Decker, "Effect of stabilization of rice bran by domestic heating on mechanical extraction yield, quality, and antioxidant properties of cold-pressed rice bran oil (*Oryza sativa* L.)," *Lwt*, vol. 48, no. 2, pp. 231–236, 2012, doi: 10.1016/j.lwt.2012.03.018.
- [11] O. M. Lai, J. J. Jacoby, W. F. Leong, and W. T. Lai, *Nutritional studies of rice bran oil*. 2019. doi: 10.1016/B978-0-12-812828-2.00002-0.
- [12] N. P. Nagendra Prasad MN, S. KR, and S. Khatokar M, "Health Benefits of Rice Bran - A Review," *J. Nutr. Food Sci.*, vol. 01, no. 03, pp. 1–7, 2011, doi: 10.4172/2155-9600.1000108.
- [13] M. Friedman, "Rice brans, rice bran oils, and rice hulls: Composition, food and industrial uses, and bioactivities in humans, animals, and cells," *J. Agric. Food Chem.*, vol. 61, no. 45, pp. 10626–10641, 2013, doi: 10.1021/jf403635v.
- [14] Y. Wang, *Applications of rice bran oil*. Elsevier Inc., 2019. doi: 10.1016/B978-0-12-812828-2.00006-8.
- [15] X. Xu and L.-Z. Cheong, "Rice Bran and Rice Bran Oil: Chemistry, Processing and Utilization," 2019.
- [16] U. Garba, R. Singanusong, S. Jiamyangyeun, and T. Thongsook, "Extraction and utilisation of rice bran oil. A review," *Riv. Ital. delle Sostanze Grasse*, vol. 96, no. 3, pp. 161–170, 2019.

Biodegradable Nursery Containers: a Sustainable Solution for Plant Growth

S.L.T. Kumarasingha

*Department of Agriculture & Food Technology
University of Vocational Technology, Ratmalana
lihini97k@gmail.com*

C.J. Abeywickrama

*Department of Agriculture & Food Technology
University of Vocational Technology, Ratmalana
Sri Lanka
chandanaaja@gmail.com*

U.A.S.K. Edirisinghe

*Department of Agriculture & Food Technology
University of Vocational Technology, Ratmalana
Sri Lanka
sagarak@uovt.ac.lk*

Abstract -The global environmental crisis has heightened the need for sustainable alternatives in various industries, especially in agriculture and horticulture. In the plant cultivation field, traditional plastic nursery containers contribute to plastic waste accumulation and environmental degradation, and biodegradable nursery containers have gained significant attention as a sustainable solution. Through a comprehensive literature review, this study investigates the environmental impact, performance, and cost-effectiveness that biodegradable nursery containers offer. Plastic waste is a challenge for sustainable development because large quantities of fossil fuel are used to manufacture plastic containers, which take around 500 years to decompose and increase other environmental issues. Not only that, in Sri Lanka, regarding solid waste disposal, 54.50% of short-term biodegradable waste and 5.90% of long-term biodegradable waste is created as a result of activities in homes and industries and cause large-scale land and water pollution. Meanwhile, waste is a big problem in environmental pollution. Therefore, biodegradable waste needs to be managed as a success for a sustainable environment, it can be made into plantable or compostable containers made from organic materials including livestock manure, postharvest agricultural waste, and agro-industrial residues that break down naturally over time, leaving no harmful residues. Thereof, the development of biodegradable nursery containers made from agricultural waste can reduce farm costs, reduce environmental contamination, and let the roots develop more naturally in the growing media, either outdoors into the ground in an open field or indoors as an eco-friendly solution for plant growth.

Keywords: *biodegradable, nursery container, sustainability, plastic waste, environmental impact*

I. INTRODUCTION

Nursery containers play a vital role in suitable agriculture by facilitating the growth and establishment of seedlings and young plants. Also, many horticultural and agricultural crops are generally cropped in individual biodegradable or non-biodegradable containers in nurseries [1] before transplantation under controlled environmental conditions for very successful cropping [2]. Plastic is the

most commonly used material for containers in nurseries including over 750 million kilograms of petroleum plastic per year. Large quantities of fossil fuel are used to manufacture plastic pots, which take around 500 years to decompose [3,4] which are not biodegradable, difficulties associated with the disposal of synthetic plastics. Not only that, recycling of nursery containers limited because of a lack of infrastructure, ultraviolet degradation, and poor resin quality. As a result most containers are deposited in landfills [5,6] and pose long-term risks of groundwater and soil contamination [7]. Therefore, non-biodegradable waste is creating lots of problems in the environment, and its disposal becoming a great difficulty in municipalities [8,9] including regulatory requirements for environmental clearance [10].

On the other hand, municipal solid waste management is an important problem in the world [11] as well as in Sri Lanka [12]. In Sri Lanka's solid waste management, 54.50% of short-term biodegradable waste and 5.90% of long-term biodegradable waste are the result of activities in homes and industries. However, results of municipal, industrial, and agricultural solid waste and biomass deposits cause large-scale land and water pollution. The effects of landfills and incineration are significant because of their potential for greenhouse gas emissions including methane, carbon dioxide [13]. Therefore, biodegradable waste needs to be managed as a success for sustainable agriculture as well as for a sustainable environment [14]. Therefore, this study summarized the biodegradable waste that proved it could be developed into nursery containers to promote environmental sustainability.

According to those, biodegradable containers are an alternative to plastic containers as a way to improve sustainability [15,16] as well as a solution to the creation of large amounts of plastic waste [17]. Further, bio-degradable containers have important factors such as strongly affecting plant growth [18], water-permeable containers within shorter irrigation intervals, most susceptible to the growth of algae and fungi, ability to plant them without removing the container [19], economically feasible, and also reducing dependence on fossil fuels and reduce emissions of greenhouse gas [6]. Therefore, the use of biodegradable nursery containers made from biodegradable waste can

reduce farm cost, reduce environmental contamination and let the roots develop more naturally in the growing media, either outdoors into the ground in open field, or indoors.

II. LITERATURE REVIEW

Solid wastes in agriculture

Agricultural wastes, which can be defined as a byproduct of farming activities, represent a significant challenge and opportunity for sustainable resource management. They are the residues from the growing and processing of raw agricultural products, including fruits, vegetables, crops, meat, poultry, and dairy products [20,21]. Also, agricultural wastes are the non-product outputs of the production and processing of agricultural products that may contain material. Basically, there are three types of agricultural waste which livestock manure, on which the agricultural land is generally devoted to farm animals like cattle, pig and poultry, then postharvest agricultural waste, which is the primary agricultural waste of husks, straw, and stalks of plant crops after harvest and finally agro-industrial residues, which are secondary residuals produced after processing agricultural crops. Also, the composition of agricultural waste depends on the system and type of activities and can be in the form of solids, liquids, or slurries [22,23].

Based on postharvest and industrial processing waste, cereal production and processing are one of the most important sectors of the food and agriculture industries in Sri Lanka [25], including annual rice production of 2.45 million MT [26] and annual maize production of around 35,000 T [27,28]. Rice husk as well as maize husk and cob are some of the plant residues that are generated in large quantities in processing industry [29], which contain high values of cellulose, hemicellulose, lignin, and ash [19,30].

According to livestock waste, manure can also be used worldwide, not only as a source of plant nutrients but also as fertilizer for soil [31,7]. Further animal manure consists of predominantly urine and feces, although it may contain bedding materials, dropped feed, scurf, and other farming wastes [32]. Also, as a source of organic matter, livestock waste improves the soil quality, especially in organic and sustainable agriculture [33]. Cow manure has useful nutrients that are an effective agronomic fertilizer that can also improve soil health. It contains the primary macronutrients nitrogen, phosphorus, and potassium, as well as secondary macronutrients and several micronutrients [34]. Also, cow manure is used as a soil amendment in agricultural systems that improve the soil structure, fertility, increase the soil organic matter, and help restore depleted organic matter in degraded areas [35,24].

Plastic waste

Plastic waste has become a pressing global environmental issue, posing significant threats to ecosystems, human health, and the overall well-being of the planet. Nevertheless, plastics are the most appealing material used for a wide variety of applications, and more than 400

million tons of plastic are produced every year in the world [13] because of their low price, strong endurance, ease of production, low density, and aesthetic look. In Sri Lanka, plastic generation has become a really big issue, with total plastic waste generated at 938 metric tons per day [36]. As a result of that huge disposal, which is generated in thousands of areas and impacts the lives of both humans and the environment, the disposal is badly affected, making it a big catastrophe in the country because it is not biodegradable, and remains in the environment once disposed of [36]. Due to their unique properties, plastics can hardly be substituted by other materials and, their collection and recycling is the only way to avoid environmental pollution.

However, plastic waste recycling is a method of reducing the quantity of net discards, and plastic recycling also offers the potential to generate demonstrable savings in fossil fuel consumption, both because the recycled plastic can supplement. Also, plastic pollution is a global problem because it can alter habitats and natural processes, reducing ecosystems' ability to adapt to climate change and directly affecting millions of people's livelihoods, food production capabilities, and social well-being [37,38]. Further, the environmental, social, economic, and health risks of plastics need to be assessed alongside other environmental stressors like climate change, ecosystem degradation, and resource use. Therefore, as citizens of Sri Lanka, it is then responsible for all of us to be aware of the impact and the issues that occurred due to the plastic waste and minimize them efficiently [39,13].

Potential of agricultural waste as biodegradable nursery containers

Biodegradable containers are environmentally friendly options for plastic containers for nursery and greenhouse activities that are based on renewable and natural materials derived from waste or by-products of industrial processes [40]. Basically, biodegradable containers can be classified into two main categories according to their form of use: plantable and compostable containers [1].

Plantable containers can be buried altogether, made by peat, coir, cow manure, or straw, with young plants or seedlings directly into the ground, making the transplanting process much faster and easier field clean-up as there is no container disposal. Therefore, the use of plantable containers can reduce farm work effort, cost, and environmental contamination. Plantable containers can also be used to let the roots develop more naturally in the growing medium, either outdoors into the ground in an open field or indoors in larger containers in greenhouse farming, where root spiraling and binding issues can be avoided. Plantable containers go through the biodegradation process; once planted in the ground, they transform to produce biomass and inorganic products [41].

Compostable containers are also used, in which plants must be removed at the moment of transplant and the containers must compost separately, either in the backyard or using industrial facilities [42]. Although compostable containers

are not degraded quickly or completely when they are placed into soil, long-term containers lasting approximately 1 year are made of materials including rice hulls, bio-plastics, cardboard or wood fibers, wheat, soy, and poultry feathers since they are not quickly degraded. Compostable materials are different from those that require industrial composting facilities to break down completely. According to that, the breakdown of industrially compostable containers requires specific conditions of temperature, moisture, pH, aeration, and microbial populations, which are not found in a conventional compost pile [1,40].

Materials for biodegradable containers

A wide variety of materials from renewable and natural sources are used to develop biodegradable containers [2,5,6,7,8] from waste or by-products of industrial processes (Table 1).

TABLE 1. DIFFERENT BIODEGRADABLE MATERIALS AND THEIR APPLICATIONS

Material	Application
Rice and wheat hull fiber	Good water and air exchange between roots and surroundings, shade or lighting, irrigation frequency and containing 35% cellulose, 25% hemicelluloses, 20% lignin, 17% ash and 3% wax
Lignocellulosic residues	To provide the required resistance and consolidate the structure and its porous nature favors water inlet and accumulation
Corn husk	Contained high values of cellulose, hemicellulose, lignin and ash water and carbon dioxide are generated without releasing toxic compounds
Coconut coir	Contains the high lignin and cellulose content, provides a favorable balance between air and water, similar to peat, higher re-wetting capacity, higher pH, lower cation exchange capacity (CEC)
Leather industry wastes	Provide its high nitrogen content
Sunflower cake from oil extraction residues	Rich in proteins that form a dense network, offering thermoplastic properties
Banana peels	Fibrous character helped to good candidate to be combined with other natural materials to obtain bio containers
Bio plastics	Can be easily degraded by microorganism, producing biomass and carbon dioxide and water
Cow manure	Improve soil health which contains the primary macronutrients as nitrogen, phosphorus and potassium, secondary

	macronutrients and several micronutrients, soil amendment in agricultural systems, improving soil structure, fertility and increasing soil organic matter
Poultry feathers	Given by the additional nitrogen (N) that enables plants growth, both in uniform and non-uniform irrigation and fertilization

Importance of biodegradable nursery containers

The importance of biodegradable nursery containers lies in their significant environmental benefits and their positive impact on sustainable gardening and reforestation practices and the implementation of effective waste management practices and solutions will contribute to the preservation of our environment and provide tangible benefits to the farm [4]. Therefore, biodegradable containers are an alternative to plastic containers as a way to improve the sustainability of current production systems [15,16] and as a solution to the generation of large amounts of waste plastic greenhouse containers [17]. Further bio-degradable containers have important factors such as strongly affecting plant growth [18], being water permeable and requiring shorter irrigation intervals and a significantly greater volume of total irrigation to produce a crop, being most susceptible to the growth of algae and fungi, [19], being economically feasible, being economically feasible, and also reducing dependence on fossil fuels and greenhouse gases [6]. Therefore, the use of biodegradable nursery containers made from agricultural waste can reduce farm costs, reduce environmental contamination.

II. CONCLUSION

Biodegradable nursery containers offer a sustainable and environmentally friendly solution for the gardening and horticultural industries. They can be made as plantable or compostable containers from biodegradable waste derived from biological sources, one of which is agricultural waste. Agricultural wastes are the products of the growing and processing of raw agricultural products, including fruits, vegetables, crops, meat, poultry, and dairy products. They can be divided into three categories as livestock manure, postharvest agricultural waste, and agro-industrial residues. Thereof, the development of biodegradable nursery containers made from agricultural waste can reduce farm costs, reduce environmental contamination, and let the roots develop more naturally in the growing media, either outdoors into the ground in an open field or indoors. This not only provides a convenient option for growers but also contributes to the conservation of natural resources and the overall health of our planet. By choosing biodegradable containers, we can support a more sustainable and greener approach to gardening and agriculture.

REFERENCES

- [1] S Barbosa L Castillo, "Biodegradable Pots for Seedlings," Materials Research Foundations, pp. 104-137, 2020.
- [2] AANSA ANWAR KHAN, TARIQ MAHMOOD, and BILQEES BANO, "Development of Bio-decomposable (Jiffy) Pots for Raising and Transplanting Nursery Plants," INTERNATIONAL JOURNAL OF AGRICULTURE & BIOLOGY, vol. 2, pp. 380-381, 2000.
- [3] S Parida, T K Kunhamu, and N Bhol, "Efficacy of Biodegradable Containers in Nursery Raised with Teak Seedlings," Indian Journal of Ecology, vol. 49, no. 5, 2022.
- [4] Hemant Ghai et al., "An Overview on Co-Pyrolysis of Biodegradable and Non-Biodegradable Wastes," 2022.
- [5] Matthew S Helgeson, William R R Graves, David Grewell, and Gowrishankar Srinivasan, "Degradation and Nitrogen Release of Zein-based Bioplastic Containers," vol. 27, no. 2, pp. 123-127, 2009.
- [6] Chengyan Yue et al., "Investigating Consumer Preference for Biodegradable Containers," vol. 28, no. 4, pp. 239-239, 2010.
- [7] Gerard L Velthof, Peter J Kuikman, and Oene Oenema, "Nitrous oxide emission from animal manures applied to soil under controlled conditions," 2003.
- [8] Navid Taghavi, Isuru Abeykon Udugama, Wei Qin Zhuang, and saeid BarouTian, "Challenges in biodegradation of non-degradable thermoplastic waste: From environmental impact to operational readiness," Biotechnology Advances , 2021.
- [9] Venu Malagavelli and P N Rao, "Effect of non bio degradable waste in Concrete slabs," INTERNATIONAL JOURNAL OF CIVIL AND STRUCTURAL ENGINEERING, vol. 1, 2013.
- [10] P Singh and V P Sharma, "Integrated Plastic Waste Management: Environmental and Improved Health Approaches," Procedia Environmental Sciences , vol. 35, pp. 692-700, 2016.
- [11] DISNA EHELIYAGODA and NIMAL PREMATILAKE, "Assessment of a Planned Municipal Solid Waste Management System in Sri Lanka," vol. 20, no. 1, pp. 58-61, 2016.
- [12] Nilanthi J G J Bandara, "Paper Presented at Conference on Developments in Forestry and Environment Management in Sri Lanka," 2022.
- [13] A A D C Amarasinghe et al., "Plastic Waste Management in Sri Lanka," JOURNAL OF RESEARCH TECHNOLOGY AND ENGINEERING, vol. 1, no. 1, 2020.
- [14] Environmental Justice Centre , "Plastic Waste Management," 2021.
- [15] Susmitha Nambuthiri et al., "Substrate Temperature in Plastic and Alternative Nursery Containers," vol. 25, no. 1, 2015.
- [16] Robin G Brumfield et al., "Economics of Utilizing Alternative Containers in Ornamental Crop Production Systems," vol. 25, no. 1, 2015.
- [17] Stephanie A Beeks, "Assessing Biodegradable Containers for Growing Long-Term Greenhouse Crops in Subirrigation System," 2007.
- [18] Jolanta Treinyte, Violeta Grazuleviciene, Danguole Bridziuviene, and Jurgita Svediene, "Properties and behaviour of starch and rapeseed cake based composites in horticultural applications," Estonian Journal of Ecology, vol. 63, no. 1, pp. 15-27, 2014.
- [19] D Ibrahim H. Mondal and Sarmina Mst Yeasmin, "Toxicity study of food-grade carboxymethyl cellulose synthesized from maize husk in Swiss albino mice," International Journal of Biological Macromolecules, pp. 965–971, 2016.
- [20] Rimika Kapoor et al., "Valorization of agricultural waste for biogas based circular economy in India: A research outlook," Bioresource Technology, vol. 304, 2020.
- [21] Muhammad Azri Amran et al., "Value-Added Metabolites from Agricultural Waste and Application of Green Extraction Techniques," 2021.
- [22] F O Obi, B O Ugwuishiwu, and J N Nwakaire, "AGRICULTURAL WASTE CONCEPT, GENERATION, UTILIZATION AND MANAGEMENT," Nigerian Journal of Technology (NIJOTECH), vol. 35, pp. 957-964, 2016.
- [23] A W M F H Amend, "Agricultural Waste Management Systems," 2011.
- [24] Nusrat Iqbal, Amrish Agrawal, Saurabh Dubey, and Jitender Kumar, "Role of Decomposers in Agricultural Waste Management," 2020.
- [25] Nastasia Belc et al., "Cereal supply chain waste in the context of circular economy," 2019.
- [26] S M P Senanayake and S P Premaratne, "An Analysis of the Paddy/Rice Value Chains in Sri Lanka," 2016.
- [27] Maurice E Ephraim, Godwin A Akeke, and Joseph O Ukpatha, "Compressive strength of concrete with rice husk ash as partial replacement of ordinary Portland cement," Journal of Engineering Research , vol. 1, no. 2, pp. 32-36, 2012.
- [28] N F C Ranaweera , G A C De Silva , M H J P Fernando , and H B Hindagala, Maize Production in Sri Lanka., 1988.
- [29] H I Owamah and O C Izinyon, "Optimal combination of food waste and maize husk for enhancement of biogas production: Experimental and modelling study," Environmental Technology & Innovation, pp. 311-318, 2015.
- [30] A T Kanengoni, M Chimonyo, B K Ndimba, and K Dzama, "Potential of Using Maize Cobs in Pig Diets — A Review," vol. 28, pp. 1669-1679, 2015.
- [31] K Kumar, S C Gupta, S K Baidoo, Y Chander, and C J Rosen, "Antibiotic Uptake by Plants from Soil Fertilized with Animal Manure," 2005.
- [32] H E Zhongqi , Paulo H PAGLIARI, and Heidi M WALDRIP, "Applied and Environmental Chemistry of Animal Manure: A Review," vol. 26, no. 6, pp. 779–816, 2016.
- [33] J O Azeez and W Van Averbeke, "Nitrogen mineralization potential of three animal manures applied on a sandy clay loam soil," Bioresource Technology , no. 101, pp. 5645–5651, 2010.
- [34] Mary A Keena and Chris Augustin, "Nutrient Characteristics of Solid Beef Manure in North Dakota," 2021.

- [35] P E Mosebi, W F Truter, and I C Madakadze, "Manure from cattle as fertilizer for soil fertility and rowth characteristics of Tall Fesecue (*Festuca arundinacea*) and Smuts Finger grass (*Digitaria eriantha*)," vol. 27, no. 10, 2015.
- [36] Nihal Cooray, V R S Peris, and K Rasaputra , "National Action Plan of Plastic Waste Management 2021-2023," Ministry of Environment Sri Lanka, 2021.
- [37] Lal Mervin Dharmasiri, "Waste Management in Sri Lanka: Challenges and Opportunities," Sri Lanka Journal of Advanced Social Studies, vol. 9, 2019.[38] J T Hikmath and Udara S.P.R S P R Arachchige, "Future Strategies in Plastic Waste Management in Sri Lanka," JOURNAL OF RESEARCH TECHNOLOGY AND ENGINEERING, vol. 1, no. 1, 2020.
- [39] G P N Gunarathna, N J G J Bandara, and S Liyanage, "ANALYSIS OF ISSUES AND CONSTRAINTS ASSOCIATED WITH PLASTIC RECYCLING INDUSTRY IN SRI LANKA," 2012.
- [40] S Barbosa and L Castillo, "Biodegradable Pots for seedlings," Advanced Applications of Bio-degradable Green Composites, 2020.
- [41] B Tomadoni, D Merino, C Casalongue, and V Alvarez, "Biodegradable Materials for Planting Pots," Materials Research Foundations, pp. 85-103, 2020.
- [42] M Waqas et al., "Optimization of food waste compost with the use of biochar," Journal of Environmental Management, vol. 216, pp. 70-81, 2018.
- [43] Khwanthipha Pandecha, Anan Pongtornkulpanich, Sukrudee Sukchai, and Tawat Suriwong, "Thermal properties of corn husk fiber as insulation for flat plate solar collector," International Journal of Renewable Energy, vol. 10, 2015.
- [44] Barbara Mariotti et al., "Coconut Coir as a Sustainable Nursery Growing Media for Seedling Production of the Ecologically Diverse Quercus Species," 2020.
- [45] Gabriel Emmanuel, Ayoola Brimmo, Matteo Chiesa, and Tuza Olukan, "The Suitability of Unprocessed Coconut Coir as Nursery Growth Media for Seedling Production in Hydroponic System," 2011.
- [46] S M P Senanayake and S P Premaratne, "An Analysis of the Paddy/Rice Value Chains in Sri Lanka," 2016.

Identification of Pathogen Causing Tomato Canker Symptoms: A Sustainable Solution for Healthy Tomato Cultivation

S.L.T. Kumarasingha
Department of Agriculture & Food Technology,
University of Vocational Technology, Ratmalana
Sri Lanka
lihini97k@gmail.com

Abstract-*Clavibacter michiganensis* subsp. *michiganensis* is a causal agent of bacterial canker in tomato. It is a serious concern which drastically decrease, yield and quality of tomato production. Drawing on a comprehensive review of relevant literature, this study analyzed the, identification of tomato canker, symptoms, phytosanitary risk, seed contamination and pathogen transmission and preventive measures. Canker disease can be affected to the plant part or entire plant due to the scab or bird's eye spots appear on fruits, plant leaves necrosis areas, yellowed or dead, steam discoloration and whole plant dead. This disease can spread by practices from transplant production, water splash by rain, overhead irrigation, chemical sprays, and machinery movement, by working people and from wet field. Accordingly, tomato canker, a devastating disease affecting tomato crops globally, poses a significant threat to agricultural production and food security. The effective control measures can be applied including the deployment of resistant cultivars, improved cultural practices and biosecurity protocols and contributes to safeguarding tomato production and enhancing global food supply chains in the face of emerging plant pathogens. This study shed light on the identification of the pathogen causing tomato canker symptoms, nursery management and cultivation emphasizing the practical insights for maintaining healthy tomato cultivation systems while minimizing the impact to avoid the inadvertent plant pathogens spread.

Keywords: *tomato canker, phytosanitary requirements, pathogen transmission, disease management*

I. INTRODUCTION

Bacterial canker of tomato, caused by *Clavibacter michiganensis* subsp. *michiganensis* (Cmm) is a vital issue for tomato cultivators. It is a most serious bacterial disease of tomato as it can drastically decrease yield and quality of tomato fruit, thus loss of the production in greenhouses as well as open field production [1]. Usually between 10² and 10⁴ Colony Forming Unit (CFU) per seed are infected of the quantity of bacteria in averages [2].

As a result of tomato canker disease caused which plant part or entire plant can be affected due to the pathogen can happen scab or bird's eye spots appear on fruits, plant leaves show necrosis areas, yellow or dead areas, plant stems

appear as woody steam, die back, discoloration and at the end fully plant can happen dead [3,4]. This disease generally transmitted from one to another seedling or plants from different practices of transplant production, try and stake of trellis tomatoes, sucker in greenhouses [2], water splash by rain, overhead irrigation or chemical sprays, machinery movement, by working people and from the wet field [4]. Although population of the canker bacteria decrease fleetly from putrid crop residue in the soil, and initiate the conditions in the following and planting season [5]. Further, the seed quality in infected tomato seeds is generally hard to identify from healthy seeds and infected seeds as well as the antedating seedling stage also appears normal [4].



Figure 1:. Appearance of tomato canker disease on fruit, and leaves

Considering the above facts, present study was conducted to identify the tomato canker disease, symptoms, phytosanitary risk, seed contamination and pathogen transmission and preventive measures. This study contributes to advancement of knowledge in plant pathology and offers practical insights to maintain healthy tomato fields while minimizing the impact to avoid the inadvertent transmit of plant pathogens.

A. Identification of tomato canker bacterium

Bacterial disease of tomato canker caused by Cmm [8], is a gram positive, an aerobic, non-motile and curved rod bacterium [9,10]. However, this bacterium quite widely distributed in the EPPO region [4]. The pathogen can be present both on the seed outside as well as seed inside of seed coat [11] and also it can happen survive on the seed coat for up to five years [12]. As the same this pathogen is survived up to 3-4 weeks periods in soil and 24 months in infected plant debris. Usually symptoms of *Clavibacter* are depending on the production place, plant of the infection time, and planting practices, etc. [13]. Different culture methods [14] can be followed [15], to identify of Cmm, which found fluidal, yellow colored colonies shown on nutrient agar medium, [16]. Also Yeast Extract-Dextrose Calcium Carbonate medium is used to culture of *Clavibacter* as non-selective media [17]. Color and clarity of prepared medium is light yellow colored opalescent gel with white precipitate. Cultural characteristics can be observed after an incubation at 25-30°C for 48-72 hours [18,19].



Figure 2. Appearance of *Clavibacter michiganensis subsp. michiganensis* isolate on YDC medium three days after plating
Source: [7]

B. Identification of canker symptoms

As a result of Tomato Canker Disease (TCD) plant part or entire plant can be infected due to the TCD and appear scab or pitting as bird's eye spots appear on fruits by minimizing its economic value [20]. Characteristic of birds-eye spot develop on infected tomato fruits and consist of small, dark cankers with white halos. Disease development, happen unilateral wilting of leaves during the early stages [3,4]. Foliar symptoms sometime show small, white, fester-suchlike spots. Plant leaves shown necrosis areas, yellow or dead areas and interveinal chlorosis which marginal necrosis consist of yellow-to-brown regions [21,6]. In plant stems canker appear as woody steam, die back, discoloration and infected vascular stem tissues appear as mealy appearance of vascular parenchyma. Not only that affected stems can observed a pale yellow-to-reddish brown abrasion of the vascular tissue, and dividing stem into two pieces lengthwise. Infected leaves appear as interveinal, pale green, water-soaked areas which snappily turned yellow-brown to

necrotic, resembling sunburn. Finally, the fully plant can be happened die during the last stage of canker infection [6,7].

C. Phytosanitary risk of Cmm

Tomato canker is a potentially serious complaint of tomato that can do in marketable plantings and domestic auditoriums [1]. Canker disease is capable of transmitting rapidly, resulting in devastating losses where with high disease severity. In the fields as well as greenhouses consist of less than 1% of infected seeds caused 60-70% crop loss [21,6]. Therefore, it is a destructive disease for tomato cultivation to cause major economic lose in worldwide tomato production. Based on that canker pathogen should be conducted of moderate phytosanitary risk due to its worldwide distribution as well as the availability of seed treatments to decrease seed borne inoculum [21,4]. The worldwide dissemination of pathogen is transmitted by contaminated seed lots, in which one infected seed in 10,000 is capable of initiating an epidemic. Although, currently there are no resistant cultivars and there are few of effective chemical controls. Thus, sanitary practices are important for disease control [22].

D. Seed contamination and pathogen transmission

Bacterial canker of tomato transmission happened to other seedling and plants with the practices of transplant production, try and stake of trellis tomatoes, water splash by rain, overhead irrigation or chemical sprays [2]. As a result of canker bacteria transmission, population decline rapidly of crop decomposing in the soil [5]. Tomato canker disease originates from contaminated seed and it is an ecological phenomenon, comprising changes in the currently substrates and production of volatile compounds due to the contamination of microbes in the seed lot. Contamination can be happened under four categories which are biological like dust, the air, human body and pests, physical like soil, chemical and cross contamination the common reasons are improper storage, handling and preparation, poor personal hygiene practices, improper sanitized utensils as well as the contamination by flies, cockroaches, insects and pests. Seed contamination can be identified from seed inspection of the consignment or based on laboratory analysis based on both size of the seed lot and an individual seed [23].

E. Preventive measures to avoid the contamination

Tomato Canker is a bacterial disease and it can severely damage to tomato crops. It causes to yield loss and fruit quality reduction. So in the current situation, indexation of tomato seeds for the canker pathogen is an important step to disease control [24] and use of pathogen-free seeds or sterilized seeds [25]. To avoid the contamination of tomato canker disease, need to encourage strict phytosanitary regulations and fulfill the guidelines for importing and transporting tomato plants, seeds, and other related materials [26]. These regulations should include inspections, certifications, and treatments to ensure that the imported materials are disease-free. Also should implement a quarantine period for imported tomato plants and seeds in

designated areas or greenhouses to prevent potential contamination of local crops. Regularly monitor the isolated plants for any signs of disease and should take immediate action if symptoms appear [27]. Further public awareness should be done that need to educate importers, growers, distributors, and other stakeholders about the risks of tomato canker and the importance of adhering to phytosanitary measures as well as encouraging them to report any suspicious symptoms promptly [28,29].

II. CONCLUSION

The identification of the tomato canker pathogen is very important and the implementation of sustainable disease management practices provide a holistic approach to safeguarding tomato crops. This study contributes to the advancement of knowledge in plant pathology and offers practical insights for maintaining healthy tomato cultivation systems while minimizing the impact.

REFERENCES

- [1] S Milijasevic, B Todorovic, and J Balaz, "Clavibacter michiganensis subsp. michiganensis, Bacterial Canker of Tomato: 1. Conventional and Molecular Identification," researchGate, pp. 185-192, 2006.
- [2] S Umesha, "Occurrence of bacterial canker in tomato fields of Karnataka and effect of biological seed treatment on disease incidence," sciencedirect.com, pp. 375-381, 2005.
- [3] J V Kolomiets, I P Grygoryuk, and L M Butsenko, "Bacterial diseases of tomato plants in terms of open and covered growing of Ukraine," vol. 15, 2017.
- [4] (2018) CABI. [Online]. <https://www.cabi.org/isc/datasheet/15338>
- [5] S Gautam, A Chauhan, R Sharma, R Sehgal, and C K Shirkot, "Potential of *Bacillus amyloliquefaciens* for Biocontrol of Bacterial Canker of Tomato Incited by *Clavibacter michiganensis* ssp. *michiganensis*," 2018.
- [6] E Pfeufer, "Bacterial Canker of Tomato," 2019.
- [7] EPPO, "PM 7/42 (3) *Clavibacter michiganensis* subsp. *michiganensis*," pp. 202-225, 2016.
- [8] Y Sen, J V D Wolf, R G F Visser, and S V Heusden, "Bacterial Canker of Tomato: Current Knowledge of Detection, Management, Resistance, and Interactions," vol. 99, 2015.
- [9] R Tripathi, R Tiwari, and K Vishunavat, "Evaluation of Different Growth Media for *Clavibacter michiganensis* subsp. *michiganensis* and Formation of Biofilm like Structures," International Journal of Current Microbiology and Applied Sciences, vol. 7, no. 5, 2018.
- [10] A Tankeshwar, "Maintenance and Preservation of Pure Cultures of Bacteria," 2019.
- [11] L De Leon, F Siverio, M M Lopez, and A Rodriguez, "Clavibacter michiganensis subsp. *michiganensis*, a seedborne Tomato Pathogen: Healthy Seeds Are Still the Goal," American hytopathological Society, vol. 95, 2011.
- [12] J Bonkowski, "Clavibacter michiganensis subsp. *michiganensis*," 2006.
- [13] A Mcleod, T Masimba, T Jensen, K Serfontein, and S Coertze, "Evaluating spray programs for managing copper resistant *Pseudomonas syringae* pv. *tomato* populations on tomato in the Limpopo region of South Africa," Crop Protection, pp. 32-42, 2017.
- [14] R A Bennett and E Billing, "Origin of the Polysaccharide Component of Ooze from Plants Infected with *Eutvinia amylovora*," Journal of General Microbiology, vol. 116, pp. 341-349, 1980.
- [15] E R Sanders. (2012) NCBI. [Online]. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4846335/>
- [16] S Aryal. (2018) Microbiology Info.com. [Online]. <https://microbiologyinfo.com/nutrient-agar-composition-preparation-and-uses/>
- [17] M Uthayasooryan, S Pathmanathan, N Ravimannan, and S Sathyaruban, "Formulation of alternative culture media for bacterial and fungal growth," vol. 8, no. 1, pp. 431-436, 2016.
- [18] (2015) Himedia. [Online]. <http://himedialabs.com/TD/M1182.pdf>
- [19] DuchefaBiochemie. [Online]. <https://www.duchefa-biochemie.com/product/details/number/Y5136>
- [20] A Burger et al., "Identification of homologues to the pathogenicity factor Pat-1, a putative serine protease of *Clavibacter michiganensis* subsp. *michiganensis*," Sciencedirect, vol. 160, pp. 417-427, 2005.
- [21] G A Shaker, "IDENTIFICATION OF THE BACTERIUM TOMATO STEM CANKER," American Journal of Infectious Diseases, vol. 10, no. 1, pp. 44-49, 2014.
- [22] M A Tancos, L Chalupowicz, I Barash, S M Sasson, and C D Smart, "Tomato Fruit and Seed Colonization by *Clavibacter michiganensis* subsp. *michiganensis* through External and Internal Routes," Applied and Environmental Microbiology, vol. 79, no. 22, 2013.
- [23] A M Kasselaki et al., "Effect of alternative strategies for the disinfection of tomato seed infected with bacterial canker (*Clavibacter michiganensis* subsp. *michiganensis*)," NJAS - Wageningen Journal of Life Sciences, vol. 58, pp. 145-147, 2011.
- [24] S Milijasevic, B Todorovic, E Rekanovic, I Potocnik, and J Balaz, "Clavibacter michiganensis subsp. *michiganensis*, Bacterial Canker of Tomato: 2. Comparison of the Effectiveness of Extraction Procedures and Sensitivity of Methods for Detection in Tomato Seeds," vol. 22, pp. 121-130, 2007.
- [25] M T Al-mohanna, "STERILIZATION AND DISINFECTION," 2016.
- [26] Mary K Bryan, "Studies on bacterial canker of Tomato," Journal of Agricultural Research, vol. 41, pp. 825-851, 1930.
- [27] Aderaje R Oloyede, Chiedu J Ogbuagor, Clement G Afolabi, and A K K Akintokun, "Biological control of bacterial canker of tomato (*Lycopersicon esculentum* Mill.) by use of non-native strains of plant growth-promoting rhizobacteria," vol. 54, no. 15-16, 2021.
- [28] Raj Utkhede and Carol Koch, "Biological treatments to control bacterial canker of Biological treatments to control bacterial canker of," pp. 305-313, 2004.
- [29] Kailash Agrawal, Dilip Kumar Sharma, and Vinod Kumar Jain, "SEED-BORNE BACTERIAL DISEASES OF TOMATO (*LYCOPERSICON ESCULENTUM* MILL.) AND THEIR CONTROL MEASURES: A REVIEW," International Journal of Food, Agriculture and Veterinary Sciences, vol. 2, pp. 173-182, 2012.
- [30] A Tankeshwar, "Colony Morphology of Bacteria," 2021.

A Comprehensive Review of Production Methods, Nutritional Properties, Applications, and Future Perspectives of Single Cell Protein Technology

K.P.S.W. Karunarathne

*Department of Agriculture and Food Technology
University of Vocational Technology
Sri Lanka.*

sulochanawimali@gmail.com

D.M.M.M. Premarathna

*Department of Agriculture and Food Technology
University of Vocational Technology
Sri Lanka.*

sankafernandoz12@gmail.com

Malkanthi Thenabadu

*Department of Agriculture and Food Technology
University of Vocational Technology Sri Lanka.*
mal.thenabadu@gmail.com

Abstract— This review aims to explore the production methods, nutritional properties, applications, and prospects for the future of Single Cell Protein. The review will provide an in-depth understanding of SCP production methods, highlight its nutritional properties, examine its various applications, and discuss potential future directions for research and development in the field. Single-cell protein (SCP) has gained significant attention as a promising alternative protein source due to its efficient production methods, favorable nutritional properties, diverse applications, and potential contributions to addressing global food security challenges. This comprehensive review aims to provide an in-depth analysis of SCP, covering its production methods, nutritional composition, applications in various sectors, and future perspectives. The review synthesizes existing literature and highlights key SCP research and development advancements.

Keywords— *Single cell protein, SCP, Submerged fermentation, Semi-solid-state fermentation*

I. INTRODUCTION

Single Cell Protein (SCP) plays a vital role in addressing protein scarcity and utilizing waste sources, offering a sustainable solution to meet nutritional needs, reduce environmental impact, foster food security, and create economic opportunities in the biotechnology sector[1] [2].

The review will provide an in-depth understanding of SCP production methods, highlight its nutritional properties, examine its various applications, and discuss potential future directions for research and development in the field.

The escalating global population has led to a significant protein shortage, making SCP an unconventional protein source with the potential to address this challenge. SCP, derived from microbial cell culture, encompasses [3]deceased or desiccated microbial cells or proteins isolated from various microorganisms grown on diverse carbon substrates[1]. By utilizing microbial fermentation techniques,

SCP can be produced from waste sources, minimizing associated environmental consequences[4] [5]. Single Cell Protein (SCP) plays a vital role in Sri Lanka, addressing protein scarcity and utilizing waste sources[6]. It offers a sustainable solution to meet nutritional needs while reducing environmental impact, fostering food security, and creating economic opportunities in the biotechnology sector[7].

The escalating global population has given rise to a significant protein shortage, posing a critical challenge. In response, Single Cell Protein (SCP) emerges as an unconventional protein source with the potential to address nutritional demands[8]. In the realm of pure microbial cell culture, SCP encompasses deceased, desiccated microbial cells or the entirety of proteins derived from yeast, bacteria, filamentous fungi, and algae cultivated on diverse carbon substrates. By harnessing microbial fermentation techniques, SCP can be derived from an array of waste sources, thereby mitigating associated adverse environmental consequences[9, 10].

II. BACKGROUND

Single-cell protein encompasses unprocessed or processed protein [11] derived from pure microbial cultures, dried cell biomass, or deceased cells [12] [13]. Algae, fungi, yeast, and bacteria, among microorganisms, contain a significant amount of protein in their biomass Low-cost materials such as agricultural residue, wood shavings, sawdust, maize cobs, and even human and animal waste can be employed for the production of single-cell protein (SCP) [12, 14]. Microorganisms are desirable protein sources due to their rapid growth rates compared to higher plants[5] [15]. Microbes have been historically used as protein sources in traditional foods and feeds, contributing to their nutritional qualities[16]. While petroleum is frequently employed as the primary carbon source for single-cell protein (SCP) production, viable substitutes comprise bagasse, citrus

byproducts, sulfite waste liquor, molasses, animal manure, whey, starch, sewage, and agricultural leftovers[17] [18].

Various types of microorganisms are employed in the synthesis of single-cell protein (SCP), including bacteria like *Cellulomonas* and *Alcaligenes*, algae such as *Spirulina* and *Chlorella*, molds like *Trichoderma*, *Fusarium*, and *Rhizopus*, and yeast strains including *Candida* and *Saccharomyces*[19] [11]. Yeast proves to be a favorable choice for the production of single-cell protein (SCP) due to its excellent nutritional value, elevated lysine content, substantial size, which facilitates easier harvesting, and its capability to thrive in environments with low pH levels [11, 20]. Moreover, due to their extensive history of usage in conventional fermentation, yeast, and fungi are the microorganisms that are most often approved and used for the synthesis of SCP[21].

Additionally, yeast has its own drawbacks, such as slower growth rates (2–5 h) than bacteria, reduced protein (45–65%), and lower methionine concentrations[22] [23]. Methionine can be added to the finished product to make up for yeast having less methionine than bacteria[24] [25]

Microbial protein, often referred to as SCP (Single-Cell Protein), has garnered widespread acclaim for several reasons. These include its substantial protein content, which ranges from approximately 60-82% of dry cell weight, remarkable substrate conversion efficiency, elevated productivity due to the rapid growth of microorganisms, and its independence from seasonal or climate-related factors[26].

While microorganisms can be harnessed in the creation of single-cell protein (SCP), SCP itself does not necessitate a wide array of fundamental ingredients. Specific vital amino acids, like lysine and methionine, which are limited in many plant and animal diets, are plentiful within SCP[27, 28].

Single-cell protein encompasses protein in its raw, purified, or consumable form, derived from pure microbial cultures, deceased, or desiccated cell biomass[15, 29]. These microorganisms, including algae, fungi, yeast, and bacteria, possess biomass with exceptionally high protein content, and they can serve as protein supplements for both human and animal consumption[1]. Affordable materials like agricultural remnants, such as wood shavings, sawdust, maize cobs, and even human and animal waste, can be employed to cultivate these bacteria [30].

Microorganisms are highly favored as sources of high-protein crops due to their rapid growth compared to larger plants[18]; while only one or two grain crops can typically be grown in a year, yeasts or molds can be harvested weekly, and bacteria can be collected daily. The use of microbes as a protein source for human and animal nutrition is not a recent development. Traditional foods and feeds like cheese, sauerkraut, miso, and silage have long contained significant microbe content, contributing to their nutritional value[19, 31]. Petroleum is the primary carbon source used in the manufacturing of SCP [37]. It has been used in several businesses all around the world [19].

Additional potential materials for the production of single-cell protein (SCP) encompass bagasse, citrus byproducts, sulfite waste liquor from pulp and paper processing, molasses, animal waste, whey, starch, sewage, and agricultural leftovers [2][15] [38].

With the arising of novel technologies, most of the impossible artefact become more possible. One of the novel technologies carry single cell protein concept which is really advanced and facilitate to people to fulfill their needs. This review depicts about the advancement of the single cell protein concept and the pros & cons in the technology and the other impacts and aspects in details. [35][44]

The escalating global population has given rise to a significant protein shortage, posing a critical challenge. In response, Single Cell Protein (SCP) emerges as an unconventional protein source with the potential to address nutritional demands. In the realm of pure microbial cell culture, SCP encompasses deceased, desiccated microbial cells or the entirety of proteins derived from yeast, bacteria, filamentous fungi, and algae cultivated on diverse carbon substrates [1]. By harnessing microbial fermentation techniques, SCP can be derived from an array of waste sources, thereby mitigating associated adverse environmental consequences [9] [1] [31] [14].

III. OBJECTIVES OF THE STUDY

This review aims to explore the production methods, nutritional properties, applications, and prospects for the future of Single Cell Protein. With the emergence of novel technologies, SCP has become an advanced solution that facilitates meeting people's nutritional needs. The review will provide an in-depth understanding of SCP production methods, highlight its nutritional properties, examine its various applications, and discuss potential future directions for research and development in the field.

IV. METHODS

Databases and Search Strategy

The search criteria for the article included the exact phrase "Single Cell Protein" in the title, abstract, and keywords. In SCOPUS database. Only articles in the final publication stage were considered, and the publication years were limited to 2000-2022 to gather relevant and up-to-date information.

The search was restricted to articles and reviews, ensuring comprehensive coverage of the topic. English-language articles were included for accessibility and understanding. The search specifically targeted journal articles, as they provide scholarly and in-depth information. By applying these criteria, the resulting articles would focus on the topic of Single Cell Protein, encompass a wide range of years, and provide insights into production methods, nutritional properties, applications, and future perspectives. This initial search criteria resulted in more than 500 research articles, which were later reduced to 82 by considering the single cell protein applications in food Industry. The studies under consideration underwent initial evaluation based on their

titles and abstracts. Subsequently, a thorough examination of the full texts was carried out to pinpoint studies aligning with the primary themes of the review.

V. RESULTS AND DISCUSSION

Trends in Publication

The trend in research publications related to Single Cell Protein (SCP) has shown a significant upward trajectory over the years, signifying a growing interest in the subject. The number of SCP publications experienced a gradual increase from 2000 to 2008, with varying annual output levels. However, starting from 2010, there was a substantial surge in publications, with a consistent rise in the number of articles each year [50][50].

The years 2020 and 2021 were particularly remarkable, witnessing a substantial increase in SCP publications, with 83 and 93 articles, respectively. This upward trend continued into 2022, with 139 publications, underscoring the increasing recognition and importance of SCP as a prominent research focus in recent years [53].

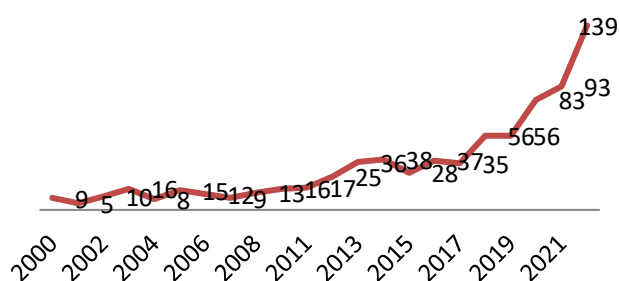


Figure 1: Publication trend over the years of 2000-2022 on CSP

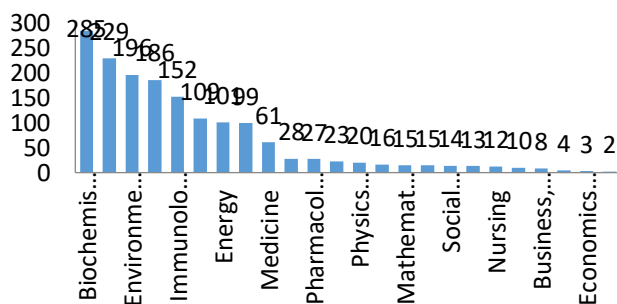


Figure 2: Disciplines on CSP research

Disciplines of SCP research

The initial search results indicate a diverse range of publications in SCP Biochemistry, Genetics, and Molecular Biology have the highest number of publications, followed by Agricultural and Biological Sciences, Environmental Science, and Chemical Engineering. This suggests a strong focus on biological and environmental aspects of Single Cell

Protein (SCP) research. Other disciplines, such as Immunology and Microbiology, Engineering, Energy, and Chemistry, also contribute significantly. However, it is worth noting that SCP research has a smaller presence in disciplines like Economics, Decision Sciences, and Business, Management, and Accounting. These results highlight the interdisciplinary nature of SCP research and the importance of collaboration between different fields for a comprehensive understanding and application of SCP

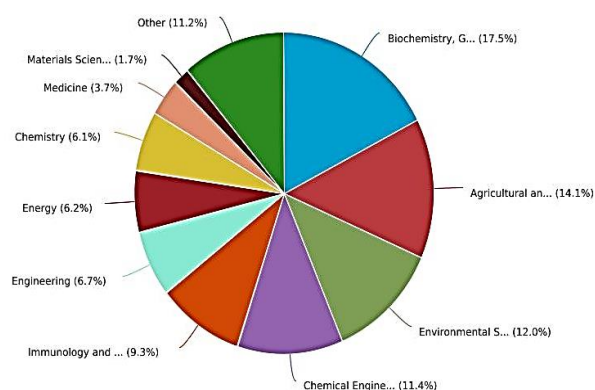


Figure 3: SCP research summarize

Historical Perspective on Single-Cell Protein

When traditional meals were scarce during the war, SCP production was first pioneered. During World War I, Germany significantly increased its production of *Saccharomyces cerevisiae* using molasses to substitute for up to 60% of imported protein. A substantial production of *Candida utilis* (formerly referred to as *Torula yeast* or *Torulopsis utilis*) using sulfite liquor from paper industry waste took place once more during World War II. Following the war, additional facilities were established in both the United States and Europe, primarily for the production of *C. utilis* [4][5].

The resurgence of interest in Single Cell Protein (SCP) is driven by the rapid growth of industry and improving living standards. This renewed interest aims to bridge the widening gap between global food production and the burgeoning population, especially in developing countries. During the 1960s and 1970s, numerous SCP production facilities were established in countries such as the UK, France, Italy, the USSR, Japan, and Taiwan[32].

When various petroleum firms proved the creation of SCP from hydrocarbons in the 1950s and 1960s, it represented a significant scientific advance. As a result of extensive research efforts in the 1970s, petroleum-derived methanol and ethanol were used as practical substrates.[36][38]

The use of renewable sources, mostly food and agricultural by products like molasses and whey, or industrial wastes rich in starch, cellulose, and hemicellulose, has gained attention again, however, as a result of concerns about substrate safety and the rise in petroleum prices. In the 1980s, the major SCP

initiatives using petroleum derivatives as substrates were shelved[32].

Types of Single-Cell Protein

Bacterial sources

Bacteria have a relatively low generation period because their cell masses grow swiftly in just 20 to 120 minutes. They can also grow on a variety of basic materials, including sugars and starches, which are edible substrates. Waste organic material and petrochemicals, such as ethanol, methanol, and nitrogen, are excellent breeding grounds for bacteria.

They can also proliferate in naturally occurring water that has been supplied with minerals and nutrients to make up for any nutrient deficiencies necessary for their growth. An advantageous element in animal feed comprises certain bacteria like *Methylophilus* spp., characterized by an exceptionally rapid generation time of approximately 2 hours. Moreover, their protein quality surpasses that of any yeast or fungus from a chemical perspective.

Many bacterial varieties, such as *Brevibacterium*, *Methylophilus methylotrophicus*, *Bacillus megaterium*, *Acinetobacter calcoaceticus*, *Acromobacter delvaevae*, *Aeromonas hydrophila*, and *Cellulomonas* spp., are found and possess the potential to generate substantial quantities of single-cell protein [33].

Algal sources

For human and animal use, certain varieties of microalgae are grown because they often provide healthy protein levels of up to 70%. They are valuable sources of lipids, notably omega-3 fatty acids, mineral salts, vitamins, and chlorophyll, alongside their protein content. However, their nucleic acid concentration, ranging from 3% to 8%, is relatively low[23].

In the vicinity of Texcoco, several Mexican and African people gathered an algae species known as *spirulina*. To make it suitable for human consumption, it was subjected to a drying process. In various regions worldwide, biomass from different species like *Chlorella* and *Senedesmus* has also been utilized as a food source[13, 15]. Their extensive use as a component in animal feed globally can be attributed to their high protein content, rapid growth, ease of cultivation, and efficient utilization of solar energy. An excellent antioxidant is green algae[33].

Fungal sources

An array of fungal species is employed in the production of single-cell proteins (SCPs). Thanks to their chemical composition and amino acid profile, protein derived from specific fungal species is preferred over protein from alternative sources. When cultivated primarily for SCP production, fungi can contain protein levels ranging from 30% to 50%[13].

Their amino acid composition aligns with the standards set by the FAO. Their protein content is abundant in lysine and threonine but lacks in cysteine and methionine, which are

sulfur-containing amino acids primarily found in plant-based sources. Nevertheless, the fungus *K. fragilis* demonstrates the capacity to synthesize sulfur-containing amino acids when it thrives on whey[15, 23].

The single-cell protein produced by fungi may also contain various nutrients apart from protein alone. These nutrients include riboflavin, niacin, thiamine, biotin, pantothenic acid, choline, pyridoxine, glutathione, p-amino benzoic acid, streptogenin, and folic acid, predominantly from the vitamin B-complex. Nevertheless, consumption of mycoprotein derived from *Fusarium venenatum* resulted in a reduction in insulin and blood glucose levels. In contrast to algae, fungi have a relatively higher nucleic acid content, ranging from 7% to 10% [33].

Production process of SCP

Technically speaking, single-cell protein (SCP) refers to the generation of microbial cell mass through the cultivation of microorganisms on readily available agricultural and industrial residues. Microbial biomass is produced through either submerged or solid-state fermentation methods. After the fermentation process, the biomass is harvested and can undergo procedures such as washing, cell disruption, protein extraction, and purification[34].

The extensive and substantial advancement of SCP techniques has greatly contributed to the progress of contemporary biotechnology [35] various fields such as microbiology, biochemistry, genetics, chemical and process engineering, food technology, agriculture, animal nutrition, ecology, toxicology, medicine, veterinary science, and economics have been employed in the exploration and enhancement of SCP procedures[15].

As single-cell protein (SCP) processes progress, they lead to the development of novel technological solutions that benefit related fields like wastewater treatment, alcohol production, enzyme technology, and nutritional science. Achieving cost reduction and quality enhancement through fermentation, downstream processing, and the refinement of producer organisms, facilitated by conventional applied genetics and recombinant DNA technologies, will play a pivotal role in shaping the future of SCP[9].

Single-cell proteins find applications in animal nutrition, such as enhancing the diets of calves, poultry, pigs, and fish, as well as enhancing the nutritional content of baked products. Additionally, they are incorporated into dietary formulations, soups, pre-packaged meals, foam stabilizers, paper manufacturing, leather processing, and various other industrial applications[36].

Single-cell protein is generated through a fermentation process. This involves the cultivation of selected microorganism strains on suitable raw materials in a specialized cultivation procedure aimed at scaling up the culture and cell mass, followed by cell separation. The process begins with microbial screening, in which potential production strains are identified from samples of soil, water,

air, or from swabs of inorganic or biological materials. These strains are subsequently enhanced through genetic methods like selection and mutation[23].

Next, an analysis of all metabolic routes and cellular structures is conducted, and the optimal strains are identified along with the technical cultivation conditions. Furthermore, process engineering and equipment technology are employed to enhance the technical efficiency of the process in preparation for large-scale application. Economic considerations, including cost and energy factors, come into play at this stage[11].

In the production of SCP, environmental considerations and safety standards are carefully considered for both the manufacturing process and the end product. Ultimately, safety and intellectual property protection raise legal and regulatory concerns, including operational licenses, product approvals for specific applications, and the legal safeguarding of novel processes and microbial strains[36].

As nearly all microorganisms have the capability to metabolize glucose, as well as a range of hexose and pentose sugars, along with disaccharides, these substances serve as the conventional source materials[5]. The cost-effectiveness of the production of microbial biomass is questioned because these materials are also used in other sectors of industry at high prices. The design and strategy of SCP procedures have been influenced by the selection of substrates that are typically in abundance[20].

Cultivation methods

Single cell protein production occurs through a fermentation process involving carefully chosen strains of microorganisms. These strains are propagated on appropriate raw materials in a technical cultivation process designed to foster culture growth and cell mass expansion, which is subsequently followed by separation procedures[37-39]. The process initiation involves microbial screening, wherein viable production strains are sourced from samples of soil, water, air, or collected from swabs of inorganic or biological materials. These strains are then refined through techniques such as selection, mutation, or other genetic methods for optimization[7].

Next, the cultivation conditions for the optimized strains are established, and a thorough analysis of all metabolic pathways and cell structures is conducted. Additionally, process engineering and equipment technology are employed to refine the technical efficiency of the production process for large-scale application. This is the stage where economic considerations, including energy and cost factors, become significant[35, 40].

Considerations for safety standards and environmental conservation are integral to the SCP production, covering both the production process and the end product. Additionally, the pursuit of safety and the protection of innovations introduce legal and regulatory considerations, such as the issuance of operational licenses, approvals for

specific product applications, and legal measures to protect novel processes and microbial strains[41].

Submerged fermentation

In a submerged process, the fermentation substrate always remains in a liquid state, containing the necessary nutrients for growth. The fermenter, housing the substrate, operates continuously, and the resulting biomass is continually harvested through various techniques. Subsequently, the product undergoes filtration or centrifugation before the drying process.

Aeration plays a vital role in cultivation to dissipate the heat generated during the process, which is managed using cooling devices. Different methods are employed to harvest microbial biomass. Single-cell organisms like yeast and bacteria are separated through centrifugation, while filamentous fungi are isolated via filtration. It is imperative to recover as much water as possible before the final drying stage, which is carried out under sterile and sanitary conditions[41].

Semi solid state fermentation

Semisolid fermentation uses more solid substrates, such as cassava waste, and does not clean the substrate before use. Fermentations in submerged cultures have higher startup costs and higher operating expenses[23].

In a multiphase system, effective stirring and mixing are essential, as it facilitates the transfer of oxygen from gas bubbles to the microorganisms within the liquid phase and enables the transfer of heat from the liquid phase to the surrounding environment during the cultivation process.

The U-loop fermentor is a specialized bioreactor designed for studying the transfer of mass and energy phenomena[42]. The fundamental steps in single-cell protein production encompass the preparation of a suitable medium with the appropriate carbon source, the prevention of contamination in both the medium and the fermentor, the cultivation of microorganisms with desired characteristics, and the subsequent separation and processing of the synthesized biomass[43, 44]. Carbon sources can include N-alkenes, gaseous hydrocarbons, methanol, ethanol, as well as renewable sources like carbon oxide molasses, polysaccharides, brewer's effluents, and other solid materials[29, 41].

Solid state fermentation

Solid-state fermentation (SSF) has been a significant focal point in extensive research endeavors, yielding a plethora of publications that explore a wide array of aspects. These facets encompass innovative bioreactor designs, precise process parameters, and a diverse range of microorganisms harnessed to produce an impressive spectrum of value-added products. Notable outputs from SSF include Single Cell Protein (SCP), animal feeds, enzymes, ethanol, organic acids, B-complex vitamins, pigments, and flavors [6, 13].

The SSF process begins by placing a solid culture substrate, such as rice or wheat bran, onto flatbeds, followed by the introduction of microorganisms to initiate the transformative journey. This concoction is then carefully housed within a controlled temperature environment, where it undergoes a metamorphic transformation over several days.

In stark contrast, liquid-state fermentation unfolds within tanks, often of considerable size, stretching from 1,001 to 2,500 square meters (10,770 to 26,910 square feet) in industrial-scale applications. This mode of cultivation is tailor-made for nurturing unicellular organisms like bacteria and yeasts [17].

Crucially, sustaining a continuous supply of oxygen to the microbes is imperative to realize liquid aerobic fermentation. This vital oxygenation is frequently achieved through the agitation of the fermentation medium. Moreover, meticulous control over a spectrum of variables, including nutrient levels, soluble oxygen, pH, ionic strength, and temperature, is indispensable for precise management of the synthesis of the desired metabolites [41].

Criteria for the selection of microorganism

To achieve substantial output in terms of biomass weight produced within a specific timeframe, it becomes necessary to employ rapidly replicating microorganisms. However, this heightened productivity leads to increased RNA production within the cells, which is undesirable due to its negative impact on the final product's nutritional value [38] [39]. In this context, a crucial parameter is the biomass yield coefficient, which quantifies the total weight of newly generated cells per unit of substrate consumed [47].

Especially when dealing with expensive substrates, this condition proves immensely beneficial. Slower growth rates result in higher substrate consumption and reduced output, ultimately compromising the yield coefficient [33].

Microorganisms exhibit varying levels of heat shock tolerance, which can confer resilience to a range of challenges when different microbial species are subjected to heat shock. This acquired stress resistance, though potentially detrimental under normal circumstances, is a notable trait possessed by these cells. Stress tolerance can be developed through various treatments, such as exposure to chemicals or heat [32].

The use of these treatments also triggers the production of a distinct class of proteins known as heat shock proteins. Whether aerobic or anaerobic, cells experience oxidative stress after a brief 30-minute heat shock at 37°C [33]. The lipid composition of cell membranes plays a critical role in determining their sensitivity to both oxidative and thermal stress. Each organism possesses a unique capacity to adapt to temperature fluctuations during exothermic fermentation processes [39] [40].

This adaptive capacity also reduces the reliance on precise cooling or heating measures. If a microorganism can thrive

within a specific temperature range, it obviates the need for meticulous temperature control. A broader spectrum of temperature tolerance among microorganisms lessens the requirement for stringent temperature regulation during fermentation processes [33].

Throughout the fermentation process, the pH levels within the growth medium tend to fluctuate. Typically, a buffer is introduced into the media, along with a pH control system in the fermenter. However, the capacity of microorganisms to thrive within a wide pH range can eliminate the need for pH regulation. It's worth noting that fungi tend to flourish at lower pH levels compared to bacteria [38].

Consequently, by maintaining a lower pH in the culture medium during cultivation, bacterial growth can be inhibited. This, in turn, can lead to reduced expenses associated with sterilization and aseptic precautions, thus providing cost-effective methods [33] [46].

Nutritional Value of Single-Cell Protein

The nutritional value of SCP, determined by its composition of amino acids, vitamins, and nucleic acids, has both positive and negative implications [40]. On the negative side, it can include characteristics such as a rigid cell wall, high nucleic acid concentration, allergenicity, and gastrointestinal effects. However, these negative aspects can be mitigated through specific processing techniques [22] [41].

Additionally, the slow utilization of SCP necessitates careful consideration of potential toxicological effects and carcinogenicity. On the positive side, SCP boasts a high protein content along with ample enzymes, minerals, and vitamins [12].

The protein content in SCP is notably high. For instance, dried cells of *Pseudomonas* sp. cultivated on standard petroleum-based liquid paraffin contain 69% protein, while algae typically contain around 40% protein [18]. The choice of raw materials used as a carbon source and the microorganisms cultivated on the media directly influence the protein composition of SCP. Bacterial proteins, in general, contain all the essential amino acids. The average protein content of bacteria, yeast, fungi, and algae varies [45] [28].

Microorganisms such as bacteria and yeast exhibit rapid growth, with doubling times usually ranging from five to fifteen minutes, whereas molds and algae take between two and four hours to double. This rapid growth rate holds promise for addressing food scarcity challenges in the modern era [49]. The amino acid composition of bacterial protein bears resemblance to that of fish protein. In contrast, fungal protein, while slightly lower than yeast protein, is essentially on par with soy protein. It's worth noting that Single Cell Protein (SCP) lacks sulfur-containing amino acids like cystine, cysteine, and methionine. Therefore, even though SCP is rich in lysine, vitamins, and various other amino acids, a diet primarily composed of SCP may require supplementary cysteine and methionine to fulfill nutritional needs [51].

When it comes to vitamins, most of the vitamins found in bacteria belong to the B group. Algae, on the other hand, tend to be particularly rich in vitamin A, with vitamin B12 primarily sourced from bacteria. Some common vitamins present in SCP include thiamine, riboflavin, niacin, pyridoxine, pantothenic acid, choline, folic acid, inositol, biotin, B12, and P-aminobenzoic acid [45].

Applications of Single-Cell Protein

SCP has a wide array of applications in both animal feed and the food industry. In the food sector, it serves multiple functions, including acting as a meat substitute, enhancing texture, flavor, serving as a carrier of vitamins, functioning as an emulsifier, and elevating the nutritional value of food products [10, 11, 22, 23].

The production of SCP employs various microorganisms and substrates, encompassing agro-industrial residues, diverse fruit waste materials, cellulosic biomass, molasses, corn starch, dextrose, sucrose, soybean meal, brewery residues, industrial wastewater, biogas, ethanol, and CO₂. Among these, substrates rich in sugars are the most commonly used for SCP production [24].

For example, a study successfully produced single-cell protein from the abundant marine weed *Turbinaria* sp. using a naturally occurring yeast in a mixed culture with palmyrah toddy under optimized conditions [11][50].

In 2019, Sri Lanka contributed approximately 0.11% of the world's fruit production, producing around 0.97 metric tons (MT) of fruits. Commonly consumed fruits in the region include banana, papaya, mango, and pineapple, with consumption steadily increasing over the past decade [9, 8, 11]. Fruit peels constitute a significant by-product, accounting for nearly 30% of the total fruit weight. These peels are rich in simple sugars like sucrose, glucose, and fructose, as well as a substantial amount of minerals and nitrogen content [31][42][50].

Therefore, fruit peels serve as valuable sources of carbon and energy for microbial growth, making them a viable and cost-effective alternative for SCP production. Given that the cost-effectiveness of SCP production is closely linked to substrate costs, utilizing waste materials from various fruits proves to be an economically sound choice [35][25].

VI. CONCLUSION

The envisioned potential of Single Cell Protein (SCP) as a substantial protein source for food has remained unrealized due to a complex interplay of economic, political, and technological factors. In industrialized nations, SCP hasn't taken center stage because these regions have witnessed a surge in the availability of high-quality protein, thanks to advances in agriculture spanning the last four decades.

However, the narrative takes a distinct turn in regions characterized by tropical climates. In these areas, SCP could

play a pivotal role as a valuable food supplement. Traditional dietary staples in such regions often lack protein content while being rich in carbohydrates. This protein deficiency, persisting over time, has contributed to a host of physical and mental health issues, causing a deteriorating impact.

Challenges extend beyond the nutritional aspect. In some parts of Africa and the Middle East, the land's inherent limitations pose a formidable hurdle in achieving food security, regardless of the protein content in the available resources. It underscores the intricate web of factors that dictate the feasibility and significance of SCP in addressing food and nutrition challenges, with economics, politics, and technology shaping the landscape in various ways.

Consequently, the production of SCP would be profitable in both tropical and arid locations, but the countries the worried party cannot afford the first capital expenditure. Additionally, they lack the technical know-how and support resources needed to continue production once it has been created. Due to financial reasons, SCP hasn't been a success even as a feed additive.

The global expansion of large-scale Single Cell Protein (SCP) processes stands as a pivotal chapter in the unfolding narrative of contemporary biotechnology. The dynamic evolution of SCP has been nothing short of a multidisciplinary marvel, drawing wisdom and inspiration from an eclectic ensemble of scientific realms. This encompassing embrace spans microbiology, biochemistry, genetics, chemical and process engineering, food technology, agriculture, animal nutrition, ecology, toxicology, medicine, veterinary science, and economics. In the process, SCP has not only redefined the contours of biotechnology but has also cast a far-reaching influence on various satellite fields, casting innovation's glow on areas as diverse as wastewater treatment, alcohol production, enzyme technology, and the ever-evolving science of nutrition.

As we peer into the future, the trajectory of SCP rests squarely on two formidable pillars: cost efficiency and the relentless pursuit of elevated quality benchmarks. To embark on this journey, a strategic focus on feedstock-related dimensions becomes paramount. Herein lies the dual challenge of curbing feedstock expenditures while concurrently elevating the quality of the resources deployed. Achieving cost reductions demands a nuanced orchestration of variables, encompassing everything from optimizing feedstock costs to refining fermentation techniques and enhancing the efficiency of downstream processing. Simultaneously, advancements in producer organisms, blending the traditional foundations of applied genetics with the cutting-edge tapestry of recombinant DNA technologies, promise to be avenues of paramount significance.

Nevertheless, it's imperative to note that the primary barriers confronting the acceptance of SCP products for human consumption are more deeply rooted in the fabric of societal norms and cultural sensibilities than in the realm of technological hurdles. Thus, the path ahead suggests that

microbial biomass will predominantly embrace its role as a valuable supplement within the ambit of animal feed applications. This pivotal role casts SCP as an indispensable force, poised to meet the multifaceted demands of the ever-evolving future.

Further research and development endeavors are aimed at promoting the use of microbial biomass as single-cell protein or as a dietary supplement, particularly in developing nations.

REFERENCES

- [1] R. K. P. Thiviya¹* and T. Madhujith³, "Bioconversion of Fruit Wastes of Papaya, Watermelon, and Banana into Single Cell Protein Production," *Tropical Agricultural Research*, Vols. : 503-514, p. 32(4), 2021.
- [2] G. D. Najafpour, CHAPTER 14 - Single-Cell Protein, Iran, 2007.
- [3] S. R.-A. M. M. a. Y. A. T. Nasser, "Single cell protein: Production and process," *American journal of food technology*, pp. 1-14, 2011.
- [4] .. E. B. Mariano García-Garibay, "SINGLE-CELL PROTEIN | Yeasts and Bacteria," *Encyclopedia of Food Microbiology*, 1999.
- [5] M. H. Z. I. A. S. R. F. A. Muhammad Sharifa a, "Single cell protein: Sources, mechanism of production, nutritional value and its uses in aquaculture nutrition," *Aquaculture*, 2020.
- [6] P. b. Anupamaa, "Value-added food: Single cell protein," *ELSEVIER*, Vols. 459-479, p. 18, 2000.
- [7] M. h. m. y. Sara rausoul -amini, "Single cell protein: production and process," *American Journal of Food Technology*, pp. 1-14, 2011.
- [8] M. N. A. a. B. P. Gour Suman¹, "Single Cell Protein Production," *International journal of current microbiology and applied science*, vol. 4, no. : 2319-7706, pp. 251-262, 2015.
- [9] M. N. S. A. a. B. P. Gour Suman¹*, "Single Cell Protein Production: A Review," *international journal of current microbiology and applied science*, vol. 4, no. 2319-7706, pp. 251-262, 2015.
- [10] J. Clerk Maxwell, A Treatise on Electricity and Magnetism, 3rd ed., vol. 2. Oxford: Clarendon, 1892, pp.68-73.
- [11] I. S. Jacobs and C. P. Bean, "Fine particles, thin films and exchange anisotropy," in *Magnetism*, vol. III, G. T. Rado and H. Suhl, Eds. New York: Academic, 1963, pp. 271-350.
- [12] K. Elissa, "Title of paper if known," unpublished.
- [13] R. Nicole, "Title of paper with only first word capitalized," J. Name Stand. Abbrev., in press.
- [14] Y. Yorozu, M. Hirano, K. Oka, and Y. Tagawa, "Electron spectroscopy studies on magneto-optical media and plastic substrate interface," *IEEE Transl. J. Magn. Japan*, vol. 2, pp. 740-741, August 1987 [Digests 9th Annual Conf. Magnetism Japan, p. 301, 1982].
- [15] M. Young, The Technical Writer's Handbook. Mill Valley, CA: University Science, 1989.
- [16] E. Marcellin, L. T. Angenent, L. K. Nielsen, and B. Molitor, "Recycling carbon for sustainable protein production using gas fermentation," *Current Opinion in Biotechnology*, vol. 76, p. 102723, 2022.
- [17] J. Delamare-Deboutteville et al., "Mixed culture purple phototrophic bacteria is an effective fishmeal replacement in aquaculture," *Water research X*, vol. 4, p. 100031, 2019.
- [18] M. Sakarika et al., "The type of microorganism and substrate determines the odor fingerprint of dried bacteria targeting microbial protein production," *FEMS Microbiology Letters*, vol. 367, no. 18, p. fnaa138, 2020.
- [19] U. Hasanudin, "The growth dynamics, chemical, amylographic profile and granular morphology changes on cassava pulp fermentation," *Asian Journal of Agriculture and Biology*, vol. 7, no. 4, pp. 617-623, 2019.
- [20] Z. W. LaTurner, G. N. Bennett, K.-Y. San, and L. B. Stadler, "Single cell protein production from food waste using purple non-sulfur bacteria shows economically viable protein products have higher environmental impacts," *Journal of Cleaner Production*, vol. 276, p. 123114, 2020.
- [21] P. Kehrein, M. Van Loosdrecht, P. Osseweijer, M. Garfi, J. Dewulf, and J. Posada, "A critical review of resource recovery from municipal wastewater treatment plants—market supply potentials, technologies and bottlenecks," *Environmental Science: Water Research & Technology*, vol. 6, no. 4, pp. 877-910, 2020.
- [22] S. H. El Abbadi and C. S. Criddle, "Engineering the dark food chain," *Environmental science & technology*, vol. 53, no. 5, pp. 2273-2287, 2019.
- [23] J. Spanoghe, P. Vermeir, and S. E. Vlaeminck, "Microbial food from light, carbon dioxide and hydrogen gas: kinetic, stoichiometric and nutritional potential of three purple bacteria," *Bioresource Technology*, vol. 337, p. 125364, 2021.
- [24] Z. Zhu, Y. Wu, W. Hu, X. Zheng, and Y. Chen, "Valorization of food waste fermentation liquid into single cell protein by photosynthetic bacteria via stimulating carbon metabolic pathway and environmental behaviour," *Bioresource Technology*, vol. 361, p. 127704, 2022.
- [25] S. Singha et al., "Novel bioplastic from single cell protein as a potential packaging material," *ACS Sustainable Chemistry & Engineering*, vol. 9, no. 18, pp. 6337-6346, 2021.
- [26] A. Nasser, S. Rasoul-Amini, M. Morowvat, and Y. Ghasemi, "Single cell protein: production and process," *American Journal of food technology*, vol. 6, no. 2, pp. 103-116, 2011.
- [27] C. E. S. Muniz, Â. M. Santiago, T. A. S. Gusmão, H. M. L. Oliveira, L. de Sousa Conrado, and R. P. de Gusmão, "Solid-state fermentation for single-cell protein enrichment of guava and cashew by-products and inclusion on cereal bars," *Biocatalysis and Agricultural Biotechnology*, vol. 25, p. 101576, 2020.
- [28] T. T. Bogale, "Microbial protein production from agro-industrial wastes as food and feed," *American Journal of Life Sciences*, vol. 8, no. 5, pp. 121-126, 2020.
- [29] M. Spiller, M. Muys, G. Papini, M. Sakarika, M. Buyle, and S. E. Vlaeminck, "Environmental impact of microbial protein from potato wastewater as feed ingredient: Comparative consequential life cycle assessment of three production systems and soybean meal," *Water research*, vol. 171, p. 115406, 2020.
- [30] N. Schultz, L. Chang, A. Hauck, M. Reuss, and C. Syldatk, "Microbial production of single-cell protein from deproteinized whey concentrates," *Applied microbiology and biotechnology*, vol. 69, pp. 515-520, 2006.
- [31] A. Zahid and R. Khedkar, "Valorisation of fruit & vegetable wastes: a review," *Current Nutrition & Food Science*, vol. 18, no. 3, pp. 315-328, 2022.
- [32] M. Sharif, M. H. Zafar, A. I. Aqib, M. Saeed, M. R. Farag, and M. Alagawany, "Single cell protein: Sources, mechanism of production, nutritional value and its uses in aquaculture nutrition," *Aquaculture*, vol. 531, p. 735885, 2021.
- [33] S. Bhushan, K. Kalia, M. Sharma, B. Singh, and P. S. Ahuja, "Processing of apple pomace for bioactive molecules," *Critical reviews in biotechnology*, vol. 28, no. 4, pp. 285-296, 2008.
- [34] J. A. Mathews, H. Tan, M. J. Moore, and G. Bell, "A conceptual lignocellulosic 'feed+ fuel' biorefinery and its application to the linked biofuel and cattle raising industries in Brazil," *Energy Policy*, vol. 39, no. 9, pp. 4932-4938, 2011.
- [35] W. Chen, T. L. Oldfield, S. I. Patsios, and N. M. Holden, "Hybrid life cycle assessment of agro-industrial wastewater valorisation," *Water research*, vol. 170, p. 115275, 2020.
- [36] S. Sultana, M. E. Ali, and M. N. U. Ahamad, "Gelatine, collagen, and single cell proteins as a natural and newly emerging food ingredients," in *Preparation and processing of religious and cultural foods*: Elsevier, 2018, pp. 215-239.
- [37] K. H. Ogbonda, R. E. Aminigo, and G. O. Abu, "Influence of temperature and pH on biomass production and protein biosynthesis in a putative *Spirulina* sp.," *Bioresource technology*, vol. 98, no. 11, pp. 2207-2211, 2007.
- [38] S. Chitapompan, C. Chiemchaisri, W. Chiemchaisri, R. Honda, and K. Yamamoto, "Organic carbon recovery and photosynthetic bacteria population in an anaerobic membrane photo-bioreactor treating food processing wastewater," *Bioresource technology*, vol. 141, pp. 65-74, 2013.
- [39] A. Nyyssölä, A. Suhonen, A. Ritala, and K.-M. Oksman-Caldentey, "The role of single cell protein in cellular agriculture," *Current Opinion in Biotechnology*, vol. 75, p. 102686, 2022.

- [40] A. De Gregorio, G. Mandalari, N. Arena, F. Nucita, M. Tripodo, and R. L. Curto, "SCP and crude pectinase production by slurry-state fermentation of lemon pulps," *Bioresource Technology*, vol. 83, no. 2, pp. 89-94, 2002.
- [41] T. U. Nwabueze and U. Otunwa, "Effect of supplementation of African breadfruit (*Treculia africana*) hulls with organic wastes on growth characteristics of *Saccharomyces cerevisiae*," *African Journal of Biotechnology*, vol. 5, no. 16, 2006.
- [42] B. C. Bratosin, S. Darjan, and D. C. Vodnar, "Single cell protein: A potential substitute in human and animal nutrition," *Sustainability*, vol. 13, no. 16, p. 9284, 2021.
- [43] S. Landaud, S. Helinck, and P. Bonnarne, "Formation of volatile sulfur compounds and metabolism of methionine and other sulfur compounds in fermented food," *Applied microbiology and biotechnology*, vol. 77, pp. 1191-1205, 2008.
- [44] P. Thiviya, A. Gamage, R. Kapilan, O. Merah, and T. Madhujith, "Single cell protein production using different fruit waste: a review," *Separations*, vol. 9, no. 7, p. 178, 2022.
- [45] Y. Sui, M. Muys, P. Vermeir, S. D'Adamo, and S. E. Vlaeminck, "Light regime and growth phase affect the microalgal production of protein quantity and quality with *Dunaliella salina*," *Bioresource Technology*, vol. 275, pp. 145-152, 2019.
- [46] T. Kuthiala, K. Thakur, D. Sharma, G. Singh, M. Khatri, and S. K. Arya, "The eco-friendly approach of cocktail enzyme in agricultural waste treatment: A comprehensive review," *International Journal of Biological Macromolecules*, vol. 209, pp. 1956-1974, 2022.
- [47] A. Tropea, A. Ferracane, A. Albergamo, A. G. Potorti, V. Lo Turco, and G. Di Bella, "Single cell protein production through multi food-waste substrate fermentation," *Fermentation*, vol. 8, no. 3, p. 91, 2022.
- [48] P. Wu et al., "Rhodospseudomonas palustris wastewater treatment: Cyhalofop-butyl removal, biochemicals production and mathematical model establishment," *Bioresource technology*, vol. 282, pp. 390-397, 2019.
- [49] P. Puligundla and C. Mok, "Valorization of sugar beet pulp through biotechnological approaches: recent developments," *Biotechnology Letters*, vol. 43, no. 7, pp. 1253-1263, 2021.
- [50] R. Singh, T. Singh, and C. Larroche, "Biotechnological applications of inulin-rich feedstocks," *Bioresource technology*, vol. 273, pp. 641-653, 2019.
- [51] M. Hosseini, S. A. Shojaosadati, and J. Towfighi, "Application of a bubble-column reactor for the production of a single-cell protein from cheese whey," *Industrial & engineering chemistry research*, vol. 42, no. 4, pp. 764-766, 2003.
- [52] A. Raziq, M. Lateef, A. Ullah, H. Ullah, and M. W. Khan, "02. Single cell protein (SCP) production and potential substrates: A comprehensive review," *Pure and Applied Biology (PAB)*, vol. 9, no. 3, pp. 1743-1754, 2020.
- [53] M. Hashem, M. Al-Qahtani, S. Alamri, Y. Moustafa, G. Lyberatos, and I. Ntaikou, "Valorizing food wastes: Assessment of novel yeast strains for enhanced production of single-cell protein from wasted date molasses," *Biomass Conversion and Biorefinery*, vol. 12, no. 10, pp. 4491-4502, 2022.

Review of 3D Food Printing Techniques: Advancements, Challenges, and Future Perspective

D.M.M.M. Premarathna
Department of Agriculture and Food Technology, The
University of Vocational Technology,
Rathmalana, Sri Lanka.
sankafernandoz12@gmail.com

K.K.D.S. Ranaweera
Department of Food Science and Technology
The University of Sri Jayawardenepura, Sri Lanka
kkdsranaweera@gmail.com

Abstract— Numerous potential uses for 3D printing in the food sector include raising the products' tastiness, variety, personalization, healthfulness, wholeness, longevity, and general well-being. The unique nutritional needs of each person may be met with the help of this remarkable additive manufacturing technology. The technology's distinguishing feature is a manner of material deposition that builds up layers sequentially from a template file. Extrusion-based food printing, binder jetting, inkjet printing, and selective sintering printing are four primary technologies in this field.

To create a really unique layout while utilizing these technologies, there are a few key considerations. The structure of the food material, printing resolution, and precision were all impacted by this; these are briefly covered in the study. Due to the multiple ways, it enhances company operations, including quicker production times, streamlined supply chains, and a wider range of usable ingredients, additive manufacturing is seen as a cutting-edge element of the food industry of the future. Therefore, before 3D printing in the food industry is used more extensively, there are a few obstacles that must be overcome.

Keywords— *Three-dimensional Food Printing, Extrusion, Binder Jetting, Inkjet, Selective Laser Sinter*

I. INTRODUCTION

During the 1980s, the technology of additive manufacturing, often referred to as three-dimensional (3D) printing, emerged and found widespread applications across a multitude of industries. [42,29] Solid free-form fabrication, also known as additive manufacturing, was pioneered in the food industry by Cornell University researchers who introduced an extrusion-based printer. 3D printing is distinguished and defined by a mode of layer-by-layer material deposition based on a predefined file format. [26,28]

The utilization of 3D printing technology in the food industry holds the promise of numerous exciting advantages, including personalized food designs, tailored digital nutrition, improved supply chain efficiency, and the diversification of food sources and distribution. Because of this technology, Thanks to this technology, everyday

designs that would be unfeasible using manual labor or traditional molds. This innovation relies on predefined data files that encompass the culinary expertise and artistic talents of chefs, nutrition specialists, and food designers [37]. Moreover, 3D food printing offers the potential for digitizing and customizing an individual's nutritional and

energy requirements based on their unique physical condition, demands, and dietary preferences [37,32,42].

The reach of conventional food distribution networks stands to be extended through the adoption of 3D food printing. With the widespread adoption of this method, production can be decentralized to areas with reduced transportation expenses and shorter delivery times, all without increasing overall transportation volumes [22]. Advancements in food printing technology are also set to introduce novel applications for insects, high-fiber plant-based materials, and plant- and animal-based by-products within the food industry [22,25].

II. METHODS

Databases and Search Strategy

The search criteria for the article included the exact phrase "3D food printing, three-dimensional food printing and additive manufacturing" in the title, abstract, and keywords. Only articles in the final publication stage were considered, and the publication years were limited to 2000-2022 to gather relevant and up-to-date information.

The search was restricted to articles and reviews, ensuring comprehensive coverage of the topic. English-language articles were included for accessibility and understanding. The search specifically targeted journal articles, as they provide scholarly and in-depth information. By applying these criteria, the resulting articles would focus on the topic encompassing a wide range of years, and provide insights into production methods, applications, and future perspectives. The studies under consideration underwent initial evaluation based on their titles and abstracts. Subsequently, a thorough examination of the full texts was carried out to pinpoint studies aligning with the primary themes of the review

III. CONTEXT AND IMPORTANCE OF 3D FOOD PRINTING

Recently, additive manufacturing (AM) or 3D printing has received increasing attention in the food industry. Because it allows for individualized nutrition plans, novel culinary creations, shorter production times, fewer steps in the supply chain, and a wider variety of raw ingredients. [22]

Now more than ever, people all around the globe are on the lookout for fresh concepts with which to advance science and technology for the sake of a better tomorrow. Emerging technologies play a crucial role in this context, allowing us to envision infinite outcomes. The emergence of these technologies would elicit both positive and negative server reactions. But now is the time to think about how food science and technology may be improved in the future of your dreams. [37,22]

IV. OBJECTIVES OF THE REVIEW PAPER

The demand for new technology is growing, and 3D printing is a well-potent sector for quick innovation and development. The future trends and 3D printing methods for food are covered in this paper. In recent times, 3D printing has been harnessed for crafting meals tailored to the specific needs of various groups, including military personnel, astronauts, seniors, and dessert enthusiasts. Achieving precise and accurate food printing is imperative to realize the intended designs flawlessly, and this article is dedicated to collating and dissecting the information necessary for accomplishing this feat [35]. Furthermore, the article provides an extensive examination of 3D printing's applications across diverse domains within the food industry, along with offering recommendations and a critical assessment of the ongoing trends and challenges associated with the realm of 3D food printing [22,37].

V. 3D FOOD PRINTING TECHNIQUES

In the realm of the food industry, commonly accessible 3D printing methods can be categorized into four main types: extrusion-based printing, selective sintering printing (SLS), binder jetting, and inkjet printing [22].

i. Extrusion-Based Printing

Originally explored under the name of fused deposition modeling for manufacturing plastic products, extrusion-based printing involves the continuous extrusion of a melted food feed (often resembling a paste-like slurry or gravy) through a moving nozzle. This molten material is deposited layer by layer onto a cooling surface during the food printing process. Depending on the temperature employed during deposition, extrusion-based printing falls into two categories: melting extrusion-based printing and soft materials extrusion-based printing [21].

Melting extrusion-based printing has gained wide application in crafting customized 3D chocolate products [13]. In this process, melted semisolid food polymer is extruded from a mobile printhead and swiftly solidifies, adhering to previous layers almost immediately after extrusion to faithfully capture the desired design's texture [22].

2. Inkjet Printing

This method dispenses a stream of droplets from either a thermal or piezoelectric printhead onto specific regions of a food surface. It is commonly used for adding decorative imagery to food items like cookies, cakes, and pizza [29]. Two types of inkjet printing techniques have been developed: continuous jet printing, where ink is rapidly ejected through a piezoelectric crystal vibrating at a constant frequency and direction, and drop-on-demand printing, where ink is expelled from printheads under controlled pressure, often involving the addition of conductive agents and materials to achieve the desired ink flow [17,16,21].

2. Binder Jetting

Binder jetting, an additive manufacturing technology, constructs models by selectively binding layers of powdered food materials with a liquid binder. Each layer of powder is evenly distributed across the fabrication platform, and a liquid binder is sprayed to bind two consecutive powder layers [37,28]. In this process, small droplets of binder, typically with diameters less than 100 μm , are sequentially deposited onto the powder bed surface, following a drop-on-demand print head's raster scanning pattern [29]. The binder fuses the current cross-sections to previously and subsequently fused ones, enabling the creation of intricate and complex structures. Throughout the fabrication process, the unfused powder contributes to the fused parts, and the unbound powder is eventually removed and recycled for future use [30,29]. Binder jetting technology also possesses the capability to produce colorful 3D edible objects by varying binder composition [29].

3. Selective Laser Sintering (SLS)

SLS is a technology that employs a high-powered laser to selectively fuse powder particles together layer by layer, culminating in a 3D structure [21]. The laser scans cross-sections on each layer's surface, selectively fusing the powder. After scanning each cross-section, the powder bed is lowered, and a fresh layer of powder is spread and created on top. This process repeats until the desired structural design is complete [38]. Ultimately, the unfused powder is removed and can be reclaimed for subsequent printing modes [22,4]. While SLS is widely used in metal and ceramic industrial manufacturing, its application in the food sector faces challenges, including the identification of suitable powdered materials that can fuse without decomposing and the creation of various edible objects using a wide range of food materials [4,21].

VI. SUBSTANCES SUITABLE FOR 3D PRINTING IN THE CONTEXT OF FOOD

According to Lipton, Arnold et al. (2010) [24, 20], extrusion-based printing finds application in printing on soft materials like flour doughs, mashed or blended

potatoes, sweet potatoes, cheese, and meat paste. It is commonly employed for surface decorations or filling images.

Achieving precision and excellence in 3D printing for the creation of visually stunning objects involves considering various factors [22, 21, 24, 6, 7]. These factors include the extrusion mechanism and method, material characteristics (such as glass transition temperature, melting point, and rheological parameters), processing variables (extrusion speed, nozzle diameter, and nozzle height), and finishing touches (such as decorations, additional material installation, and moldings).

To improve the quality of surface images, edible liquids like sugar, honey, and concentrated fruit juices are utilized on food surfaces through the application of an inkjet printer [20, 21, 28].

The viscosity and rheological properties of edible ink [8] play a pivotal role in achieving flawless and accurate printing. Lower viscosity edible inks are more suitable for expulsion through tiny printhead orifices [34, 5, 6]. The viscosity range for appropriate inks in continuous jets is relatively narrow. Temperature manipulation can also impact ink jetting by altering rheological characteristics and surface energy [32, 33]. Lower temperatures reduce surface energy, minimizing ink spreading. The ink's composition influences the temperature required to achieve the correct viscosity, which is essential for optimal flowability [33, 41].

The quality and resolution of the final image are significantly influenced by the compatibility between the printed food and the substrate surfaces. Surface chemistry and ink-substrate interaction affect the interaction features after ink droplets are jetted onto the surface [34]. Sometimes, enhancing substrate surface compatibility may be necessary by applying a binder film or another compatibility-enhancing layer before printing to achieve high-quality results [33, 34, 41].

Understanding the properties of powdered material and binder is essential for successful fabrication. The binder should possess specific characteristics, including viscosity, surface tension, ink density, and more, to prevent nozzle spreading [27]. Binder concentration is a critical factor for achieving the necessary dimensional accuracy in part manufacturing [27]. The flowability of the powder is crucial for the binding process, with binder jetting working best with free-flowing powders that have good packing and spreading capabilities [27, 28].

The choice of powder material is vital, with non-sticky, low tendency-to-aggregate materials being preferable [28]. For complex morphologies, selective sintering of sugars and sugar-rich powders can be employed, enabling the rapid creation of intricate food items without additional processing [27]. It's advisable to use sugar products with a relatively low melting point [2]. Ideal edible powder for SLS should be free-flowing and pourable without

noticeable clumping [38]. To achieve desired outcomes, processing variables such as laser type, laser diameter, laser strength, and scanning speed should be programmable [18].

Material properties, including particle size, flowability, bulk density, and wettability, directly affect the printing precision and accuracy in SLS [9, 8]. The interaction between the laser beam and powdered materials is critical, with the strength of this interaction dependent on the laser type, laser energy density, air temperature, and layer thickness, all impacting material fusion [9, 35]. While increased heat and speed boost production rates, they can compromise precision and resolution, and a larger laser spot diameter can make structures less prone to breakage [21, 22].

V. ADVANCEMENTS IN 3D FOOD PRINTING

Because chefs and other decorators find it quite difficult to generate such distinctive and multipurpose shapes, the constructions made utilizing these techniques are quite complex. [22] Food printers will support and encourage the adoption of an engineer-to-order strategy with a short lead time in the food manufacturing supply chain. [35,32] It is more cost-effective to place production facilities close to the final consumers so that the customized food supply chain may be reconfigured, allowing items to be delivered to clients with shorter lead times, acceptable prices, and convenience while using fewer resources. [21,25]

The prevention of diseases has been connected to individualized dietary recommendations for a person's nutritional needs. [30,22] Eating foods that are nutrient-dense is crucial for maintaining a healthy lifestyle, especially for people who suffer from deficiencies and malnutrition. According to the recommended amounts that individuals should take, 3D-printed food can give the control needed to add the right quantity of required protein, sugar, vitamins, and minerals to the foods [31,32]

Due to a number of factors, the US Army has shown a particularly keen interest in the use of 3D food printing in military nutrition. [30] On the battlefield, this technology enables the following: 1) the production of meals on demand; 2) meals that can be personalized and customized depending on each soldier's nutritional needs; and 3) the extension of the shelf life of food products by storing them as raw materials rather than finished goods. [15]

To diversify meal options and cater to the nutritional needs of soldiers, the U.S. Army has ventured into the realm of ultrasonic agglomeration, a technique that bonds particles together using ultrasonic waves [21,22].

In the context of extended space missions, maintaining crew health and meeting nutritional requirements is of paramount importance [36,21]. Traditional packaged foods tend to degrade over time, prompting NASA to explore

ways to meet nutritional needs and extend the shelf life to five years for prolonged voyages [36].

The challenge of cooling requirements in spacecraft consumes substantial resources, as noted by Lin in 2015 [19] and Davide and Xavier in 2015 [3]. Tastier 3D-printed foods, featuring ingredients like peas, mashed potatoes, and broccoli, have been successfully introduced to the market, particularly catering to the elderly and those with chewing and swallowing difficulties [40].

In the domain of 3D food printing, a melting extrusion-based printer has been developed by Natural, specifically designed for chocolate printing and surface decoration [7]. In the American market, extrusion-based printing has been employed to produce various items, including cake toppings, processed cheese, and sugar cookies [20]. SLS technology, utilizing sugar or sugar-rich granules, has been harnessed to create intricate structures that conventional methods cannot replicate [10]. The Liu and Zhang project in 2017 achieved remarkable success in crafting a variety of complex structures using sugar powders and SLS [21].

A significant breakthrough in consumable structure manufacturing has been ushered in through binder jetting technology [22]. Researchers at 3D Systems have devised binders for the creation of a wide array of colorful and flavorful edible objects, ranging from intricate sculptural cakes to salad dressings with distinct flavors and uniquely shaped designs [14]. Inkjet printing, owing to its capacity to handle low-viscosity materials, is primarily employed for surface filling and image decoration, such as embellishing cakes and cookies [24]. Halder and Patil in 2021 developed an edible medium capable of printing high-resolution images on edible substrates like cookies and cakes, ensuring their safety for consumption [12].

VI. HURDLES IN THE FIELD OF 3D FOOD PRINTING

Consideration of the physical and geometric limitations of printing materials is a critical aspect when designing a 3D model for food production. This introduces significant complexity to the design process, which is currently lacking suitable software solutions. The vast diversity of food components further complicates the development of tailored software for the food industry [10].

In comparison to traditional cooking methods, 3D printing imposes constraints on the range of food items that can be generated. The fragility of printed food structures and their often-unfavorable textures arise from the fact that food ingredients are typically much softer than the weakest plastics used in 3D printing [42,36].

Presently, much of the research relies on trial-and-error methods to address this challenge. However, scientists are actively working on innovative techniques aimed at predicting the behavior of various materials during the printing process. This predictive capability would significantly narrow the gap. These techniques involve a deep understanding of materials and their behavior concerning printing stability [43]

Due to the risk of cross-contamination when printing food in 3D, safety issues are crucial, and sophisticated, and should be closely monitored. Throughout the entire course that the food material takes through the printer, a food printer must ensure and facilitate the safety and sanitation of the interior. owing to the potential for food to become stopped somewhere along the way, bacterial buildup, cross-contamination, and security issues. [1213]

Both microbial stability and the risk of cross-contamination represent critical factors that profoundly impact the quality of printed food. These considerations must be integrated into the design of the printer and carefully managed during the printing process [8,9]. It's worth noting that high-quality printers often employ materials like stainless steel and BPA-free components, which can help mitigate concerns about materials coming into contact with the food [7,8].

Researchers have been actively working towards integrating 3D food printing into the food industry [22]. However, challenges related to the production of colorful, multi-flavored, multi-textured items, as well as ensuring printing accuracy, precision, and overall process efficiency, present hurdles that have limited the widespread adoption of this technology within the food industry [8,10].

VII. FUTURE PERSPECTIVES

Robotics and automation can be used with 3D printing technology to secure the profitability of diverse food and other sectors. [22] As a fast-evolving idea to use and access resources instantaneously, apps utilizing artificial intelligence (AI) would elevate these techniques to an advanced level. [10] Artificial intelligence and machine learning applications are one of the primary considerations currently. [21,37,42]

The "lotus effect" in nanotechnology can be integrated with food products that are not sticky or cling to hands or wrappings. This can be used as a technique to reuse lunch trays and wrapping boxes. Leveraging nanotechnology in the realm of 3D food printing opens up new avenues for innovation. This integration has the potential to reduce the impact on sustainability, the environment, and the accumulation of waste [21,22,23].

VIII. CONCLUSION

Three-dimensional printing technology holds the promise of ushering in a new era of sustainable food technology, enabling the creation of unique structures and products. This emerging technology stands to have a profound impact on both the future of the food industry and the lives of individuals, driven by its numerous technological advantages.

Exploring this technology further, it becomes evident that there is considerable potential in optimizing pre- and post-processing procedures. Additionally, three-dimensional printing can be harnessed for the development and refinement of functional foods, unlocking innovative possibilities for customized nutrition and dietary solutions.

Furthermore, a key aspect to consider is the potential for reduced maintenance costs associated with these printers, making them more accessible and economically viable. A particularly exciting prospect lies in the hands of industry professionals who could potentially pioneer the creation of cost-effective, high-quality printers. Such advancements would democratize the field of food printing, allowing a broader range of individuals to engage successfully in this innovative sector. As a result, the transformative impact of three-dimensional food printing could extend its reach to a more extensive and diverse audience, amplifying its potential benefits for both the food industry and consumers alike.

REFERENCES

- [1] Ahn, S. H., et al. (2002). "Anisotropic material properties of fused deposition modeling ABS." *Rapid prototyping journal*.
- [2] Bourell, D. L., et al. (2008). *Rapid manufacturing using infiltration selective laser sintering*. Engineering Systems Design and Analysis.
- [3] Davide, S. and T. Xavier (2015). "Review of 3D food printing."
- [4] Diaz, J. V., et al. (2021). Method for the production of an edible object by powder bed (3d) printing and food products obtainable therewith, Google Patents.
- [5] Diaz, J. V., et al. (2018). Method for the production of edible objects using sls and food products, Google Patents.
- [6] Duan, B., et al. (2010). "Three-dimensional nanocomposite scaffolds fabricated via selective laser sintering for bone tissue engineering." *Acta biomaterialia* 6(12): 4495-4505.
- [7] Galdeano, J. A. L. (2014). *3D printing food: The sustainable future*, Universitat Politècnica de Catalunya. Escola Tècnica Superior d'Enginyeria
- [8] Godoi, F. C., et al. (2018). *Fundamentals of 3D food printing and applications*, Academic press.
- [9] Godoi, F. C., et al. (2016). "3d printing technologies applied for food design: Status and prospects." *Journal of Food Engineering* 179: 44-54.
- [10] Gray, N. (2010). Looking to the future: Creating novel foods using 3D printing, Food Navigator. com.
- [11] Gu, D. D., et al. (2012). "Laser additive manufacturing of metallic components: materials, processes and mechanisms." *International materials reviews* 57(3): 133-164.
- [12] Haldar, S., et al. (2021). *3D Printing Applications in Food Processing. 3D Printing Technology and its Diverse Applications*, Apple Academic Press: 51-79.
- [13] Hao, L., et al. (2010). "Material characterisation and process development for chocolate additive layer manufacturing." *Virtual and Physical Prototyping* 5(2): 57-64.
- [14] Izdebska, J. and Z. Zolek-Tryznowska (2016). "3D food printing—facts and future." *Agro FOOD Industry Hi Tech* 27(2): 33-37.
- [15] Jennifer, K. (2014). US army looks to 3D print food for soldiers.
- [16] Kruth, J.-P., et al. (2007). "Consolidation phenomena in laser and powder-bed based layered manufacturing." *CIRP annals* 56(2): 730-759.
- [17] Lanzetta, M. and E. Sachs (2003). "Improved surface finish in 3D printing using bimodal powder distribution." *Rapid prototyping journal*.
- [18] Lekurwale, S., et al. (2022). "Selective Laser Sintering (SLS) of 3D Printlets using a 3D Printer comprised of IR/red-diode Laser." *Annals of 3D Printed Medicine*.
- [19] Lin, C. (2015). "3D food printing: A taste of the future." *Journal of Food Science Education* 14(3): 86-87.
- [20] Lipton, J., et al. (2010). Multi-material food printing with a complex internal structure suitable for conventional post-processing. 2010 International Solid Freeform Fabrication Symposium, University of Texas at Austin.
- [21] Liu, Z. and M. Zhang (2019). 3D food printing technologies and factors affecting printing precision. *Fundamentals of 3D food printing and applications*, Elsevier: 19-40.
- [22] Liu, Z., et al. (2017). "3D printing: Printing precision and application in food sector." *Trends in Food Science & Technology* 69: 83-94.
- [23] Mantihal, S., et al. (2017). "Optimization of chocolate 3D printing by correlating thermal and flow properties with 3D structure modeling." *Innovative food science & emerging technologies* 44: 21-29.
- [24] Pallottino, F., et al. (2016). "Printing on food or food printing: a review." *Food and Bioprocess Technology* 9(5): 725-733.
- [25] Payne, C. L., et al. (2016). "Insects as food and feed: European perspectives on recent research and future priorities." *Journal of Insects as Food and Feed* 2(4): 269-276.
- [26] Periard, D., et al. (2007). *Printing food. 2007 International solid freeform fabrication symposium*
- [27] Peters, F., et al. (2006). "Comparative study of patient individual implants from β -tricalcium phosphate made by different techniques based on CT data." *Materialwissenschaft und Werkstofftechnik: Entwicklung, Fertigung, Prüfung, Eigenschaften und Anwendungen technischer Werkstoffe* 37(6): 457-461.
- [28] Pinna, C., et al. (2016). *Additive Manufacturing applications within Food industry: an actual overview and future opportunities*. Proceedings of the Summer School Francesco Turco, AIDI-Italian Association of Industrial Operations Professors: 18-24.
- [29] Pitayachaval, P., et al. (2018). A review of 3D food printing technology. MATEC web of conferences, EDP Sciences.
- [30] Sachs, E. M., et al. (1993). *Three-dimensional printing techniques*, Google Patents.
- [31] Sarwar, M. H., et al. (2015). "Effects of eating the balance food and diet to protect human health and prevent diseases." *American Journal of Circuits, Systems and Signal Processing* 1(3): 99-104.
- [32] Severini, C. and A. Derossi (2016). "Could the 3D printing technology be a useful strategy to obtain customized nutrition." *Journal of Clinical Gastroenterology* 50(1): S175-S178.
- [33] Shastry, A. V., et al. (2004). *Edible inks for ink-jet printing on edible substrates*, Google Patents.
- [34] Shastry, A. V., et al. (2009). *Edible inks for ink-jet printing on edible substrates*, Google Patents.
- [35] Shirazi, S. F. S., et al. (2015). "A review on powder-based additive manufacturing for tissue engineering: selective laser sintering and inkjet 3D printing." *Science and technology of advanced materials* 16(3): 033502.
- [36] Smith, S. M., et al. (2005). "The nutritional status of astronauts is altered after long-term space flight aboard the International Space Station." *The Journal of nutrition* 135(3): 437-443.
- [37] Sun, J., et al. (2015). "A review on 3D printing for customized food fabrication." *Procedia Manufacturing* 1: 308-319.
- [38] Traini, T., et al. (2008). "Direct laser metal sintering as a new approach to fabrication of an isoelectric functionally graded material for manufacture of porous titanium dental implants." *Dental materials* 24(11): 1525
- [39] Von, H., et al. (2015). "Method for Producing a Three Dimensional Food Product." Google patents.
- [40] Wiggers, K. (2015). "Why 3D Food Printing is More Than Just a Novelty—It's the Future of Food." online article). <http://www.digitaltrends.com/cool-tech/3d-foodprinters-how-they-could-change-what-you-e>
- [41] Willcocks, N. A., et al. (2011). *High resolution ink-jet printing on edibles and products made*, Google Patents.
- [42] Yang, F., et al. (2017). "Recent development in 3D food printing." *Critical reviews in food science and nutrition* 57(14): 3145-3153.
- [43] Zhu, S., et al. (2019). "Extrusion-based 3D printing of food pastes: Correlating rheological properties with printing behaviour." *Innovative Food Science & Emerging Technologies* 58: 102214.

Advancements in Manufacturing Technology and Emerging role of Mechatronics

Automated Rice and Grain Cooker: Design and Development of a Smart Kitchen Appliance

H.G.R.Lakshan

*Department of Electrical & Electronics
Technology
University of Vocational Technology
Ratmalana, Sri Lanka
rlakshan.crossculture@gmail.com*

Sondarnagallage D.A.Sanjeewa

*Department of Electrical & Electronics
Technology
University of Vocational Technology
Ratmalana, Sri Lanka
sdasanjeewa@uovt.ac.lk*

P.I.Madushanka

*Department of Electrical & Electronics
Technology
University of Vocational Technology
Ratmalana, Sri Lanka
ishanmadushanka933@gmail.com*

H.M.R.G.Herath

*Department of Electrical & Electronics
Technology
University of Vocational Technology
Ratmalana, Sri Lanka
ravindu@ieee.org*

C.M.S.Madushan

*Department of Electrical & Electronics
Technology
University of Vocational Technology
Ratmalana, Sri Lanka
shashikamadushan0220@gmail.com*

Abstract— In the modern world, busy lifestyles often lead to consuming fast foods, which can increase the risk of chronic health conditions and metabolic syndrome. To minimize these risks, individuals can prepare meals at home, gaining control over the cooking process. Rice cookers can be time-consuming. Though it may not seem significant in isolation, such tasks can become burdensome amidst a busy lifestyle. A new solution aims to streamline the rice cooking process, making it efficient, user-friendly, and time-saving. The cooker can cook various grains and is compact, requiring less space than traditional cookers. This space-saving design enhances its practicality and convenience, allowing busy individuals to enjoy home-cooked rice without the laborious efforts. This innovative solution envisions a future where rice cooking is a breeze, enriching lives and catering to the demands of modern-day living.

Keywords—Rice-Grain Cooker, Smart Kitchen Appliance

I. INTRODUCTION

In the modern world, all of us are busy with day-to-day activities, leaving little time for meal preparation at home. As a result, many individuals opt to have their meals at restaurants or consume fast food. Insufficient time to prepare nutritious meals can increase the risk of developing chronic health conditions [1]. Frequent consumption of fast food or quick service restaurant meals has been associated with negative health outcomes and adverse effects on body weight. Studies have shown that individuals who eat at fast food restaurants regularly perceive their health status to be poorer and have a higher body mass index (BMI) [2]. Additionally, the intake of fast foods on two or more occasions per week has been linked to an increased risk of insulin resistance, a condition that can lead to type 2 diabetes [3]. Moreover, higher consumption of fast foods has been linked to an increased risk of metabolic syndrome, a cluster of conditions that includes high blood pressure, high blood sugar, excess body fat, and abnormal cholesterol levels [4]. Individuals with a higher intake of fast foods also tend to exhibit greater insulin resistance, as indicated by insulin resistance index measurements [4]. Specific fast-food items, such as hamburgers and fried chicken, have also been associated with detrimental health effects. A study revealed that individuals consuming such

items two or more times per week had a 1.40 times higher incidence rate of type 2 diabetes compared to those who did not destroy them [5]. Furthermore, the accessibility to fast food services have been implicated in health outcomes. A higher level of accessibility to fast-food establishments has been associated with an increased risk of mortality and acute coronary hospitalizations [6]. Moreover, consuming fast food at least twice a week has been shown to increase the risk of developing type 2 diabetes and mortality from coronary heart disease [2]. Lastly, the specific consumption of French fries has been found to have negative health implications. An increased intake of French fries has been associated with a 21% higher risk of developing diabetes [3].

In conclusion, these findings highlight the importance of reducing frequent fast-food consumption as part of a healthy diet to mitigate the risk of various chronic health conditions and promote overall well-being. To minimize the associated health risks, one of the most effective solutions is to prepare meals at home. By cooking meals at home, individuals gain greater control over the cooking process, from selecting ingredients to determining portion sizes and cooking methods. This level of control empowers individuals to make healthier food choices that align with their dietary preferences and nutritional needs. Although leftovers from curries can be conveniently stored in the refrigerator and reheated for later use, However, regarding rice, the reheating process is not as straightforward. While rice cookers facilitate rice cooking, preparing and washing the rice can be time-consuming. Though it may not seem significant in isolation, such tasks can become burdensome amidst a busy lifestyle.

Setiawan et al. [6] introduced a concept for an automated rice cooker using a 3D model, but they did not physically develop the system. On the other hand, H.-Q. Zhao and H. Zhao [1] and Rahman et al. [2] successfully developed physically automated rice cookers; however, their devices were specifically designed for cooking rice only. In light of this, we are embarking on a pioneering initiative to design a fully automated rice and grain cooker that can be operated smoothly through a mobile phone application. The aim is to streamline the rice cooking process, making it efficient, user-friendly, and time-saving. By enabling users to operate the

cooker remotely with just a few taps on their smartphones, we seek to alleviate the hassle of traditional rice preparation, empowering individuals to enjoy freshly cooked rice conveniently and without unnecessary time investments. In contrast, our proposed cooker offers versatility by being capable of cooking various grains besides rice. Moreover, one significant advantage of our system is its compact size, which requires significantly less space compared to the cookers mentioned above. This space-saving design enhances its practicality and convenience in different kitchen settings without compromising functionality or performance. Our innovative solution enhances comfort, allowing busy individuals to savor the goodness of home-cooked rice without laborious efforts. Through seamless automation, we envision a future where rice cooking is a breeze, enriching lives and catering to the demands of modern-day living.

II. HARDWARE DESIGN OF THE PROTOTYPE

3D model of the proposed rice-grain cooker is shown in figure 1.

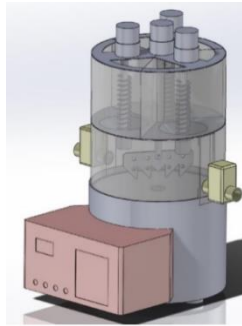


Fig. 1. 3D model of the proposed rice-grain cooker

The proposed system consists of three DC servo motors, helical screws, and three distinct compartments: the storage compartment, the washing compartment, and the cooking compartment. Additionally, the system includes a water inlet, a water outlet, and a controlling unit for seamless operation. For the prototype version, we have chosen Perspex as the material to design the storage and washing compartments.

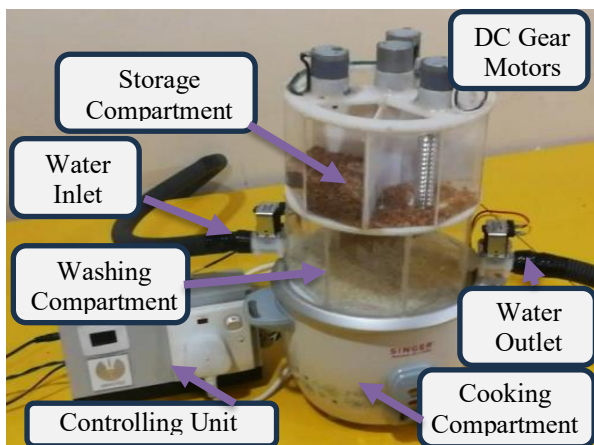


Fig. 2 Prototype design

The storage compartment is designed with three separate cabins, allowing for the simultaneous storage of three different types of grains. This design feature offers a significant advantage as users can conveniently select the grain type and

quantity they desire. Once the user confirms their selection using the app, the corresponding helical screw is activated, initiating the rotation to feed the seeds into the washing compartment for further processing. The amount of grain fed is determined by the number of turns in the system. To facilitate feeding and draining water to the washing compartment, solenoids are employed.

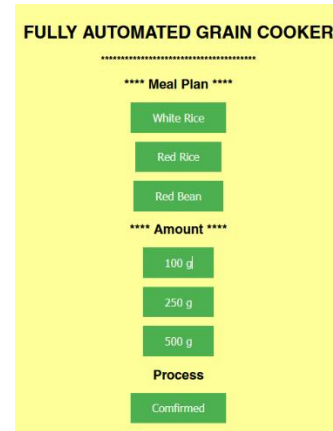


Fig. 3. User interface

The interface for the system is hosted on a local WiFi network, allowing the operator to select the type of meal conveniently and the desired quantity through the user-friendly interface. Upon selecting the meal plan, the online platform transmits the data to the controller, which is then stored in the memory location for reference. Once the cooking process is completed, the system sends an alert to the operator, indicating the successful completion of the task. To develop the printed circuit board (PCB) for this system, the team opted for the Easy EDA tool. Initially, a multi-layer PCB was planned for the system; however, due to challenges in procuring components from China amid the prevailing situation in the country, the team revised the design to a single-layer PCB and successfully developed it locally.

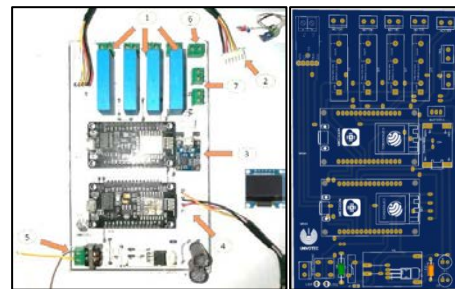


Fig. 4. PCB design

TABLE I. COMPONENTS OF THE CONTROLLER BOARD

No	Description
1	Solid state relays
2	Thermocouple module
3	Battery charger
4	OLED Connection
5	Power supply with smoothing & regulating
6	Heater connection
7	Solenoid connections

III. ARCHITECTURE OF THE SYSTEM

The implemented sensors continuously monitor the water

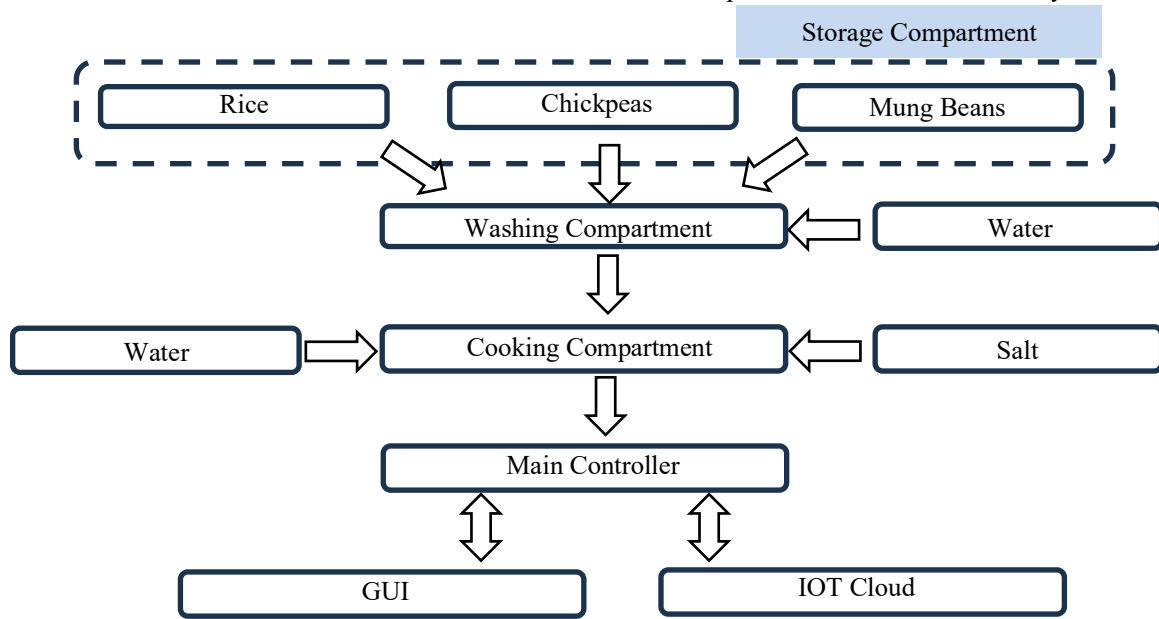


Fig. 5. System architecture

The storage compartment houses three essential grains for cooking, namely rice, chickpeas, and mung beans.



Fig. 6. Available grains

In the Washing compartment, the grains can be washed at any desired time, as per the user's request, and are connected to the water supply for this purpose. Meanwhile, in the cooking compartment, users can customize the amount of salt added to suit their taste preferences, and they also have the option to select the water level for the cooking process.

To ensure seamless functioning, these three processes are efficiently controlled using signals from various sensors and commands from a dedicated mobile application.

availability in the tap line, check the availability of grains in the storage compartment, detect overheating, and assess Wi-Fi connectivity status. Furthermore, the system incorporates a fail-safe mode and an emergency stop feature for enhanced safety and user control. The ESP8266 microcontroller unit (MCU) serves as the central controller for the rice grain cooker system. The system incorporates the LM32 sensor module, which collects temperature readings. For user interface and interaction, a touchpad and display are integrated to provide a graphical user interface (GUI). Motors are employed to control conveyors and rotors, ensuring the precise and efficient functioning of the rice grain cooker. Furthermore, an Android application has been developed to enhance the system's usability. The app allows users to remotely access and operate the rice grain cooker via the internet, providing convenience and flexibility in controlling the cooking process from any location.



Fig. 7 Entire process

By leveraging the capabilities of the ESP8266 MCU and integrating sensor modules, mechanical components, and a user-friendly interface, the rice grain cooker system achieves an efficient and user-centric design. The Android app's internet connectivity enables seamless remote control, empowering users to easily manage and monitor the cooking process without the need for direct physical interaction with the appliance.

IV. OVERALL OPERATION OF SYSTEM

The operation of the fully automated rice and grain cooker begins with the user powering up the appliance and initiating the process by providing the command to start. If the user has specified the type and amount of grain to be cooked through their mobile app, the machine receives this data and configures the basic settings accordingly. The feeding screw is then set in motion to measure the required amount of grain accurately. Once the measurement is complete, the washing blade is activated to cleanse the grain thoroughly. The washing process involves three cycles, and the excess water is efficiently drained through the drain solenoid port. Subsequently, the washed rice or grain is carefully filled into

the cooker through the filling port, with fresh water added for cooking. The washing blade is then deactivated, and the microcontroller switches on the heater to initiate the cooking process. The cooker's temperature is closely monitored using a thermocouple to ensure precise cooking conditions. Depending on the measured temperature, the microcontroller takes appropriate actions: if the temperature surpasses the desired value, the heater is turned off; if it falls within the selected range, the user is informed about the cooking progress. Finally, upon successful completion of the cooking process, the automated rice and grain cooker reaches its end state, ready to serve deliciously cooked grains.

V. CONCLUSION

Encouraging individuals to reduce their fast food consumption is essential for mitigating the risk of developing chronic health conditions.. One effective strategy to promote healthier eating habits is by making cooking at home more convenient and time-efficient. In response to this need, an automated rice and grain cooker has been developed, aimed at significantly reducing the time and effort required to prepare rice and grains.

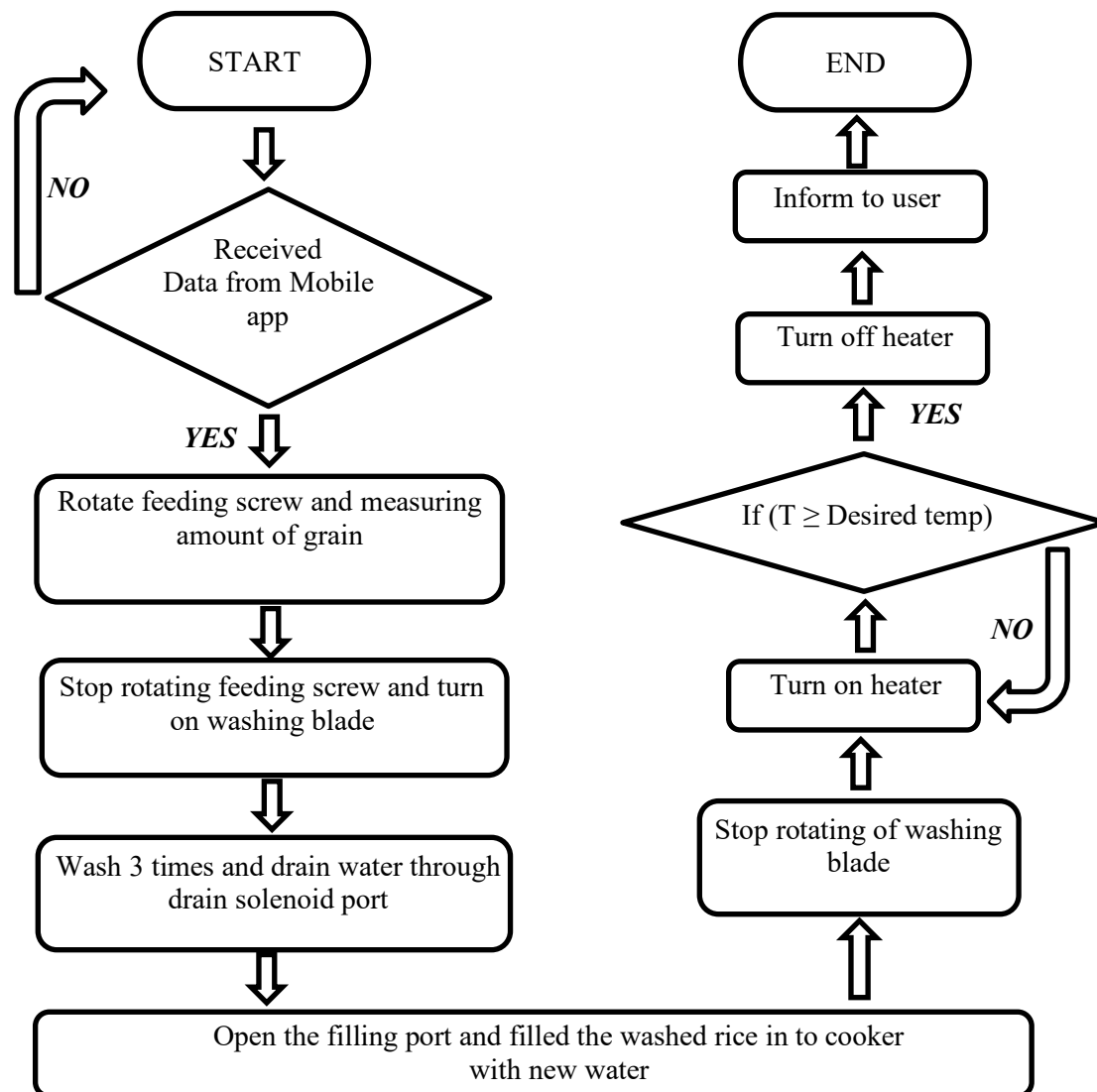


Fig. 8. System flow chart

The automated cooker comprises three compartments designed to facilitate the washing and cooking process seamlessly. The system can be conveniently operated remotely using a smartphone, enabling users to select the type of grains stored in the storage cabins and initiate the washing and cooking procedures, all at their fingertips. By employing the smartphone app, individuals can effortlessly control the entire process with just a few button touches.

The convenience and time-saving features of this automated cooker allow users to start cooking rice or grains remotely, even before arriving home. This not only streamlines the cooking process but also encourages people to opt for homemade meals over fast food options. By making home-cooked meals more accessible and appealing, individuals are more likely to embrace healthier eating habits, contributing to better overall health and well-being.

REFERENCES

- [1] V. P. Dighikar and S. Singh, "To Assess the effect of Fast Food among Adolescent Group", *J. Pharm. Res. Int.*, vol. 33, no. 39A, pp. 201–206, Jul. 2021.
- [2] Z. Bahadoran, P. Mirmiran, and F. Azizi, "Fast Food Pattern and Cardiometabolic Disorders: A Review of Current Studies," *Health Promot Perspect*, vol. 5, no. 4, pp. 231–240, Oct. 2015, doi: 10.15171/hpp.2015.028.
- [3] D. A. Alter and K. Eny, "The Relationship Between the Supply of Fast-food Chains and Cardiovascular Outcomes," *Canadian Journal of Public Health*, vol. 96, no. 3, pp. 173–177, May 2005, doi: <https://doi.org/10.1007/bf03403684>.
- [4] S. Krishnan, P. F. Coogan, D. A. Boggs, L. Rosenberg, and J. R. Palmer, "Consumption of restaurant foods and incidence of type 2 diabetes in African American women," *The American Journal of Clinical Nutrition*, vol. 91, no. 2, pp. 465–471, Dec. 2009, doi: <https://doi.org/10.3945/ajcn.2009.28682>.
- [5] F. A. Rahman, J. R. Simanjuntak, E. Simanjuntak, P. Pangaribuan, P. Pangaribuan, and W. A. Cahyadi, "Automation Rice and Water Filling System on Rice Cooker Via Internet of Things," *Journal of Electrical, Electronics and Informatics*, vol. 4, no. 2, p. 72, Aug. 2020, doi: 10.24843/jeei.2020.v04.i02.p06.
- [6] M. A. Pereira *et al.*, "Fast-food habits, weight gain, and insulin resistance (the CARDIA study): 15-year prospective analysis," *The Lancet*, vol. 365, no. 9453, pp. 36–42, Jan. 2005, doi: [https://doi.org/10.1016/s0140-6736\(04\)17663-0](https://doi.org/10.1016/s0140-6736(04)17663-0).
- [7] K. J. Duffey, P. Gordon-Larsen, L. M. Steffen, D. R. Jacobs, and B. M. Popkin, "Regular Consumption from Fast Food Establishments Relative to Other Restaurants Is Differentially Associated with Metabolic Outcomes in Young Adults," *The Journal of Nutrition*, vol. 139, no. 11, pp. 2113–2118, Sep. 2009, doi: <https://doi.org/10.3945/jn.109.109520>.
- [8] S. Kechagias, A. Emmeresson, O. Dahlqvist, P. Lundberg, T. Lindstrom, and F. H. Nystrom, "Fast-food-based hyper-alimentation can induce rapid and profound elevation of serum alanine aminotransferase in healthy subjects," *Gut*, vol. 57, no. 5, pp. 649–654, Feb. 2008, doi: <https://doi.org/10.1136/gut.2007.131797>.
- [9] N. Babio *et al.*, "Association between red meat consumption and metabolic syndrome in a Mediterranean population at high cardiovascular risk: cross-sectional and 1-year follow-up assessment," *Nutrition, metabolism, and cardiovascular diseases: NMCD*, vol. 22, no. 3, pp. 200–207, Mar. 2012, doi: <https://doi.org/10.1016/j.numecd.2010.06.011>.
- [10] M. Rashid, R. Ahamed, M. Z. Islam, M. M. Rashid, M. M. Ferdous, and M. Abdur Razzak, "MODELING AND PERFORMANCE ANALYSIS OF ELECTRIC RICE COOKER," 2014. [Online]. Available: <https://www.researchgate.net/publication/272291532>
- [11] S. Setiawan, M. I. Rahmatullah, I. Wijaya, and A. Wiyono, "The Design of Automatic Rice Cooker 3 in 1 with Circuit Control Based on Solidworks as Three Dimensional Modelling Software," 2021.

Mould Coating to Improve the Surface Finish of the Cast Iron Products

N.I.L.Aththanayaka

Department of Mechanical and Manufacturing Technology
University of Vocational Technology
Rathmalana, Sri Lanka
man19b202@uovt.ac.lk

K.G.Alahapperuma

Department of Mechanical and
University of Vocational Technology
Rathmalana, Sri Lanka
gayanthi111@yahoo.com

Abstract— The importance of foundry coating to improve the surface quality of castings cannot be simplified. Surface finish is one of the most desired characteristics of a product surface. In this study, the impact of coating on surface finish was investigated by using different kinds of coating samples and evaluating whether coating gives effect to product surface finish. The experiment was conducted for four different compositions, and sand-casting process was used as the process to manufacture the final product. The surface quality of the cast components was assessed by measuring the surface roughness, with the use “surf test instrument”. The average reading of each sample was computed as a Roughness Average (RA) value. In this study, four components were cast using the same pattern, and the chosen “special additive” was the variable of chosen mould coating formulation. The common ingredients of the formulation are miniran powder, fire clay, kaolin and water. Special additives for the four products were coal powder, dextrin, furan resin and furnace oil. The comparison of surface quality was made among the four cast components. From the findings, it was shown that product surface covered with coal powder coating has the best surface finish.

Keywords— *Mould Coating; Sand Casting; Special Additives; Surface Roughness.*

I. INTRODUCTION

Melt casting is one of the main methods of production of metallic components. Among casting processes, sand casting plays a major role due to lower cost involvement and possibility of lower production runs. Additionally, most of the metals can be sand cast. Cast iron, aluminium, cast steel and brass are the metals, widely shaped with the process. This process is mainly suitable for parts that don't require a high degree of dimensional accuracy.

Among these merits, one major drawback of sand casting is poor surface finish. The quality of casting surface mainly depends on the quality of the mould surface. Silica sand is the main constituent (more than 95%) contained in the moulding sand composition, improvement of mould surface quality depends mainly upon applying a proper mould coating. In addition to the provision of aesthetic appearance, improvement of corrosion resistance, wear resistance, and provision of thermal barrier are among the other expectations from a proper mould coating.

To realise the behaviour of coatings with refractory materials, characteristics of coatings need to be known.

The general parameters that characterise foundry coatings are specific gravity, viscosity, solid content, coating thickness, colloidal stability, wettability and surface tension, coating permeability and coating penetration depth etc.[8].

Generally, a refractory coating needs to possess the qualities of good adhesion to the substrate, enough refractory properties, be permeable to reduce air entrapment, fast drying power, no tendency to crack or blister on drying and high covering power etc.[8].

For a mould coating to possess the required qualities, the coating needs to consist of the following components.

- Refractory filler
- Binder agents
- Suspension agents
- Liquid carrier
- Special Additives [1].

A. Refractory Mineral

Refractory minerals possess very high melting temperatures, and therefore, for fusing, they need to be heated to high temperatures. Their processing also takes place at high temperatures, and they are intended to be used in high-temperature environments. In coating composition, refractory materials are dispersed in the binder and it determines the shape of the coating film. Due to the presence of a refractory material, density, hardness and viscosity increase, while permeability reduces. The other characteristics that a mould coating should exhibit include, suitable particle shape, particle size (PS) and particle size distribution (PSD), chemically inertness, consistency in cleanliness and pH, free from volatile elements, be compatible with the chemical binders and not wetted by molten metal. Apart from these, a mineral substance's particle size, particle size distribution and particle shape are important parameters that indicate its performance in a coating. The efficiency of a coating is determined by its refractory material. It may be either a single material or a blend of materials. Approximately, 50% to 70% of a coating is made with its refractory material. These refractory materials include silica, coke, graphite, zircon flour, anthracite, talc, clays, mica, chromite, alumina Plumbago etc. [1,8].

B. Binding Agent

The purpose of the binder is to hold the refractory mineral particles together and to the sand mould surface also. The available variety of binders in coating mixes include natural binders such as starches and wood-derived resins also. A properly functioning binder needs to possess acceptable film hardness, and enough flexibility to allow sand expansion, and it does not cause porosity in the casting due to gases. As the particle size of the refractory decreases, the amount of binder required increases. Generally, the binder needs up to 1 to 5% of the coating. It is worth determining the minimum amount of the binding agent, since too little amount may cause poor adhesion, while the excess amount may result in a brittle coating that may crack and spill off before casting. Furthermore, organic binders usually evolve gas upon heating. Thus, if the local concentration of the binder in certain points of the mould surface is higher, it may cause a higher concentration of gas/es, locally. Thus, such defects as lapping and porosity may result. It is worthy to mention that, most of the organic binders that are used in water suspensions are subjected to biological degradation. However, such reactions don't occur with spirit-based mould coatings. Spirit-based suspensions need natural or synthetic resins. These include phenol formaldehyde, urea formaldehyde, phenol, novolac, furan and natural wood resins etc. [1,8].

A. Suspending Agent

The main purpose of suspending agents is to hold the refractory mineral particles in a suspension. And enable the coating to maintain its required viscosity. Clays, polymers and gums are the commonly used suspending agents. They increase the easiness of remixing when the coating is applied by dipping, brushing, swabbing or spraying. These agents prevent mineral particles from separating for a long period in storage. They control the flow characteristics of the coating also. A suspension agent makes up between 1% and 5% of the coating [1,8].

B. Liquid Carrier

The medium that contains the coating constituents is a liquid carrier, and it acts as the vehicle that transports the mineral materials onto the sand mould surface. Therefore, these coatings are usually suspensions of refractories in a liquid carrier. Approximately, 20 to 40% of a coating is made up of the liquid carrier. There are many factors to be considered in selecting a carrier, and some of them include compatibility of the carrier with refractory and/or sand binder, method of drying, flammability and other characteristics during burning, toxicity odour, application, labour and floor space [1,8].

After applying, the coating is required to be dried well and to prevent forming gas when it comes into contact with hot liquid metal. When the liquid carrier is removed by combustion or evaporation, the sand surface is covered with a protective layer. This layer needs to prevent or minimize the penetration of molten metal into the sand, preventing or reducing the burning and erosion of sand. The most widely used carrier types are aqueous-based and organic solvent-based types. Aqueous carriers are the best in considering

toxicity, non-flammability, and from an environmental point of view. It doesn't have a flash point also. However, it needs to be heated for drying. Compared to organic solvent-based coatings, their tendency to form casting defects such as 'runs' and 'tears' is higher. The potential of aqueous coatings for breakage of cores is also higher. In contrast to the aqueous-based type, organic solvent-based coating possesses fast drying, they are especially recommended to be used on large surfaces of moulds and cores. Due to toxicity and flammability, usage of this category of coatings is threatened by environmental protection agencies [1,8].

C. Special Additives:

These additives are used to enhance properties of the coating such as refractoriness, dry strength, surface smoothness and application characteristics. They ultimately contribute to the overall performance of casting [1].

These additives can be categorised as below.

- Reducing agent - up to 5%
- Cushioning material - up to 3%
- Cereal binders - up to 2%
- Iron oxide powder - up to 2%

II. REVIEW OF LITERATURE

In literature, several past studies are found related to surface coating in melt-cast moulds. In a very recent study in 2023, Deng et al found in their study that mould coating thickness essentially affects the coating's resistance to heat, which directly affects the microstructure of castings. They analysed the as-cast surface and coating surface for nine different coating thicknesses. They found a close relationship between coating thickness and as-cast surface roughness. Accordingly, they could derive the coating thickness with as-cast surface analysis [2].

In 2019, Luo and his group's research was based on an analysis of coating thickness on the interfacial heat transfer and slug microstructure. The coating was based on boron nitride. According to the results, interfacial heat transfer decreased with the increase in coating thickness and was much more sensitive when the thickness of the coating was below 0.1 mm [3].

Nunes and his group 2017 conducted another analysis with two high-pressure die-cast moulds, which had been subjected to severe wear problems. To check the advantages and effects of the coating application, some critical parts of the moulds were coated. Different types of coatings were used, and wear residence behaviour and wear mechanisms were carefully analysed. As per the outcomes, some of the coatings have clearly shown better behaviour, minimising the wearing problems of the moulds [4].

In 2016, Omidiji et al conducted research to check the influence of refractory coating mix design on the surface roughness of the plate shape castings produced with evaporative patterns. The coating composition consisted of Kaolin and silica sand, and Kaolin acted as the binder. The carrier was methyl alcohol with 99% concentration. Nine

runs were conducted, and process temperature was recorded as a process parameter. The lowest surface roughness was achieved with 10% Kaolin and 90% silica flour mix design. 650°C was the related pouring temperature [5].

One study by Chisamera et al was in 2015, to check skin variation in iron castings using different surface coatings. It was found when the mould coating contained Sulphur, the graphite nodulising potential of casting was adversely affected, while it contained Mg, which was reversed and graphite nodules were properly formed [6].

In 2015, Xu and his group developed a good coating based on spraying the coating on a green sand mould surface, used for the casting of steel. The coating mixture mainly consisted of zirconium powder and corundum, and the remainder were organic bentonite, organic and inorganic binders, polyvinyl butyral (PVB), additives and solvent carrier. The coating was with high strength and showed high anti-cracking qualities at high temperatures. Gas evolution was low. The surface finish of the casting was good [7].

Hamasaiid et al had a study in 2007, to investigate the influence of die coating thickness, coating composition and cast alloy composition on the heat transfer at the cast mould interface. Two coatings of graphite-based and TiO₂ were investigated. Two alloys were used; Al-Si-Mg-based and Al-Si-Cu ones, respectively. With thermocouples, thermal histories throughout the die surface were recorded. As a result, the coating material has a weak influence when the alloy remains in a liquid state, and the thermal resistance mainly depends on the thickness and the porosity of the coating. As the thickness of the coating increases, the heat transfer coefficient (HTC) decreases. When solidification occurs, the HTC of graphite-based coating becomes higher than the TiO₂-based one with equal thickness. HTC is larger for Al-Si-Mg alloy than for Al-Si-Cu alloy. Therefore, the solidification time of the Al-Si-Cu alloy is larger than the Al-Si-Mg one [9].

III.METHODOLOGY

In this study, efforts were made towards determining good surface finish, of castings using different mould coating. Four different casting mixes were made by introducing four types of special additives to the already existing mould coating composition. Five cast items were produced with one pattern, and by using five types of mould coatings. The quality of the surface was determined by computing surface roughness (Roughness Average, RA Value) on each test sample. This surface roughness is obtained by the “Surf Test SJ 301”.

The main components of the existing coatings are miniran powder, fire clay, kaolin and water. The extra added component to each mix is “special additives”. The chosen four special additives are coal powder, dextrin, furan resin and furnace oil. The comparison of surface roughness was made among the five cast products, four products made with each “special additive” added composition and the product

made with the existing mould coating composition. In cereal binder – dextrin and reducing agent of furnace oil, coal powder and furan resin were used as the special additives.

A. Preparation of Test Samples

The influence of different forms of “special additive” added mould coating compositions on the surface of sand cast mouldings was investigated in this study. Table 1 displays the quantities of added ingredients in each mix design.

TABLE I. COMPOSITION OF MOULD COATING SAMPLES

Material	Test Samples				
	S 1	S 2	S 3	S 4	S 5
Miniran Powder	100g	100g	100g	100g	100g
Water	150g	150g	150g	-	150g
Diesel	-	-	-	150g	-
Fire Clay	5g	5g	5g	5g	5g
Kaolin	10g	10g	10g	10g	10g
Coal Powder	4g	-	-	-	-
Dextrin	-	2g	-	-	-
Furan Resin	-	-	4g	-	-
Furnace Oil	-	-	-	4g	-

IV.RESULTS AND DISCUSSION

In this study, the surface roughness of the selected cast iron item was analyzed by varying the applied mould coating. The obtained readings are graphically shown the Fig. 1, which depicts a variation of the surface roughness, Ra, of the various sample sections. The graph shows that the surface roughness values of the different test samples vary drastically across different sections.

Based on Fig. 1, it is revealed that the surface roughness of the test sample with coating on the mould surface ranges from 23.03µm to 10.34µm. This means these findings support the concept that coating can essentially impact surface finish. The coating affects the value of surface roughness because it covers the irregular and uneven surface of the mould. According to the graph, the sample 4 with the furnace oil shows the highest surface roughness and sample 1 with coal powder has the lowest surface roughness, compared to other test samples.



Fig. 1: Variation of surface roughness (RA) value in test samples

The average surface roughness value of three readings of each sample was taken to ensure precision and accuracy, and the average results are shown in

TABLE II COMPOSITION OF MOULD COATING SAMPLES

Roughness Average	Sample 1 (With Coal Powder)	Sample 2 (With Dextrin)	Sample 3 (With Furan Resin)	Sample 4 (With Furnace Oil)	Sample 5 (Exist)
Average surface roughness, (µm)	14.89	16.64	15.43	19.16	19.23

* Surface roughness, Ra (µm), accuracy 0.01 µm.

average surface roughness of the test samples, which were made via sand casting is shown graphically. The surface roughness, Ra, of the final product was depicted in Fig. 2 as a bar graph. The figure shows that the surface finish of the finished product varies due to the varied coating effects.

According to the Fig.2, all types of coating materials have acceptable lower surface roughness, Ra. Of all five samples tested using different kinds of special additives in coating materials, coating with coal powder (sample 1) has the lowest average surface roughness value. Sample 1 (with coal powder), sample 2 (with dextrin), sample 3 (with furan resin), sample 4 (with furnace oil) and sample 5 (sample with existing coating), the obtained average Ra (µm) values were 14.89, 16.64, 15.43, 19.16 and 19.23, respectively.

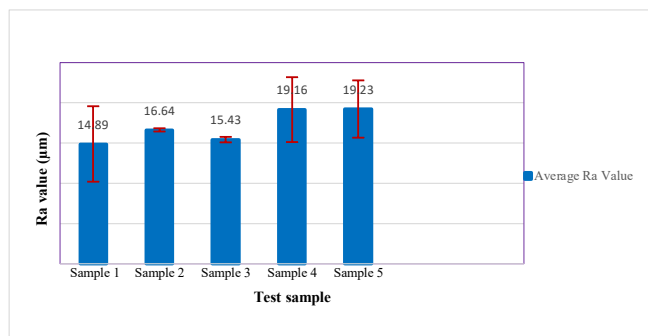


Fig. 2: Comparison between average surface roughness values of the cast samples

Two tail t-tests were conducted, for the coating with the existing composition and one of the modified (special additive added) composition, each time. Accordingly, four such pairs were tested. The obtained results are shown in Table III.

Null hypothesis: There is no difference between the results of the existing coating and the modified coatings. Alternative hypothesis: There is a difference between the results of the existing coating and the modified coatings

Since the obtained p values are greater than 0.05 for all four cases, there is no evidence to reject the null hypothesis. Therefore, it can be concluded that there is no significant difference between the surface roughness readings of the existing coating and any of the modified coatings.

TABLE III RESULTS OF T-TEST (IN EACH CASE, EQUAL VARIANCES ARE ASSUMED FOR THE TWO SAMPLES; EXISTING COATING AND SPECIAL ADDITIVE ADDED COATING)

Analysed Factor	Existing Coating	Coating with Coal Powder	Coating with Dextrin	Coating with Furan Resin	Coating with Furnace Oil
Mean	19.23	14.89	16.64	15.4266	19.15
Variance	12.64	21.95	0.04	0.1166	16.26
Observations	3	3	3	3	3
Pooled Variance	17.29				
Hypothesized Mean Difference	0				
df	4				
t Stat	1.278				
P(T<=t) one-tail	0.135				
t Critical one-tail	2.131				
P(T<=t) two-tail	0.27				
t Critical two-tail	2.77				

Several things could have affected the results. The mould-making process also could have an impact on surface finish. The composition of moulding sand and the variation of composition could also have affected the results. Even not be sufficiently accurate, since only approximate weights of ingredients were taken, practically.

The multiple variations between the test conditions might have caused the variation in casting qualities. Furthermore, reclaimed green sand could result in a poor surface finish for green and molding. In this experimental investigation, the molten metal was accidentally poured into the sand mould numerous times, and it might have affected the variation in the final product's surface quality. Furthermore, the coating application procedure might have affected the surface finish. The applied coatings were of unequal thickness, and the brush action could be visible on the castings. In mould making, when sand is compacted manually, there might be locally highly stressed parts in the sand moulds.

The study was based on the improvement of the surface quality of cast Iron products, by improving the surface quality of the related sand moulds. Therefore, the major area of study is limited to sand casting, which is only a fraction of total cast products. In the modern world, the contribution of sand casting to the total cast output is not smaller.

This production process has many advantages, including low cost involvement, flexibility, high heat resistance etc., which can't be easily reached by other casting methods. For high-temperature metals such as nickel, steel and titanium, sand casting is the most widely used casting process. This process is widely employed in the aerospace and automotive industries, preferably to produce low-cost components. Since the surface quality of sand-cast products is lower compared to the other permanent mould cast components, improving the quality of sand mould surfaces is a prime researchable area.

CONCLUSION AND RECOMMENDATIONS

It is concluded that the experimental study successfully achieved its major goal of investigating the surface finish of test products. In this experimental investigation, test samples with mould coating effect have shown practically a better surface finish in all selected samples, with 14.89 μm for sample 1, 16.64 μm for sample 2, 15.43 μm for sample 3, and 19.16 μm for sample 4, compared to 19.23 μm for sample 5 of current coating. The results indicate that the use of special additives can overcome the poor surface finish in sand casting of cast iron products.

Finally, utilizing the coating of sample 1 is the ideal way to achieve a superior surface finish in the sand-casting

process. In the selected mixture, added amounts of miniran powder, water, kaolin, fire clay, and coal powder, as a special additive were 100 g, 150 g, 10 g, 5 g, and 4 g (37.2%, 55.8%, 3.7%, 1.8% and 1.5%) respectively.

The following recommendations are made for future experimental efforts in this case, to improve the surface properties of related castings, further.

1. Use a spraying system to apply the coating in order to keep the coating surface with even thickness.
2. Other qualities and properties of castings such as wear resistance, hardness, dimensional accuracy and surface microstructure can be critically investigated for future development of the products.

REFERENCES

- [1] Introduction to Foundry Coatings, HR International LLC.
- [2] F. Deng, S. Kian and W. Volk, "An Indirect Evaluation Method of Mould Coating Thickness in AISI Alloy Permanent Mould Casting Production", *International Journal of Metallurgy*, vol.17, issue 3, pp. 2072- 2084, 2023.
- [3] M. Luo, D. Li, W. Qu, X. Hu, Q. Zhu and J. Fan, "Mould Slug Interfacial Heat Transfer Characteristics of Different Coating Thicknesses: Effects on Slug Temperature on Microstructure in Swirled Enthalpy Equilibrium Device Process", *Materials*, 2019.
- [4] V. Nunes, F. G. J. Silva, M. F. Andrade, R. Alexandre and A. P. M. Baptista, "Increasing the Lifespan of High Pressure Die Cast Moulds Subjected to Severe Wear", *Surface and Coatings Technology*, vol. 332, 25, pp. 319-331, December 2017.
- [5] B. V. Omidiji, R. H. Khan and M. S. Abolarin, "Silica - Kaolin Mix Effect on Evaporative Pattern Castings Surface Roughness", *Archives of Foundry Engineering*, vol. 16, issue 3, pp. 83-88, 2016.
- [6] S. Chisamera, N. Ivan, I. Riposan and S. Stan, "Iron Casting Skin Management in No - Bake Mould - Effects of Magnesium Residual Level and Mould Coating", *Article in China Foundry*, pp.222 - 230, May 2015.
- [7] Z. L. Xu, J. Wang, S. S. Yang, Q. L. He and H. S. Xiong, "Application of Alcohol Based Spraying Coating on Green Sand Mould for Steel Casting", *IOP Conference Series: Materials Science and Engineering*, 103, 012012, 2015.
- [8] U. C. Nwaogu and N. S. Tiedje, "Foundry Coating Technology: A Review", *Materials Science and Application*, vol. 2, pp. 1143 - 1160 2011.
- [9] A. Hamasaiid, M. S. Datgusch, C. Davids, S. Tovar, T. Loulou, F. Rezai - Aria and G. Dour, "Effect of Mould Coating Materials and Thickness on Heat Transfer in Permanent Mould Casting of Aluminium Alloys", *Metallurgical and Materials Transactions A*, vol. 38, pp. 1303 - 1316, 2007.

Change of Technical Properties of Polyvinyl Chloride Products in Outdoor Environment

K. G. Alahapperuma
Department of Mechanical and
Manufacturing Technology
University of Vocational Technology
Ratmalana, Sri Lanka
kgalahapperuma@uovt.ac.lk

A.M. P.B. Samarasekara
Department of Materials Science
and Engineering
University of Moratuwa
Katubedda, Sri Lanka
bandu@uom.lk

Sampath Weragoda
Department of Materials Science
and Engineering
University of Moratuwa
Katubedda, Sri Lanka
sampathw@uom.lk

Abstract—Nowadays, polymers have captured a substantial component of human involvements in various fields, due to their diverse attractive properties. Poly Vinyl Chloride (PVC) is one of the highly demanding thermoplastic polymers that is extensively used in various industries. Susceptibility to degradation when exposed to natural outdoor weathering is a key disadvantage of this polymer. This study was carried out to analyze the degradation characteristics of PVC based products exposed to outdoor weathering for different time durations. The study was conducted using 63mm diameter UPVC (Unplasticised Poly Vinyl Chloride) commercially available pipes. Initially, tensile strength, percentage elongation at break, hardness and percentage water absorption values were measured for the unexposed set of samples (reference sample set). Next, the prepared samples were allowed to expose to natural outdoor weathering environment, including light/dark and wet cycle. Eight sets of samples were removed from the test environment at different time intervals (30, 60, 90, 120, 150, 180, 210 and 240 days). Tensile strength, percent elongation at break, hardness, percent water absorption and visual inspection tests were performed for these samples after each time interval. Test results obtained from actual weathering were compared with the reference sample's results. According to the experimental results, somewhat gradual and little reduction of tensile strength, percentage elongation at break and hardness were observed with the increase of outdoor exposure time of test samples. Original colour of the samples were gradually changed, and a noticeable colour change was observed at the end of 150 days exposure to outdoor environment. Samples exposed to outdoor environment for 240 days showed the maximum water absorption of 0.03%. Experimental results did not indicate a significant property variation after outdoor exposure of products. Property retention of tensile strength, percentage elongation at break and hardness were 94%, 91% and 96% respectively after exposure to 240 days.

Keywords—polyvinyl chloride, outdoor weathering, property retention, polymer

I. INTRODUCTION

Polymers, whether natural or synthetic, are organic materials, with large molecules and are made of many repeating units. These polymer materials display many

processing and serviceable properties that make them useful for various fabrications. Due to these advantages, their usage has been widespread to many areas of human life, by today [1-5, 15].

Polymers can be classified as 'natural polymers' and 'synthetic polymers'. Biopolymers and dry material originated from plants represent natural polymers. For example, cellulose, starch, chitin, etc., are natural polymers found in the environment [2 –11].

Synthetic polymers are developed predominantly from petroleum by-products. Plastics are one major category of synthetic solid polymers that consist of longer polymeric molecules and hence higher molecular weights. In addition to the petroleum products, synthesis of plastics involve many organic and inorganic materials, including gases. Poly Ethylene (PE), Poly Propylene (PP), Poly Vinyl Chloride (PVC), Polyethylene Terephthalate (PET) and Poly Styrene (PS) are the most widely used, plastic materials. Their total usage represents 90.3% by weight of total usage of all polymeric materials, and the remaining 9.7% is represented by the all other types of polymeric materials. Domestic appliances, transportation, construction, shelters, healthcare products, chemical industry, storage and packaging etc. are main sectors of application of present day synthetic polymers [1-11, 15].

Even a small variation in the chemical structure of polymeric materials may result in large variations in their properties and thereby their intended purposes in applications. Even though plastic materials are only one portion of all polymeric materials, they themselves consist of an extremely large group of materials. [1-9].

Of all plastic materials, PVC is the third mostly consumed polymer. PVC is regarded as an economical, safe, highly durable material and is applied extensively in various industries and many other sectors of human life. It is regarded as a high quality versatile material, mainly due to its light weight, ease of processing and recyclable characteristics, desirable physical and mechanical properties with good mechanical strength, toughness, abrasion resistance, chemical, heat, flame and corrosion resistance. Additives such as lubricants, heat stabilizers, impact modifiers, fillers and UV stabilizers enhance

PVC's durability and make it suitable for a wide range of applications. The first patent for a polymerisation process to obtain PVC was in 1913, and it is produced commercially since 1933 [4,9,10].

PVC comes in two basic forms; rigid form and flexible form. Rigid form is called Un- plasticized Poly Vinyl Chloride (UPVC) and also as Rigid Poly Vinyl Chloride (RPVC). Due to incorporation of plasticizers, PVC attains softer and more flexible nature than UPVC. PVC is used in electrical cable insulation, plumbing, inflatable products, signage, synthetic leather and many other applications including profiles for doors and windows. It is also used to manufacture bottles, other non- food packaging, and bank cards as well. [2-13]. Organic materials change their properties due to environmental influences such as UV light, moisture, heat, and chemical elements such as acids, solvents, alkalis and some salts. These changes can be undesirable for the intended applications. The aforementioned changes of original properties causes to a reduction in the polymer's molecular weight and also results in cracking and chemical degradation of products [3-13].

Exposure to incident UV radiation, photo- chemical reactions such as chain scissions do occur and either water and/or chemical oxidizers may accelerate these natural processes. These changes may reduce the performance of PVC polymer products and may lead to failure of products at a fast rate. Therefore, analysis of the degradation behaviour of PVC under the natural environment is necessary to investigate and control the life time of this PVC-polymer products, as a service requirement. Therefore, the main objective of this research is to study the degradation characteristics of PVC exposed to natural environment inclusive of UV radiation [4,9,11,12].

II. LITERATURE REVIEW

Polymer science is fuelled by the need to create new materials for new applications. One of such a succeeded material is polyvinyl chloride and this material is manufactured on a huge scale, and often abundant. Being the third most widely used polymer, it is regarded as a multipurpose material. It is used extensively across a wide range of applications, in many different sectors of human life, in either flexible or rigid form [3-10].

It is widely recognised that UV rays in sunlight (wave lengths in between 250nm-400nm) is an important factor causing photo degradation to some organic materials including PVC polymer.

Photo-oxidative degradation results in the breaking of the PVC polymer chains, producing free radicals and reduces the molecular weight, causing deterioration of mechanical properties. Thus, original material converts into a deteriorated material after a duration of exposure, which is not straightforward to predict [4,9,11,12]

In order to protect against the damaging effect by UV rays on PVC, addition of UV light absorbers, light stabilisers, hydro-peroxide decomposers, antioxidants,

pigments and fillers are an efficient solution in practice [4-13].

III. EXPERIMENTAL

Materials

This analysis was performed on commercially available 63 mm UPVC pipes.

Testing of Samples

Altogether, nine sets of test pieces were prepared from the selected materials. First, original Shore hardness, tensile strength, percentage elongation and water absorption properties of the selected materials were tested for the reference samples. Next, the remaining eight sets of prepared samples were exposed to outdoor weathering environment, for different time durations. The same tests as before were performed for these samples at the end of each test period. Obtained results and properties were compared with those of the original (reference) set of samples.

Outdoor Weathering Exposure Test

The test was performed by exposing the prepared samples to outdoor environment including light, dark and wet cycles, for different time durations. Accordingly, each of eight sets of samples were removed from the test environment at the end of 30days, 60days, 90days, 120days, 150days, 180days, 210days and 240days, respectively. After the outdoor weathering exposure test, tensile strength, percent elongation at break, hardness, water absorption properties and visual inspection properties were tested for these samples under standard conditions.

Tensile Test

This test was performed with the use of Universal Testing machine and by the test, properties of tensile strength and percentage elongation were tested. Altogether twenty seven PVC test pieces were prepared for the test as per the standard dimensions. Out of them, three test pieces were considered as the reference sample. The rest of the twenty four test pieces (i.e. eight sets with three test pieces in one set) were exposed to outdoor weathering test. In each case, average of readings of all three test pieces was considered as the value of the property (i.e., either tensile strength or percentage elongation at break). These values were compared with those average values of the reference test pieces. The strain rate of the universal testing machine was 50 mm/min, at 25°C. Test conditions followed for this test were in agreement with the ASTM- D 638 standard.

Hardness Test

In total, nine PVC test pieces were prepared, each with 30 mm x 30 mm dimensions. Out of them, one test piece was considered as the reference sample. Other eight test pieces were exposed to outdoor weathering test. For the reference sample, and after each piece was exposed to outdoor weathering for the prescribed time duration, the measurement of hardness was carried out, for them. This was carried out according to the ASTM D 2240 standard. D scale of Shore hardness tester was used for hardness measurement. Hardness results

of this test were compared with the values of the reference sample.

Water Absorption Test

Nine sets of test pieces with each set having three test pieces, were prepared, and each piece was with 2.5 cm x 2.5 cm dimensions. Each one's initial weight was measured, and one set was taken as the reference sample. Remaining eight sets of were exposed to outdoor weathering test. When each and every set of samples was taken out of the test environment after the prescribed time duration, each piece was immersed in water for 24 hours. The weight was again measured after the water immersion time. The average of weight difference thus obtained was used to calculate the percentage water absorption (by weight), in each time. These values of percentage of water absorption were compared with that of the reference sample. Readings of the reference sample had been taken, initially. This test was performed according to the ISO 62 standard.

Visual Inspection Test

Here again, nine test pieces were prepared, each with 25 mm X 25 mm dimensions. One was considered as the reference sample. Other eight test pieces were exposed to outdoor weathering. When each and every sample was exposed to outdoor for the prescribed duration, physical appearance of each piece was compared with that of the reference sample.

IV. RESULTS AND DISCUSSION

Tensile Strength

Fig. 1 indicates somewhat gradual reduction of tensile strength with the increase of exposure time to outdoor environment. Tensile strength of reference sample has been 55.6 N/mm² and the value has been reduced only up to 52.3 N/mm² at the end of 240 days' exposure to outdoor. Reduction of tensile strength may be caused by the initiation of molecular-chain scission, and its progress taken place due to environmental degradation [2-14]. Since degradation is a temperature dependent process it has been attempted to model the process through an Arrhenius type model.

Tensile strength property retention is indicated as 94% by these test results.

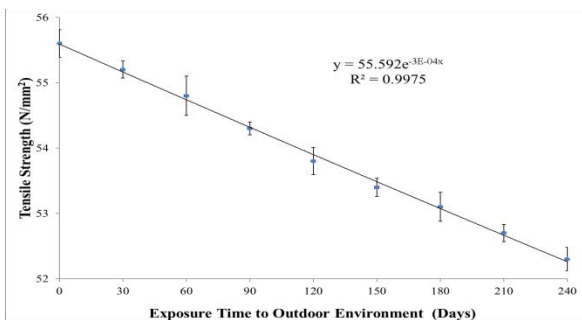


Fig. 1. Tensile strength versus exposure time to outdoor environment

Percent Elongation at Break

Test results of percentage elongation at break is shown by the Fig. 2. Average elongation at break value of reference samples was 86.4% while the average reading was reduced only up to 84.0% at the end of 240 days' exposure to outdoor.

Reduction of elongation at break must also have happened due to the same reason as reduction of tensile strength [4-14]. Percentage property retention of percent elongation, after 240 days' exposure to outdoor weathering was 91%. This result is also an indication of slow rate of degradation of PVC, under environmental exposure.

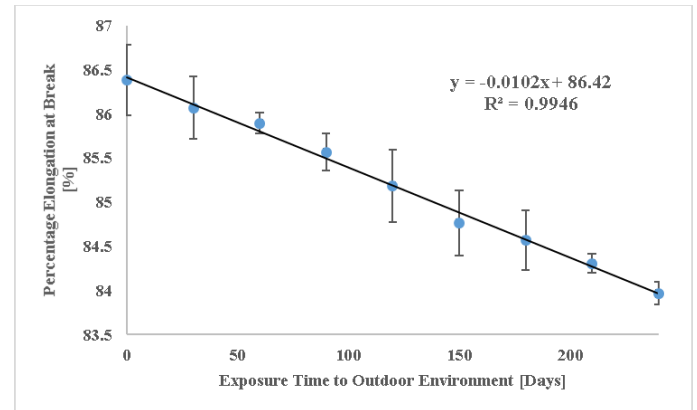


Fig. 2. Percent elongation at break versus exposure time to outdoor environment

Hardness Properties

Fig. 3 indicates the hardness test results. Hardness values also reduced gradually with the environmental exposure duration. Average hardness value of reference sample was 78 Shore D hardness, while the average hardness value has been reduced only down to 75 Shore D hardness, after 240 days' exposure to outdoor.

According to the test readings, approximately 96% hardness property has been retained after the said duration of 240 days' exposure to outdoor.

With respect to hardness also, shown rate of environmental degradation of PVC is at a fairly low rate.

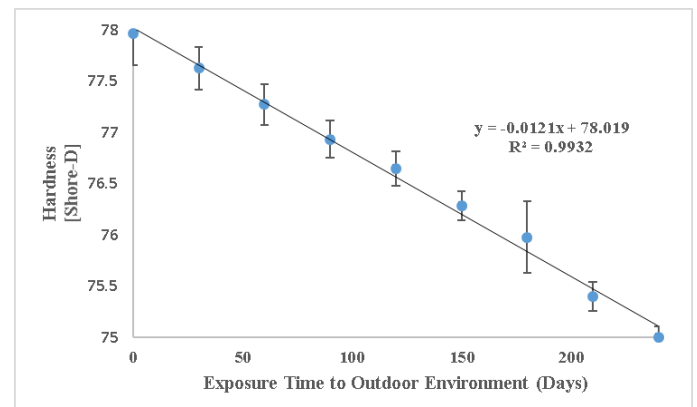


Fig. 3. Hardness versus exposure time to outdoor environment

Water Absorption Properties

Percent water absorption values of outdoor exposed PVC samples is shown in Figure 4. Water absorption has increased gradually with the increase of exposure time. Average water absorption of reference sample has been 0.011%, while the average value has been increased only up to 0.03% after 240 days' exposure to outdoor environment. This increase of water absorption may either be due to loosened surface structure or surface cavities, or sometimes may be due to both, created by molecular degradation phenomenon [2-14]. Therefore the process cannot be modelled by an exponential function as in the case of other properties.

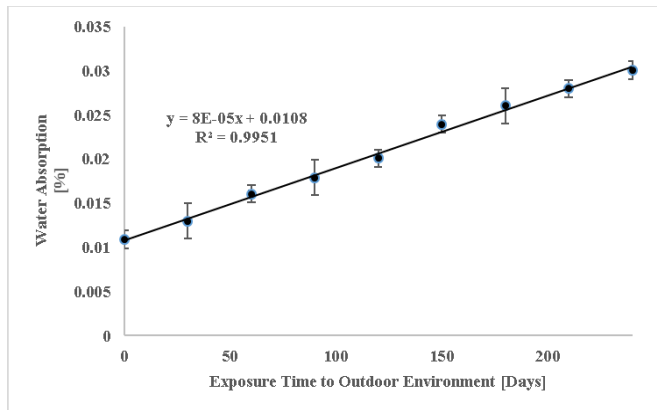


Fig. 4. Percent water absorption versus exposure time to outdoor environment

Visual Inspection

Surface colour of the samples has been changed significantly, from dark grey to light grey, by 150 days' exposure to outdoor environment, and after that until 240 days exposure, change of colour was not distinguishable by the naked eye.

The main reason of colour change could be due to dehydrochlorination, during the degradation process [2-14].

V. CONCLUSION

Experimental results indicated that the degradation of tested PVC samples after the weathering period was not significant. However, the rate of degradation indicated that the property retention may reach below 80% as shown in table 1.

TABLE I. PREDICTION OF PROPERTY RETENTION TIME TO REACH 80%

Property	Retention Time (Number of days)
Tensile Strength	860
Percentage Elongation	902
Hardness	1400

These are significantly short periods for an application that is constantly exposed to outdoor environment. Therefore it is recommended that the tested

PVC material is not exposed to weathering, especially sunlight which contribute to chemically accentuated weathering, in order that it can be used for a longer duration.

REFERENCES

- [1] D. P. Egodage, H. T. S. Jayalath, A. M. P. B. Samarasekera, and D. A. S. Amarasinge, "Fabrication of antimicrobial material for food packaging aApplications" Proceedings of International Forestry and Environment Symposium," vol. 21, 2017.
- [2] P. Y. Gunapala and A. M. P. B. Samarasekera, "Extraction and modification of chitosan from fishery waste to develop biodegradable polyethylene films" 12th ERU Symposium, pp. 38-39, 2013.
- [3] Kahawita, K. D. H. N., and A. M. P. B. Samarasekera, "Extraction and characterisation of cellulose fibers from fawmill waste," Moratuwa Engineering Research Conference (MERCon), pp. 343-348, 2016.
- [4] K. G. Alahapperuma, and A. M. P. B. Samarasekera, "Study of the photodegradation phenomenon of polypropylene based sheets," TecEx International Research Symposium, University of Vocational Technology, 2019.
- [5] Scott, Gerald. "Why degradable polymers?." In Degradable Polymers, Springer, Dordrecht, pp. 1-15. 2002.
- [6] A. M. P. B. Samarasekara and H. V. H. H. Senavirathne and A. H. W. O. Sandaruwan, "Preparation of biodegradable polymer materials using agricultural waste," Proceedings of International Forestry and Environment Symposium, vol. 17, p.51, 2012.
- [7] L. D. Rajapaksha, H. A. D. Saumyadi, A. M. P. B. Samarasekara, D. A. S. Amarasinghe and, L. E. Karunanaya, "Development of cellulose based light weight polymer composites," Moratuwa Engineering Research Conference (MERCon), pp. 182-186, 2017.
- [8] A. M. P. B. Samarasekara and F. A. P. C. D. Jayasuriya, "Synthesis of biodegradable polyolefins based polymer composites using degradable natural materials," Proceedings of International Forestry and Environment Symposium, vol.18, 2014.
- [9] K. G. Alahapperuma and A. M. P. B. Samarasekara, "Analysis of Poly Vinyl Chloride based products," Annual Journal, International Post-graduate Research Conference, University of Kelaniya, Sri Lanka, vol. 06, 2018.
- [10] K. G. Alahapperuma and A. M. P. B. Samarasekara, "Analysis of degradation characteristics of polymer products during engineering applications," Proceedings of Annual Sessions, (Transactions Part B), Institution of Engineers, Sri Lanka, pp. 679-685, 2018.
- [11] S. Umadaran, P. Somasuntharam and A. M. P. B. Samarasekara, "Preparation and characterisation of cellulose and hemi-cellulose based degradable composite material using sugarcane waste," Moratuwa Engineering Research Conference (MERCon), pp. 367-372, 2016.
- [12] K. G. Alahapperuma and A. M. P. B. Samarasekara, "Degradation of Poly Vinyl Chloride based engineering products upon exposure to ultra violet radiation," Tropical Africultural Research, Post Graduate Institute of Agriculture, University of Peradeniya, Sri Lanka, vol. 30(4), pp.117-123, 2018.
- [13] A. Greco, F. Ferrari and A. Maffezzoli, "UV and thermal stability of soft PVC plasticised with cardanol derivatives" Journal of Cleaner Production," vol. 164, pp. 757-764, 2017.
- [14] Emadyousif Ali Hasan, "Photostabilisation of Poly Vinyl Chloride", Journal of Taibah University for Science", vol. 09, Issue 04, pp. 421-448, Oct. 2015.
- [15] KG Alahapperuma, "Study of the deterioration of mechanical properties of polypropylene sheets under Sri Lankan outdoor environmental conditions" -8th Annual Research Symposium, Institute of Technology, University of Moratuwa, (ITUMRS-2021), September 2021.

A Role of IOT in Industrial Data Monitoring: A Review

B.N.Ekanayake

*Department of Electrical & Electronics
Technology
University of Vocational Technology
Ratmalana, Sri Lanka
sdsanjeewa@uovt.ac.lk*

D.G.S.A.Munasinghe

*Department of Electrical & Electronics
Technology
University of Vocational Technology
Ratmalana, Sri Lanka
sdsanjeewa@uovt.ac.lk*

K.O.Kotalawala

*Department of Electrical & Electronics
Technology
University of Vocational Technology
Ratmalana, Sri Lanka
sdsanjeewa@uovt.ac.lk*

Sondarangallage D.A.Sanjeewa

*Department of Electrical & Electronics
Technology
University of Vocational Technology
Ratmalana, Sri Lanka
sdsanjeewa@uovt.ac.lk*

Abstract— The rapid development of the Internet of Things (IoT) has transformed industries through the integration of devices, sensors, and data analytics, allowing for seamless communication and data sharing. This paper provides an in-depth examination of IoT-based industrial data monitoring and control systems, with a focus on their design, applications, and problems. The review analyzes the significance of implementing IoT into industrial operations, emphasizing advantages such as real-time insights, predictive maintenance, cost savings, and improved decision-making. Recent research is evaluated, bringing insight into new approaches in a variety of industries ranging from manufacturing and healthcare to energy and logistics. The Industrial Internet of Things (IIoT) and its importance in data monitoring are reviewed, with an emphasis on the role of sensors in gathering real-time data for efficient operations. Regardless of the possible benefits, the issues of data security and privacy, scalability, interoperability, and reliability are addressed. Addressing these problems and capitalizing on the potential of IoT-based systems can help industries improve efficiency, production, and competitiveness.

Keywords— *Internet of Things, Data Monitoring, Industrial Internet of Things, IIOT*

I INTRODUCTION

The concept of the Internet of Things (IoT) has arisen as a revolutionary force across multiple sectors in today's rapidly growing technology world, transforming the way we interact with devices and data [1]–[4]. The Internet of Things (IoT) is an interconnected network of physical devices, sensors, software, and data analytics that allows for seamless communication and data sharing across various components. The Internet of Things (IoT) was born in the early 2000s, when the goal of a worldwide interconnected network of devices was initially defined. The combination of developments in wireless communication, sensor technology, and cloud computing, on the other hand, brought IoT into reality [5]–[7].

Industry utilization of IoT has resulted in an evolution in how data is gathered, monitored, and used for operational

analysis. The potential to connect different industrial assets, ranging from machinery and equipment to environmental sensors, has led to the Industrial Internet of Things (IIoT) [5], [8]. By enabling real-time monitoring, predictive maintenance, and data-driven decision-making, the IIoT has reshaped traditional manufacturing processes, supply chain management, and industrial automation.

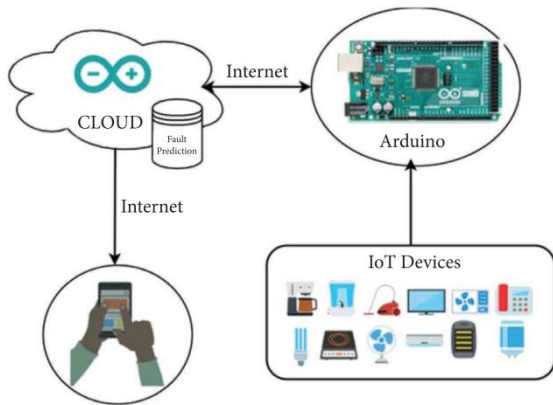
The interaction of IoT and industrial data monitoring systems, especially IoT-based industrial data monitoring and control systems, is the main objective of this research study. These systems combine hardware, software, and data analytics in continuous management, resulting in an overall structure that enables industries to monitor, analyze, and improve their operations with surpassing accuracy. This review paper's key contribution is its attempt to serve as a comprehensive resource for researchers, academics, and engineers interested in delving into the complexities of IoT-based industrial data monitoring systems. This study seeks to give a roadmap for learning the current landscape of data monitoring systems within industrial settings by defining the evolution of these systems, explaining their key components, and emphasizing their applications in the real world.

These technologies have the ability to improve efficiency, reduce delays, improve the allocation of resources, and enable predictive maintenance techniques [9]. As industries become more data-driven, the knowledge gained from these technologies enables decision-makers to shift from reactive to proactive methods, resulting in cost savings and increased productivity. We give an in-depth overview of IoT-based data monitoring systems in the following sections of this research paper. We look at their architecture, the importance of sensors and data collection, and the use of cutting-edge technology like edge computing and cloud computing [10]. This study also explores real-world case studies that highlight the practical application and benefits of IoT-based industrial data monitoring systems.

The paper is split into the following eight sections: Section 2 analyzes the IoT-based industrial data monitoring and control system and its applications, as well as the importance of implementing IoT in the industry, and Section 3 provides a review of current related studies. Section 4 discusses the Industrial Internet of Things in the data-monitoring system; it also categorizes data monitoring sensors and other devices. Section 5. discusses IoT data monitoring and control, as well as outstanding challenges. Section 6 summarizes the overall review.

II IOT-BASED DATA MONITORING AND CONTROL SYSTEMS AND THEIR APPLICATIONS

IoT-based data monitoring and control systems represent an important modification in the field of manufacturing, merging IoT capabilities with industrial processes to bring in a new era of productivity, predictive maintenance, and data-driven decision-making. These systems combine many components, including as sensors, communication protocols, data processing algorithms, and cloud-based platforms, to establish a comprehensive framework that allows information to flow effortlessly between physical assets and digital systems.



Architecture of IOT based automation system[11]

The ability to gather, transmit, and analyze real-time data from industrial assets is the fundamental concept of implementing IoT-based data monitoring and control systems. Sensors embedded in machinery, equipment, and even ambient elements collect a wide range of data points, including temperature, pressure, vibration, and energy usage. This data is then sent to centralized data processing units using communication networks such as Wi-Fi, cellular, or even low-power protocols.

IoT-based data monitoring and control systems have applications in many different kinds of industries, including manufacturing[12]–[14], energy, transportation, and healthcare. These systems enable predictive maintenance in manufacturing by evaluating sensor data to detect errors and potential equipment faults before they occur. Real-time monitoring of consumption trends improves energy management by enabling better energy utilization[3], [15] and cost reductions. The transportation business benefits from leveraging data from vehicles and logistical operations to track and optimize routes and schedules. Healthcare facilities use IoT technology to remotely monitor patients' vital signs and ensure timely response.

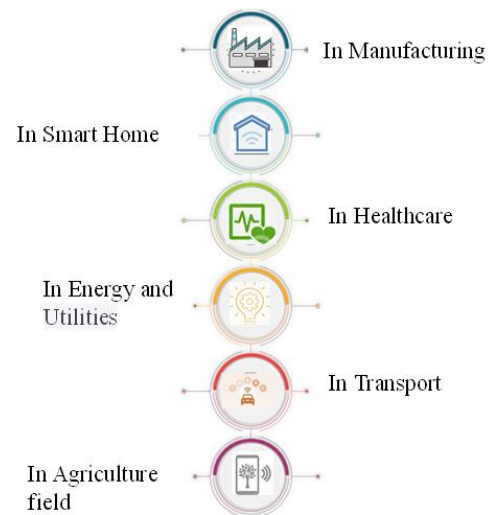
The Importance of Data Monitoring and Control Systems Enabled by IoT

The importance of IoT based data monitoring and control systems arises from their ability to shift industries from reactive to proactive modes of operation. Traditional data gathering systems frequently need manual inspections and periodic maintenance, which leaves space for inefficiency, unexpected interruptions, and increased operational expenses. This is changing as IoT based technologies provide real-time data into asset well-being, performance cycles, and potential issues. This move from a "fix when broken" to a "predict and prevent" strategy enables enterprises to optimize resource allocation, reduce downtime, and boost overall production.

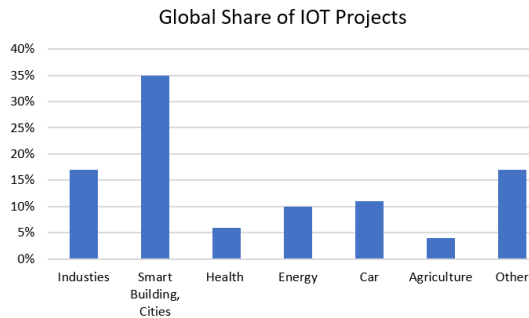
Benefits of Using IoT in Data Monitoring in the Industry

Incorporating the Internet of Things (IoT) into data monitoring within industries offers a multitude of advantages that revolutionize conventional operations. By seamlessly integrating sensors, connectivity, and analytics, IoT transforms the industrial landscape, driving efficiency, innovation, and competitiveness. These benefits encompass

- Real-Time Insights
- Predictive Maintenance
- Efficient resource allocation
- Cost Savings
- Data-Driven Decision-Making
- Enhanced Safety
- Scalability
- Competitive Advantage
- Environmental Impact



Iot in different industries



The top IoT application areas – based on real IoT projects

The Internet of Things (IoT) is utilised in various industrial areas, with significant sectors shown in Figure 2. Figure 3 depicts the global market share of IoT projects on a global scale [29]. The illustration highlights the substantial market presence of the Smart Building and Cities industries, accounting for 35% of the market share, and the Automotive sector, holding an 11% share. Additionally, the Industries and Others sectors maintain noteworthy market shares of 17% each. Furthermore, the impact of the Internet of Things (IoT) is observed in several sectors such as Health, Energy, and Agriculture, with respective contributions of 6%, 10%, and 4% to the overall global IoT industry.

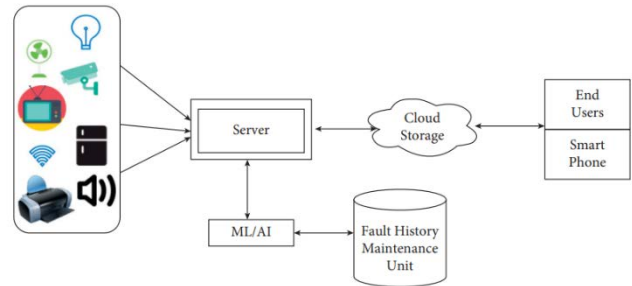
III REVIEW OF RECENT STUDIES:

This section dives into a comprehensive analysis of recent studies that offer insights on the advanced technology of industrial data monitoring and control systems research. We discover significant insights into the current trends, breakthroughs, and problems impacting the landscape of this dynamic sector by combining the data and techniques of these studies. This section attempts to provide a quick yet useful overview of recent research that is bringing the progress of industrial procedures toward greater efficiency, adaptability, and intelligence through a study of numerous industries and new methodologies.

One of the pioneering advancements was the introduction of a real-time remote monitoring and control (RT-RMC) architecture tailored for cathodic protection (CP) systems [16]. By harnessing the potential of GSM and Web of Things (WoT) technologies, the system achieves wireless communication of CP voltage and current readings from underground pipelines. This architecture boasts a range of features, including on-site monitoring via an LCD display, remote monitoring through a Human-Machine Interface (HMI), long-distance monitoring facilitated by SMS notifications, and web-based accessibility via a WoT platform. The architecture's ability to swiftly detect and mitigate damage in real time further accentuates its significance.

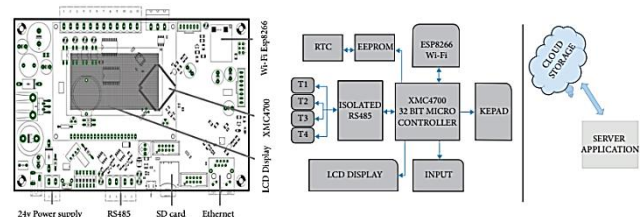
The notion of "Remote Monitoring and Control of Industrial Parameters using an Embedded Web Server" was introduced by Koshatwar et al. [17]. This concept materializes through an embedded web system, powered by an ARM11 processor and a real-time operating system. Enabling status monitoring and data acquisition via common web browsers, this system operates in both data acquisition and control modes, supporting remote signal acquisition and device control. Notably, an embedded web server mode enhances the system's capability for online data sharing.

The fusion of cloud computing and Human-Machine Interface (HMI) technologies resulted in a compelling study on "Industrial Parameter Control and Monitoring Using



Cloud Computing and HMI" [18]. Through the integration of OPC Data Hub software and Siemens-made digital modules for PLC S7-200, this approach enables efficient data collection and parameter control. The architecture's connection to a database allows for comprehensive comprehension of the operational state across the plant, with notifications sent via email or SMS upon parameter modifications.

In the domain of IoT, the study by [7] presents a "Smart Sensor Network based Industrial Parameters Monitoring in IOT Environment utilizing Virtual Instrumentation Server." This study focuses on real-time temperature and humidity monitoring in industrial settings, leveraging My RIO and



LabVIEW for observation. The implementation of a server VI program and a client VI program facilitates online data sharing, underscoring the system's adaptability and sensor data collection mechanisms.

Continuing the trajectory of IoT applications, the work by [19] introduces an "Industry 4.0-based Energy Efficient Architecture for Furnace Monitor and Control in Foundries." This architecture leverages IoT principles for efficient furnace control and monitoring, employing PIC16f877A and Philips lpc2148 ARM-based microcontroller for multi-stage control. The establishment of local area networks (LAN) for connecting dispersed furnaces enriches the practicality of the proposed solution.

IoT-based PCB architecture for the heat treatment process [19]

A noteworthy approach presented in [20] centers on "Monitoring and Diagnosing Industrial Systems using Wireless Sensor Networks." This study proposes a digital system for energy usage evaluation, condition monitoring, diagnosis, and control, using wireless sensor networks connected to a wired infrastructure. Employing two hardware topologies, the study addresses data security and communication modes, demonstrating the potential for versatile monitoring and control.

The review further extends to the realm of IoT's foundational principles. Mehta et al. [6] discuss the transformative concept of the "Internet of Things," envisioning a connected world of smart devices that

autonomously interact to accomplish tasks across various sectors. The nascent yet expanding applications of IoT across healthcare, logistics, transportation, and more underscore its significance in shaping modern technology.

Transitioning to the realm of home and office automation, Abella et al. [21] introduce an "Home/Office Automation" application that enhances comfort, energy conservation, and remote surveillance. The study's novel design of a WSN platform highlights energy independence and compactness as pivotal attributes. Moreover, intelligent hardware-software co-design contributes to low-power operation and energy efficiency.

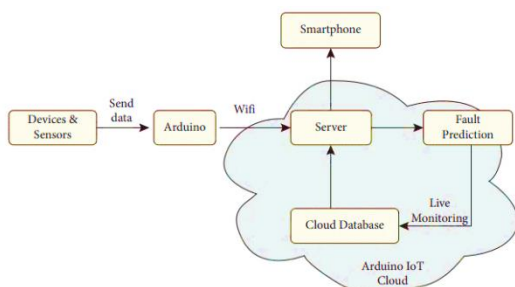
: Framework for office automation [22]

In the same domain, Uppal et al. [22] present a prototype for a "Smart Office" that integrates IoT, cloud computing, and machine learning for efficient workplace device control and automation. The architecture's ability to forecast malfunctions contributes to proactive maintenance strategies, while the integration of various smart devices underscores the potential for comprehensive office automation.

The review further delves into specific implementation frameworks. Uppal et al.'s study [11] introduces an "Arduino-based Office Automation System," highlighting the integration of sensors, electrical devices, and a smartphone app. The study showcases the potential for wireless device control using an Arduino board, catering to a range of office appliances while facilitating real-time monitoring.

: Architecture of the proposed methodology in [11]

Telagam et al. [7] introduce a paradigm-shifting



approach with their study on "Smart Sensor Network based Industrial Parameters Monitoring in IOT Environment utilizing Virtual Instrumentation Server." The authors address the need for efficient monitoring in industries while mitigating resource-intensive solutions. Their architecture leverages an ARM processor-controlled data collection system, utilizing the S3C2440 32-bit ARM processor with a built-in DM9000 Ethernet controller. By employing embedded C and porting the application to an ARM9 CPU, this architecture exemplifies a blend of hardware and software expertise. The implementation of an embedded web server supports remote monitoring and control, crucial for enhanced production and process plant availability. Furthermore, the addition of GSM mobile communication enhances universal access, enabling seamless interaction with the system.

Aravind R. et al.'s [4] focus on "IOT-based Real-Time Data Monitoring System for Industry" is rooted in the pivotal role of surveillance in ensuring security. This study revolves around the integration of an embedded system,

microcontroller, sensor networks, and PIR sensor technology. By embracing a reactive strategy, this architecture minimizes computational power while providing extensive control over industrial machinery through wireless connections, whether via Wi-Fi, Bluetooth, or the Internet.

Saqlain et al.'s framework [14] lays the groundwork for "IoT-based Industrial Data Management for Smart Manufacturing." Acknowledging the significance of data processing in modern industrial contexts, this study proposes a comprehensive framework encompassing five layers: physical, network, middleware, database, and application. The integration of modern industrial communication protocols facilitates secure data transmission, effectively supporting large-scale data collection and smart manufacturing practices. This framework holds the potential to enhance industrial production, bolster revenue, and elevate product quality.

Kelly et al.'s work [23] delves into the intricacies of integrating 802.15.4 with an IP network, crucial for enabling the seamless connection of IoT devices and home monitoring mechanisms. This study emphasizes the need for customizable packet routing, ensuring security and adaptability across diverse wireless sensor networks. While presenting an effective approach, this research acknowledges the challenges posed by the lack of IPv6 connectivity, highlighting potential hurdles in the path of implementation.

Transitioning to the realm of smart home automation, Patchava et al. [24] introduce an IoT-based approach utilizing Raspberry Pi. By integrating computer vision algorithms with Raspberry Pi modules, this study explores the management of home appliances linked to an internet-based monitoring system. The integration of motion sensors and cameras for sensing and surveillance further the concept's potential, including the prospect of energy monitoring systems.

Rout et al.'s [25] research culminates in the creation of an IoT-based prototype for a smart home automation system, accompanied by a dedicated Android app. With the central component being an Atmega16 microcontroller, this prototype showcases real-time device status observation, actuation, and data transfer over cloud infrastructure. The Blynk platform is employed to facilitate communication between the NodeMCU module and application devices, thereby exemplifying a comprehensive approach to home automation.

Syafrudin et al. [26] delve into real-time monitoring systems that harness big data processing and IoT-based sensors. By focusing on assembly line progress and error identification, this study underscores the effective utilization of IoT devices for data analysis and processing. The architecture's deployment of MongoDB, Kafka, and Storm enhances the scalability and efficiency of continuous sensor data processing, laying the foundation for predictive models and streamlined assembly line management.

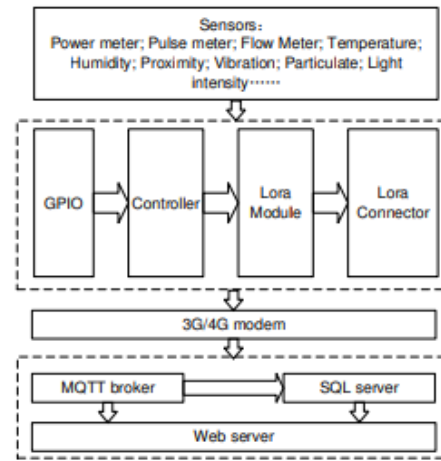
To ensure data integrity, Hang et al.'s [27] innovative study revolves around an integrated IoT platform powered by blockchain technology. With the aim of facilitating real-time monitoring and secure data management, this study

proposes a novel approach to ensure tamper-proof records and device interaction. The integration of blockchain technologies with IoT architecture promises secure data and commerce interoperability, effectively addressing concerns of scalability and data security.

Sunchu et al.'s [28] strategy for intelligent office management harnesses RFID tagging technology and Raspberry Pi 3. By enabling flexibility through the MQTT protocol, this architecture streamlines remote monitoring and control of office devices. Notably, this approach reduces energy consumption, enhancing both efficiency and personnel workload management.

Gan et al.'s [3] interactive IoT system focused on energy usage monitoring in companies integrates non-invasive sensors, communication networks, cloud databases, and web servers. Through the MQTT protocol, this architecture enables automatic publishing of energy consumption data, fostering human-data interaction through a user-friendly dashboard. Beyond energy management, this system's potential extends to lowering emissions and optimizing various aspects of industrial energy consumption.

Sunchu et al. [28] propose an intelligent office system integrating Raspberry Pi 3 and RFID tech for streamlined operations. RFID readers gather data, transmitted to MQTT and Amazon servers. Unique ID tagging controls equipment, reducing staff workload. This IoT-RFID combo, transmitting info to the cloud and via a dedicated app, enables remote device control via the MQTT protocol. Gan et al.'s [3] study focuses on real-time energy monitoring, utilizing IoT, non-invasive sensors, communication networks, cloud databases, and web servers. MQTT



Proposed system structure in [19]

IV. INDUSTRIAL INTERNET OF THINGS IN THE DATA-MONITORING SYSTEM

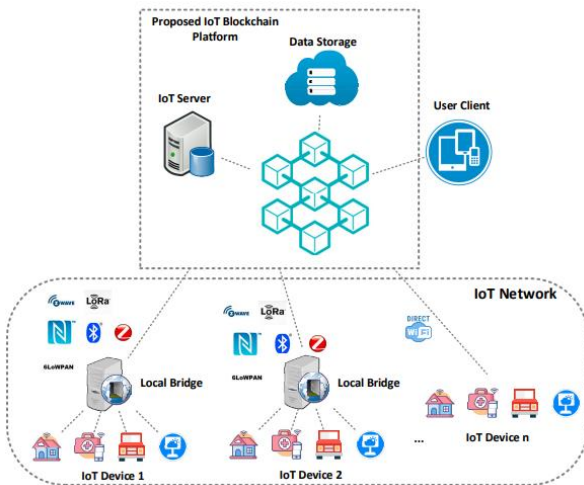
The goal of the Industrial Internet of Things (IIoT) is to make industries smarter and more connected. Consider it giving internet power to machines and equipment utilized in factories, farms, and other industrial environments. IIoT connects machines in the same way that our smartphones and gadgets are connected online, allowing them to share information and collaborate in novel ways. It's like giving these machines a method to communicate with one another and with humans.

Sensors are at the heart of the IIoT. These act as digital eyes and ears, gathering data from machinery. Temperature, pressure, speed, and even things we can't see, like vibrations, are all measured by these sensors. This data is then transmitted to computers via dedicated networks. Smart software is used by these computers to understand the data and determine what is going on. They can even forecast when a machine will fail before it happens. This is known as "predictive maintenance," and it saves companies a lot of money as well as time.

IIoT is used in a variety of industries. In manufacturing, IIoT is used to monitor machinery, ensuring that they are running properly and swiftly resolving problems. In agriculture, IIoT enables farmers to track soil conditions, weather patterns, and even livestock health, resulting in higher agricultural yields and healthier animals. Energy firms employ IIoT to more efficiently manage power networks, cutting waste and expenses. The transportation and logistics industries benefit from the use of IIoT to track shipments, optimize routes, and manage vehicle fleets. IIoT is also used in healthcare to track medical equipment and improve patient care. In short, IIoT is changing the way industries work and assisting them in being more efficient, dependable, and inventive.

V CHALLENGES IN IIoT BASED INDUSTRIAL DATA MONITORING SYSTEMS

While IIoT-based industrial data monitoring and control systems have enormous possibilities for increasing efficiency and productivity, they also bring about significant problems that must be properly managed.



protocol transmits energy data to a central center, and an Apache-powered web server offers human interaction through a dynamic dashboard, enhancing industrial energy management's efficiency.

IoT blockchain platform conceptual scenario [19]

- **Data Security and Privacy-** The security and privacy of data gathered, communicated, and stored is one of the most important challenges in IoT-based industrial systems. Because these systems collect so much sensitive data, damage could have a wide-ranging such as industrial espionage, operational disruptions, and even safety hazards. End-to-end encryption, secure authentication systems, and strong access controls are critical. Furthermore, data sharing across interconnected devices and networks needs strict privacy policies to protect the rights of individuals and businesses.
- **Scalability and interoperability-** Industrial installations can include a broad variety of devices and equipment
- **failover plans, and backup systems** becomes critical to ensuring that control systems can function even when individual components fail.

from several manufacturers, each of which uses a separate set of protocols and standards. operation, resulting in delays, inefficiencies, and even system breakdowns. Furthermore, as the number of connected devices increases, the systems must be scalable in order to accommodate the increased data load without compromising performance or generating delays.

- **Reliability and Redundancy-** For decision-making and control, IoT-based industrial systems rely mostly on real-time data. As a result, data stream reliability and availability are crucial. Data errors might result from network disruptions, hardware problems, or software flaws, potentially leading to wrong actions or choices. Implementing redundancy mechanisms,

Sector	Purpose	Impact
Manufacturing [26,13,30,03,05]	IOT is a vital tool in the manufacturing industry, providing tools and solutions to improve productivity, efficiency, and overall operations.	The manufacturing sector has seen a dramatic transformation because to the Internet of Things (IoT), which has increased production, efficiency, and competitiveness. Predictive maintenance, process optimization, quality control, inventory management, supply chain visibility, energy efficiency, worker safety, customized products, asset tracking, remote monitoring and control, data analytics, enhanced customer service, product lifecycle management, and a competitive advantage are some of the major effects.
Building, Cities and Home automation [24,22,28]	The Internet of Things (IoT) is being used for a number of applications in building automation, cities, and homes that improve overall quality of life, sustainability, efficiency, and safety. The following are the primary goals and advantages of IoT in these fields:	The Internet of Things (IoT) offers numerous benefits such as energy efficiency, security, and environmental sustainability, enhancing urban planning, traffic management, waste management, and public transportation. It also enhances home automation, personalization, cost savings, and home entertainment.
Healthcare [31,32]	The purpose of the healthcare monitoring system is to constantly monitor a patient's physiological parameters from sensors on their body. It detects abnormality conditions and sends a message to the doctor or emergency center within one minute. The system aims to reduce power consumption, increase speed, enhance communication coverage area, and provide security and privacy to patient's data.	The healthcare monitoring system mentioned in the source utilizes IoT (Internet of Things) technology. It uses sensor nodes to monitor physiological parameters such as heart rate, body temperature, ECG signals, and blood pressure. The system is capable of detecting abnormal conditions in the patient's body and sending a message to the doctor or emergency center within one minute. It also emphasizes on reducing power consumption, increasing speed, enhancing communication coverage area, and providing security and privacy to patient's data through advanced encryption standard (AES) techniques.
Energy [10,03,15,21,19]	The purpose of the IoT based real time energy monitoring system discussed in the source is to control and monitor the energy consumption of a switchgear industry. The system helps the industry understand the day-to-day energy pattern and facilitates energy conservation measures to minimize energy consumption.	The energy and utilities industry has been greatly impacted by the Internet of Things (IoT), which has improved sustainability, dependability, and efficiency. Smart grids, asset management, renewable energy integration, demand response, energy efficiency, water and wastewater management, grid security, predictive analytics, customer interaction, and environmental sustainability are some of the innovations that have resulted from it.
Agriculture [33]	The purpose of the IoT-based agricultural production system is to stabilize the supply and demand of agricultural products by developing environment sensors and a prediction system for the growth and production number of crops.	Agriculture has been significantly impacted by the Internet of Things (IoT), which has changed the farming sector by giving farmers access to useful data and solutions that increase efficiency, sustainability, and productivity. Precision farming, soil monitoring, crop health and pest control, supply chain optimisation, predictive analytics, livestock management, automated irrigation, resource efficiency, decision support systems, rural connectivity, and environmental sustainability are some of the major effects.

To address these issues, a comprehensive approach combining technology solutions, legal frameworks, and

industry best practices is required. As the Internet of Things continues to transform the industrial landscape, overcoming these challenges will be critical to realizing the full potential of data-driven industrial monitoring and control systems.

VI CONCLUSION

The transformative power of IoT-based industrial data monitoring and control systems cannot be underestimated. This review highlights the significant impact of IoT on industries, from predictive maintenance to real-time insights, and emphasizes the importance of real-world case

studies illustrating practical implementations. The growth of the Industrial Internet of Things (IIoT) has created new opportunities for effective data collection and decision-making across multiple industries. The review, however, recognizes the difficulties in assuring data security, attaining scalability and interoperability, and preserving system stability. To take full advantage of IoT-based systems, industries have to develop complete strategies that address these issues through a combination of technological solutions, regulations, and industry standards. By harnessing the power of IoT, industries may plot a course toward greater efficiency, sustainability, and success.

REFERENCES

- [1] V. Lakshmikantha, A. Hiriyannagowda, A. Manjunath, A. Patted, J. Basavaiah, and A. A. Anthony, "IoT based smart water quality monitoring system," *Global Transitions Proceedings*, vol. 2, no. 2, pp. 181–186, Nov. 2021, doi: 10.1016/j.gltp.2021.08.062.
- [2] S. Gupta, M. Kohli, R. Kumar, and S. Bandral, "IoT Based Underwater Robot for Water Quality Monitoring," in *IOP Conference Series: Materials Science and Engineering*, IOP Publishing Ltd, Jan. 2021. doi: 10.1088/1757-899X/1033/1/012013.
- [3] S. Gan, K. Li, Y. Wang, and C. Cameron, "IoT Based Energy Consumption Monitoring Platform for Industrial Processes," in *2018 UKACC 12th International Conference on Control, CONTROL 2018*, Institute of Electrical and Electronics Engineers Inc., Oct. 2018, pp. 236–240. doi: 10.1109/CONTROL.2018.8516828.
- [4] Aravind R, Yadikumarani, Meghna K, R Divyashree, Harshitha Naregowda5, "IOT based Real Time Data Monitoring for Industry." [Online]. Available: www.ijert.org
- [5] T. C. Anil Kumar, N. Bhusal Sharma, A. K. Mishra, P. Patil, S. Sarveswara Reddy, and R. Bhargava, "Fault identification model using IIoT for industrial application," *Measurement: Sensors*, vol. 24, Dec. 2022, doi: 10.1016/j.measen.2022.100526.
- [6] R. Mehta, J. Sahni, and K. Khanna, "Internet of Things: Vision, Applications and Challenges," in *Procedia Computer Science*, Elsevier B.V., 2018, pp. 1263–1269. doi: 10.1016/j.procs.2018.05.042.
- [7] N. Telagam, N. Kandasamy, M. Nanjundan, and A. Thotakuri, "Smart sensor network based industrial parameters monitoring in IOT environment using virtual instrumentation server," *International Journal of Online Engineering*, vol. 13, no. 11, pp. 111–119, 2017, doi: 10.3991/ijoe.v13i11.7630.
- [8] O. Peter, A. Pradhan, and C. Mbohwa, "Industrial internet of things (IIoT): opportunities, challenges, and requirements in manufacturing businesses in emerging economies," *Procedia Comput Sci*, vol. 217, pp. 856–865, 2023, doi: 10.1016/j.procs.2022.12.282.
- [9] M. Sanwar Hossain, M. Rahman, M. Tuhin Sarker, M. Ershadul Haque, and A. Jahid, "Open Software and Data A smart IoT based system for monitoring and controlling the sub-station equipment," 2019, doi: 10.1016/j.ijot.2019.10.
- [10] J. Mocnej, M. Miškuf, P. Papcun, and I. Zolotová, "Impact of Edge Computing Paradigm on Energy Consumption in IoT," Elsevier B.V., Jan. 2018, pp. 162–167. doi: 10.1016/j.ifacol.2018.07.147.
- [11] M. Uppal *et al.*, "A Real-Time Data Monitoring Framework for Predictive Maintenance Based on the Internet of Things," *Complexity*, vol. 2023, 2023, doi: 10.1155/2023/9991029.
- [12] D. Mourtzis, E. Vlachou, and N. Milas, "Industrial Big Data as a Result of IoT Adoption in Manufacturing," in *Procedia CIRP*, Elsevier B.V., 2016, pp. 290–295. doi: 10.1016/j.procir.2016.07.038.
- [13] W. Chen, "Intelligent manufacturing production line data monitoring system for industrial internet of things," *Comput Commun*, vol. 151, pp. 31–41, Feb. 2020, doi: 10.1016/j.comcom.2019.12.035.
- [14] M. Saqlain, M. Piao, Y. Shim, and J. Y. Lee, "Framework of an IoT-based Industrial Data Management for Smart Manufacturing," *Journal of Sensor and Actuator Networks*, vol. 8, no. 2, Apr. 2019, doi: 10.3390/jsan8020025.
- [15] M. D. Mudaliar and N. Sivakumar, "IoT based real time energy monitoring system using Raspberry Pi," *Internet of Things (Netherlands)*, vol. 12, Dec. 2020, doi: 10.1016/j.ijot.2020.100292.
- [16] N. H. Abdulwahab, A. A. Abed, and M. A. Jaber, "Real-time remote monitoring and control system for underground pipelines," *International Journal of Electrical and Computer Engineering*, vol. 12, no. 5, pp. 4892–4902, Oct. 2022, doi: 10.11591/ijece.v12i5.pp4892-4902.
- [17] R. G. Koshatwar and S. D. Sawant, "Remote Monitoring and Control of Industrial Parameters using Embedded Web Server."
- [18] W. A. Siddique, "Controlling and Monitoring of Industrial Parameters Through Cloud Computing and HMI Using OPC Data Hub Software," *Indian J Sci Technol*, vol. 13, no. 2, pp. 114–126, Mar. 2020, doi: 10.17485/ijst/2020/v13i02/148768.
- [19] M. Dinesh *et al.*, "An Energy Efficient Architecture for Furnace Monitor and Control in Foundry Based on Industry 4.0 Using IIoT," *Sci Program*, vol. 2022, 2022, doi: 10.1155/2022/1128717.
- [20] F. Salvadori *et al.*, "Monitoring and Diagnosis in Industrial Systems Using Wireless Sensor Networks."
- [21] C. S. Abella *et al.*, "Autonomous Energy-Efficient Wireless Sensor Network Platform for Home/Office Automation," *IEEE Sens J*, vol. 19, no. 9, pp. 3501–3512, May 2019, doi: 10.1109/JSEN.2019.2892604.
- [22] M. Uppal, D. Gupta, S. Juneja, G. Dhiman, and S. Kautish, "Cloud-Based Fault Prediction Using IIoT in Office Automation for Improvisation of Health of Employees," *Journal of Healthcare Engineering*, vol. 2021. Hindawi Limited, 2021. doi: 10.1155/2021/8106467.
- [23] S. D. T. Kelly, N. K. Suryadevara, and S. C. Mukhopadhyay, "Towards the implementation of IIoT for environmental condition monitoring in homes," *IEEE Sens J*, vol. 13, no. 10, pp. 3846–3853, 2013, doi: 10.1109/JSEN.2013.2263379.
- [24] Vamsikrishna Patchava, Hari Babu Kandala, P Ravi Babu, "A Smart Home Automation Technique with Raspberry Pi using IIoT". 2015 International Conference on Smart Sensors and Systems : 21st-23rd December 2015.
- [25] K. K. Rout, S. Mallick and S. Mishra, "Design and Implementation of an Internet of Things based Prototype for Smart Home Automation System," 2018 International Conference on Recent Innovations in Electrical, Electronics & Communication Engineering (ICRIEECE), Bhubaneswar, India, 2018, pp. 67-72, doi: 10.1109/ICRIEECE.44171.2018.9008410.
- [26] M. Syafrudin, G. Alfian, N. L. Fitriyani, and J. Rhee, "Performance analysis of IIoT-based sensor, big data processing, and machine learning model for real-time monitoring system in automotive manufacturing," *Sensors (Switzerland)*, vol. 18, no. 9, Sep. 2018, doi: 10.3390/s18092946.
- [27] L. Hang and D. H. Kim, "Design and implementation of an integrated IIoT blockchain platform for sensing data integrity," *Sensors (Switzerland)*, vol. 19, no. 10, May 2019, doi: 10.3390/s19102228.
- [28] R. Sunchu, S. Palli, V. V. S. R. Datta and M. Shanmugasundaram, "Intelligent System for Office Environment Using Internet of Things," 2019 3rd International Conference on Trends in

- Electronics and Informatics (ICOEI), Tirunelveli, India, 2019, pp. 717-721, doi: 10.1109/ICOEI.2019.8862689.
- [29] K. L. Lueth, "The Top 10 IoT Segments in 2018 – based on 1,600 real IoT projects," *IoT Analytics*, Apr. 07, 2022. <https://iot-analytics.com/top-10-iot-segments-2018-real-iot-projects>
- [30] H. M. R. G. Herath, K. K. W. S. P. K. Jayasundara, Y. K. A. Yadhasighe and S. D. A. Sanjeeva, "The design and implementation of an IOT-based real-time air purification system for outdoor environment," *2022 2nd International Conference on Advanced Research in Computing (ICARC), Belihuloya, Sri Lanka, 2022*, pp. 314-319, doi: 10.1109/ICARC54489.2022.9754097
- [31] H.A.I. Chandimal, W.H.K.P. Werahera, M.H.A.P. Bandara Sondarangallage D.A. Sanjeeva "Design and Implementation of *Bedsore Preventing System with Predicting and Monitoring Bedsore-Causing Parameters*" , in International Research Symposium 2022
- [32] Naveen, R. K. Sharma and A. R. Nair, "*IoT-based Secure Healthcare Monitoring System*," 2019 IEEE International Conference on Electrical, Computer and Communication Technologies (ICECCT), Coimbatore, India, 2019, pp. 1-6, doi: 10.1109/ICECCT.2019.8868984.
- [33] M. Lee, J. Hwang and H. Yoe, "Agricultural Production System Based on IoT," *2013 IEEE 16th International Conference on Computational Science and Engineering*, Sydney, NSW, Australia, 2013, pp. 833-837, doi: 10.1109/CSE.2013.126.

Sustainable Product Recovery: A Review on Remanufacturability Potential of Worn-Out Journal Bearings Used in Locomotive Engines

M.R.P.P. Wijesiri

*Department of Mechanical and Manufacturing Technology
University of Vocational Technology
Ratmalana, Sri Lanka
wpnima@gmail.com*

H.N.W. Gunasekara

*Department of Mechanical and Manufacturing Technology
University of Vocational Technology
Ratmalana, Sri Lanka
hasith.gunasekara@uovt.ac.lk*

Abstract— Remanufacturing, a process that restores used products to a "like-new" functional state, offers a promising approach to sustainable production. This paper investigates the remanufacturing of connecting rod big-end bearings in locomotive engines in the local context, focusing on material identification, manufacturing processes, damage identification, and remanufacturing technologies. The study outlines the key steps in the remanufacturing process, encompassing collection, disassembly, cleaning, repair, quality assurance, and environmental considerations. Damage identification techniques include visual inspection, microscopic inspection, surface roughness measurement, dye penetrant inspection, magnetic particle inspection, and ultrasonic testing. Specific technologies for repairing journal bearings are examined, with High-Velocity Oxy-Fuel (HVOF) thermal spray identified as a suitable method for journal bearings. Testing methods to validate the functionality and performance of remanufactured bearings. This review paper serves as a foundation for future developments in journal-bearing remanufacturing technology and sustainable product recovery practices, emphasizing the need for further research to assess the cost-benefit of the process.

Keywords— journal bearings, remanufacturing process, locomotive remanufacturing

I. INTRODUCTION

Remanufacturing, a process that recovers used products to a "like-new" functional state complete with a matching warranty, is gaining recognition as a greener mode of production. It can be both profitable and environmentally friendly compared to conventional manufacturing. This approach is especially well-suited for intricate electromechanical and mechanical products with valuable cores that, when recovered, add substantial value relative to their market and original costs. Since remanufacturing recovers a significant portion of materials and value from a product's initial manufacturing, often at a low extra cost, the resulting products can be obtained at reduced prices. However, remanufacturing is not fully understood due to its novelty in research terms [1].

When exploring which products are suitable for remanufacturing, no definitive rules exist regarding what can or cannot undergo this process, and there's no predetermined list of products eligible for remanufacturing. Nevertheless, remanufacturing excels when applied to high-value, complex, and durable products that are not marketed as status symbols. Examples of remanufactured products encompass machine tools, electrical motors and compressors, starter motors,

automatic transmissions, car and truck engines, office photocopiers, excavation equipment, power bearings, defense equipment, computer and telecommunications devices, air-conditioning units, pumps, industrial food-processing equipment, aerospace components, carpet tiles, and rolling stock. However, it's less successful in markets where customers perceive remanufactured goods as inferior, as seen in the lifestyle and fashion industries [1] and [2]. The connecting-rod big-end bearing [3]; [4]; [5] is a critical component. These bearings connect the connecting rod journals, which are offset from the rotation axis, to the larger ends of the pistons' connecting rods. They are sometimes referred to confusingly as crank pins or rod-bearing journals. A pressurized oil feed is directed through an angled oil passage drilled from the main journal.

Furthermore, there is significant positive feedback about remanufacturing, as evidenced by SKF's website [6]. According to SKF, "Re-manufacturing requires fewer raw materials, consumes less energy, and generates less waste than manufacturing a product from scratch. The resultant savings in each of these areas are considerable, usually resulting in a product of similar quality that costs less for both the remanufacturer and the consumer. Remanufacturing is a crucial aspect of a resource-efficient manufacturing industry [7]. Accordingly, this study aims to identify the remanufacturability potential of worn-out journal bearings used in locomotive engines.

II. METHODOLOGY

The review was carried out according to the Prisma method [8] [9]. According to the aim of this study, these areas were considered for review; the connecting rod journal-bearing manufacturing process; the identification of damages in journal bearings and possible causes for damages; the basic remanufacturing steps; the technologies that can be used for recovering the damaged journal bearings in engines; and the inspection and testing methods used in the remanufacturing process

Initially, 80 previous studies were identified by using search strings such as "Journal bearing manufacturing process", "Remanufacturing steps", "Failures of journal bearings", "Recovering of journal bearings", and "The inspection and testing methods". Then unrelated articles were screened to obtain 62 full-text articles that are directly relevant to this study. Thematic coding was carried out under themes of "Journal Bearing Manufacturing Processes", "Material identification in a journal bearing", "Steps of remanufacturing", "Damages identification in journal bearings", "The Technology of Repairing Journal Bearings in

Engines”, “HVOF Sprayed Overlays for a Trimetal Bearing” and “Testing Methods”. Finally, 53 articles have been referred to and cited to achieve the objectives of this review paper.

III. LITERATURE REVIEW

Many studies have been done on areas like remanufacturing processes and technologies and product design for remanufacturing. This research has been focused on the remanufacturing of worn-out connecting rod big end bearings (journal bearings) in locomotive engines and investigates the potential of remanufacturing worn-out connecting rod big end bearings in locomotive engines. Further, it is important to study material identification, manufacturing processes of big-end journal bearings, and damage identification of big-end journal bearings in an engine to develop a framework for the worn-out connecting rod big-end bearing remanufacturing process.

In the literature on the remanufacturing of automobiles, most research has been based on the remanufacturing of engines. Research on “The Value of Remanufactured Engines: Life-Cycle Environmental and Economic Perspectives,” published on 08 February 2008, [10];[11], provides useful information about the importance of remanufacturing used automotive engines to like-new condition and the price difference for the consumer of the remanufactured engine, with the greatest savings realized. From this article, top management of government departments can identify the importance of remanufacturing engine parts rather than new purchasing. According to Margarete A. Seitz and Peter E. Wells [12], business process management journal, implementation of corporate sustainability in the case of automotive engine remanufacturing is a specific product recovery operation among some European car manufacturers. Another piece of research was found in the “IET Digital Library,” International Conference on Responsive Manufacturing—Green Manufacturing [13]. In this research, the service condition of heavy-duty caterpillar engines and the failure of main parts have also been analyzed. In addition, the concept of remanufacturing for engines was discussed, and the classification of key technologies for remanufacturing was summarized.

A. Journal Bearing Manufacturing Processes [29][34][35].

Journal-bearing manufacturing processes involve several steps to produce high-quality bearings. Here are the typical manufacturing processes for journal bearings:

1. Material Selection
2. Casting or Forging
3. Machining
4. Heat Treatment
5. Surface Finishing
6. Lubrication Grooves and Oil Holes
7. Quality Control
8. Assembly

It's important to note that the available manufacturing processes can be different from each other, and it depends on the type of journal bearing, its intended application, and the manufacturer's production capabilities. Advanced manufacturing techniques, such as computer numerical

control (CNC) machining and automation, may also be applied to improve efficiency and accuracy.

B. Material Identification in a Journal Bearing

When we select any item for remanufacturing, the most important thing is identifying the material that made it. The material is the foundation of the item. Hence, it is very important to decide on remanufacturing capability and the continuation of the process or research. It's important to note that journal bearings can be made from various materials, including different types of metals (such as steel, bronze, or Aluminium alloys) or advanced materials (such as composites or self-lubricating materials). The specific material used in a journal bearing depends on factors such as load capacity requirements, operating conditions (temperature, speed, lubrication), and application-specific considerations.

Identifying the material used in a journal bearing can be accomplished through several methods. Here are a few common approaches:[37].Manufacturer's Specifications, Visual Examination, Material Testing, Cross-Reference with Standards, Previous Research or Literature, and Consultation with Experts.

C. Steps of Remanufacturing[16]

The identified steps and processes involved in remanufacturing can vary depending on the industry, product complexity and manufacturer's practices. Remanufacturing may also involve considerations such as reverse engineering, component testing, or retrofitting to meet updated standards or regulations.

Most established steps emphasize the key processes involved in remanufacturing within the technical industry, focusing on the refurbishment and restoration of used products or components to meet quality standards and environmental objectives. The most common steps involved in remanufacturing are collection and sorting, disassembly, cleaning and inspection, repair and replacement, reassembly, testing and quality assurance, finishing and refurbishment, packaging and documentation, distribution and sales, and, as a last step, environmental considerations. It means remanufacturing promotes sustainability by extending product lifespan, reducing waste, and conserving resources. [36] As well, these are the most dedicated remanufacturing steps for one selected component in a large system.

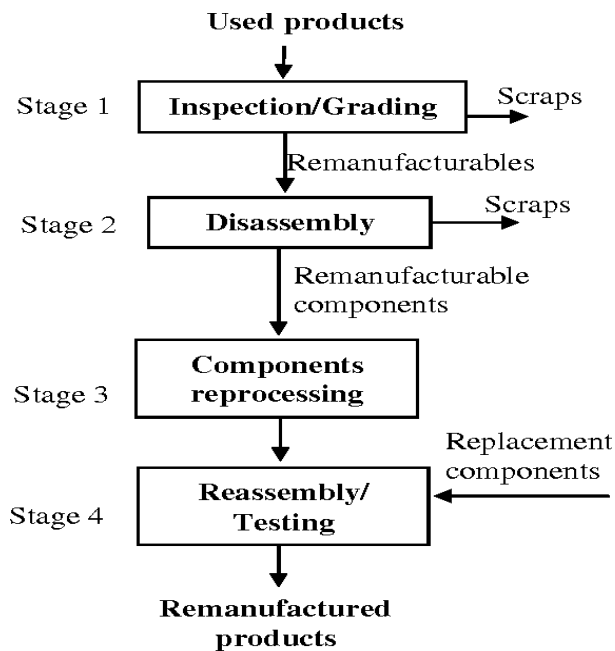


Fig 1: Key remanufacturing process and material flow [17]

Based on the results of a different study by S. Tsang Mang Kin, S.K. Ong, and A.Y.C. Nee called "Remanufacturing Process Planning" [18], it is emphasized that the remanufactured core should ideally come out of its previous use phase unharmed and free of any secondary effects caused by the remanufacturing processes. Consequently, during the selection of the process sequence, careful attention must be accorded to the potential adverse impacts of each step on the component. As a result, the typologies of remanufacturing processes can be methodically grouped into five primary categories, as delineated below:

- Remove surface and shape defect

Flaws such as cracks, scratches, nicks, burrs, areas afflicted by burning or corrosion, and inclusions are systematically eradicated through machining processes, which encompass operations like turning, milling, drilling, and grinding.

- Material addition or surface replacement

Surface addition or replacement involves the renewal of a component featuring "cavities" back to its intended form and overall dimensions, achieved via material additive techniques like welding, powder coating, and laser cladding. The choice of method hinges upon the surface's characteristics and requisites. Due to the application of elevated temperatures, preliminary heating is essential to avert fracturing. When warranted, stress-relief grooves might be incorporated. Opting for a fresh surface often proves more pragmatic, yielding enhanced performance. After the integration of these overlays, finishing processes are administered to align with the stipulated specifications.

- Restore material properties

The restoration of desired material properties is achieved through conditioning procedures, such as heat treatment. These processes encompass actions like annealing,

normalizing, and demagnetization, which eliminate unwanted residual states or render the component more resilient against its imposed loads and environmental conditions. These treatments can span the entirety of the material or extend to a subsurface layer, as observed in case hardening. To illustrate, when addressing wear-related design concerns, the consensus leans toward incorporating a hardened surface, whereas for bolstering fatigue resistance, the core material should exhibit toughness while the surface is endowed with compressive residual stresses.

- Assembly and fastening manipulation

For sub-assemblies involving multiple parts, adjusting the assembly is necessary when putting the parts together. This adjustment can change the sizes, causing them to not fit as intended. For instance, when remanufacturing a connecting rod, the larger end's surface needs to be smoothed after fastening the rod bolts. If not, fastening the bolts could lead to problems with alignment. It's important to complete the assembly and fastening steps before starting the restoration process.

- Surface finish

To attain precise surface quality and exact dimensional tolerances, meticulous finishing is crucial. This can be achieved through methods like grinding, reaming, honing, hard turning, and burnishing. For different surface types, such as those requiring painting, coating, or polishing, pertinent operations are carried out. This final step is reserved for the end due to the potential for subsequent processes to impact surface quality.

D. Damages Identification in Journal Bearings [28][38][39]

Identifying damages in a journal bearing requires a careful inspection and examination of the bearing. These are some common types of damages that can occur in a journal bearing and guide to identify them: Surface Wear, Scoring or Scratching, Babbitt or Overlay Damage, Overheating or Thermal Damage, Fatigue Failure, Misalignment or Distortion, Contamination.

However, to effectively identify damages in a journal bearing, it is recommended to conduct a detailed visual inspection, complemented by measurements, material testing, and possibly oil analysis. If significant damage is observed, it is advisable to consult a bearing specialist or engineer with expertise in bearing analysis and failure diagnosis. Major damages in used connecting rod big end journal bearings are also similar to those above, and types of major damages can be categorized as cavitation and wear. Cavitation damage occurs when small gas bubbles form rapidly and then collapse, generating high-pressure pulses that lead to localized harm on the bearing surface. This phenomenon is prominent in heavy-duty diesel engines, mainly attributed to intense dynamic loads, pin oscillations, oil flow turbulence, and related factors. Wear-related damage brings about alterations in the bearing's However, to effectively identify damages in a journal bearing, it is recommended to conduct a detailed visual inspection, complemented by measurements, material testing, and possibly oil analysis. If significant damage is observed, it is advisable to consult a bearing specialist or engineer with expertise in bearing analysis and failure diagnosis. Major damages in used connecting rod big end journal bearings are

also similar to those above, and types of major damages can be categorized as cavitation and wear. Cavitation damage occurs when small gas bubbles form rapidly and then collapse, generating high-pressure pulses that lead to localized harm on the bearing surface. This phenomenon is prominent in heavy-duty diesel engines, mainly attributed to intense dynamic loads, pin oscillations, oil flow turbulence, and related factors. Wear-related damage brings about alterations in the bearing's shape, impacting the pressure of the oil film and the longevity of the bearing shell. The present study focuses on investigating wear and cavitation damage in connecting rod big-end bearings [28].

E. The Technology of Repairing Journal Bearings in Engines.

The specific technologies and methods used for repairing or rebuilding journal bearings may vary depending on the type of engine, bearing design, and the expertise of the repair facility or technician. It is noted that there is no satisfactory data regarding the remanufacturing of connecting rod big-end journal bearings. But there are different types of journals bearing repairing details which are large, and the word "repairing" is used to describe those details. These technologies aim to restore the bearing surface to its original specifications or within acceptable tolerances. These are some commonly employed methods. [22]; [40]; [41]

- Grinding
- Polishing
- Honing
- Lapping and
- Coating

In automotive engine applications, plain journal bearings must possess a blend of characteristics, including strength (for fatigue and wear resistance), conformability, anti-seizure properties, and embeddability. Modern bearing linings feature a composite microstructure comprising a moderately strong matrix containing softer phase regions. Traditionally, there are two types of plain bearings: tri-metal and bimetal. Both consist of a lining of approximately 0.25mm of bearing alloy on a steel half-shell backing. Bimetal bearings usually have a lining of aluminium-tin alloy, resulting in an aluminium-based matrix with a tin-soft phase. They are mainly used in high-volume gasoline passenger cars and some light truck applications. On the other hand, tri-metal bearings have a lead-bronze alloy lining, resulting in a copper-tin matrix with a soft lead phase. A thin overlay of typically lead-based alloy, around 0.015mm thick, is added for improved seizure resistance. Tri-metal bearings find use in diesel passenger cars, heavy trucks, and high-speed gasoline engines that demand greater bearing alloy strength [23].

At TWI Ltd, development efforts showcased high-velocity oxy-fuel (HVOF) spraying as an alternative bearing manufacturing process. It serves as a pathway to create innovative bearing materials with microstructures unattainable through conventional casting and rolling methods [23]. In HVOF spraying, powder particles sized between 15-60mm are injected into a high-temperature, high-speed gas jet within a specially designed spray gun. The jet is formed by the combustion of a fuel (gas or liquid) with oxygen under high pressures and flow rates within the gun. Powder particles reach temperatures that allow them to become molten or semi-molten. By scanning the spray jet

across the substrate, a coating layer with minimal porosity is formed through the successive impact, bonding, and solidification of particles. Importantly, the substrate experiences only minimal heating during this process [23].

Several metal spraying methods are commonly employed for this purpose: [22][40]-[41].

- Flame Spraying [42]:

In flame spraying, a metal wire or powder is melted using a flame and propelled onto the bearing surface using compressed air or another gas. The molten metal particles solidify upon impact, forming a coating on the substrate. Flame spraying is versatile and can be used with various metals and alloys.

- Plasma Spraying [44]:

Plasma spraying utilizes a high-temperature plasma flame to melt and propel the metal coating material onto the bearing surface. Plasma is generated by ionizing a gas, typically argon, in a plasma torch. The molten metal particles are accelerated by a carrier gas and form a coating upon impact. Plasma spraying offers excellent control over the coating properties and can be used with a wide range of metals, ceramics, and composite materials.

- High-Velocity Oxy-Fuel (HVOF) Spraying:

HVOF spraying is a high-pressure and high-velocity method that involves combusting a mixture of fuel gas and oxygen to produce a supersonic jet of hot gases. The hot gases propel fine metal or alloy particles onto the bearing surface, resulting in a dense and strongly adherent coating. HVOF spraying produces coatings with excellent wear resistance and bond strength. [23][41] [43].

- Electric Arc Spraying [45]:

This involves using an electric arc between two consumable metal wires. The heat generated by the arc melts the wires, and compressed air or gas propels the molten metal droplets onto the bearing surface. Arc spraying is commonly used for applying coatings to materials such as zinc, aluminium, and their alloys.

In Sri Lanka Railways, MTU engines are available in S8, S9, S10, S12, and S14 power set engines. As per the manufacturer, in the scheduled repairs named "W 6" and "QL 4," engine connecting rod bearings are to be replaced. [24] [25]. In that case, new bearings were ordered, and the material of a new bearing as per the supplier's details is aluminum alloy. [26]

F. HVOF Sprayed Overlays for a Trimetal Bearing. [23];[41] ;[43].

The most suitable thermal spray method for Aluminum Alloy journal bearings is High-Velocity Oxy-Fuel (HVOF) thermal spray. HVOF thermal spray is a process that uses a high-velocity stream of particles to deposit a coating onto a substrate. The process is capable of producing coatings with excellent adhesion, wear resistance, and corrosion resistance. For small, big-end journal bearings in engines, the most suitable metal spraying method is typically high-velocity

Oxygen Fuel (HVOF) Spray HVOF spraying offers several advantages that make it an excellent choice for this application. The reasons are listed below [46].

- (i) **Coating Quality:** HVOF spraying produces dense, well-bonded coatings with minimal porosity, creating a strong mechanical bond.
- (ii) **Wear Resistance:** This exhibits exceptional wear resistance. The surface leads to dense and tightly packed coatings, providing superior protection against friction and wear.
- (iii) **Thickness Control:** HVOF spraying allows precise control over the coating thickness. This is beneficial for small, big-end journal bearings, as it enables the application of a uniform and consistent coating that meets the required specifications.
- (iv) **Reduced Heat Affected Zone:** HVOF spraying generates relatively low heat, minimizing the potential for thermal damage to the bearing or the surrounding components.
- (v) **Versatility:** This can be used with a wide range of metals and alloys, providing flexibility in choosing a coating material that suits the specific requirements of the big-end journal bearing.
- (vi) **Cost-Effectiveness:** While HVOF spraying may require specialized equipment, it is generally considered a cost-effective process for small components like big-end journal bearings.

G. Testing Methods

It is important to test remanufactured bearings for their performance to ensure the process is productive and worth considering the time, material, and manpower consumed. Also, it involves a series of steps to ensure its functionality and performance. Because sometimes the replacement of a new one is more economically fair than using the remanufactured product. By using the correct testing methods and obtaining testing results, the remanufactured product and process can be validated. These are the general processes which can be applied to establish bearing remanufacturing.

- **Visual Inspection:**

This is the most basic method of measuring the surface quality of a netting rod's big end bearing. It involves looking at the surface of the bearing with the naked eye to check for any visible defects or irregularities. [47]-[48][50]. Visual inspection is a method used to measure the surface quality of connecting rod big end bearings. This method involves inspecting the bearing surface with the naked eye or with a magnifying glass to identify any defects or irregularities. The inspector should look for any signs of wear, corrosion, pitting, scoring, or other damage. The inspector should also check for any signs of improper installation, such as incorrect bearing clearances or misalignment. Visual inspection is a relatively simple and cost-effective method.

- **Microscopic Inspection:**

This method involves using a microscope to inspect the surface of the bearing for any defects or irregularities. [31].

Microscopic inspection is a method used to measure the surface quality of connecting rod big end bearings. This method involves the use of a microscope to inspect the surface of the bearing for any signs of wear, corrosion, or other damage. The microscope is used to magnify the surface of the bearing and allows for a detailed inspection of the surface. The inspector will look for any signs of wear, corrosion, or other damage that could affect the performance of the bearing.

- **Surface Roughness Measurement:** [32]; [49]

Surface roughness measurement serves as a technique to assess the surface quality of a connecting rod's big end bearing. This approach employs a profilometer, a device designed to gauge the surface roughness of a material. Representing the target's features as a surface enables rapid measurement of 3D structures across a wide expanse. This non-contact roughness meter and profile measurement system can swiftly quantify surface roughness and minute features, including burrs, within just one second. The system automatically configures settings like sensitivity based on the target's height, size, material, and colour. This eradicates measurement errors, enhances efficiency, and empowers inexperienced users to swiftly gather data.

- **Dye Penetrant Inspection (DPI):**

DPI is another non-destructive testing method that can be used to detect surface defects such as cracks and fractures. A liquid dye penetrant is applied to the bearing surface, and after a specified time, the excess penetrant is removed. A developer is then applied, causing the penetrant trapped in the defects to bleed out and become visible.

- **Magnetic Particle Inspection (MPI):**

MPI is a non-destructive testing method used to detect surface and near-surface defects in ferromagnetic materials. A magnetic field is applied to the bearing, and iron particles are applied to the surface. Any magnetic flux leakage caused by defects will attract the particles, making the flaws visible under proper lighting conditions.

- **Ultrasonic Testing (UT):**

UT uses high-frequency sound waves to detect internal flaws or defects in the bearing material. It can identify issues like cracks, voids, or inclusions that may not be visible to the naked eye. This method requires specialized equipment and expertise to perform.

IV. SUMMERY OF POTENTIAL TECHNOLOGIES FOR JOURNAL BEARING REMANUFACTURING

This literature review explores various facets of remanufacturing journal bearings, with a particular focus on connecting rod big-end bearings in locomotive engines. The investigation delves into material identification, manufacturing processes, damage identification, and potential technologies for remanufacturing these critical components. On the other hand, journal-bearing manufacturing involves a series of meticulous steps, including material selection, casting or forging, machining, heat treatment, surface finishing, lubrication grooves, quality control, and assembly. Advanced techniques, such as CNC machining and automation, can enhance efficiency and accuracy in the manufacturing process. Remanufacturing processes and technologies have garnered significant attention in recent

years. This study addresses the remanufacturing of worn-out connecting rod big-end bearings, a crucial component in locomotive engines. The research aims to understand the potential of remanufacturing these bearings and to establish a comprehensive framework for the remanufacturing process. Few researches have been conducted to define a clear framework for automotive remanufacturing [51]. Several research studies emphasize the significance of remanufacturing in the automotive industry [52]. For instance, research highlights the life-cycle environmental and economic benefits of remanufactured engines, emphasizing the cost savings for consumers. Moreover, some European car manufacturers have successfully implemented corporate sustainability through automotive engine remanufacturing.

The remanufacturing process involves a set of steps that can vary based on the industry, product complexity, and manufacturer's practices. Key processes in remanufacturing include collection and sorting, disassembly, cleaning and inspection, repair and replacement, reassembly, testing and quality assurance, finishing and refurbishment, packaging and documentation, distribution and sales, and environmental considerations.

A. Damages Identification in Journal Bearings

Identifying damages in journal bearings requires a careful inspection, involving common types of damages like surface wear, scoring, babbitt or overlay damage, overheating, fatigue failure, misalignment, and contamination. Visual examination, microscopic inspection, surface roughness measurement, dye penetrant inspection, magnetic particle inspection, and ultrasonic testing are common methods for damage identification.

B. The technology of Repairing Journal Bearings in Engines

Various technologies and methods are employed for repairing or rebuilding journal bearings. These include grinding, polishing, honing, lapping, and coating. The choice of technology depends on the bearing design and engine type.

C. High-velocity Oxy-Fuel Sprayed Overlays

High-velocity oxy-fuel (HVOF) thermal spray is identified as the most suitable method for journal bearings, particularly those made of Aluminum Alloy. HVOF spraying offers numerous advantages, including high coating quality, exceptional wear resistance, precise thickness control, reduced heat-affected zone, versatility in material selection, and cost-effectiveness.

D. Testing Methods

To ensure the effectiveness of the remanufacturing process, testing methods are employed to validate the functionality and performance of remanufactured bearings. These methods include measurement and tolerance checks, bearing clearance checks, crankshaft end play checks, lubrication system evaluation, and functional testing. Various non-destructive testing methods, such as visual inspection, microscopic inspection, surface roughness measurement, dye penetrant inspection, magnetic particle inspection, and ultrasonic testing, are also utilized to measure the surface quality of connecting rod big-end bearings.

The study of remanufacturing guides a sustainable and economically viable approach to facing the challenges of resource depletion and environmental degradation. By embracing remanufacturing practices, industries can reduce their ecological footprint while still delivering high-performance components. The importance of this research is underscored by the economic challenges faced by developing countries like Sri Lanka. Remanufacturing presents a sustainable solution, which can contribute to cost savings and promote responsible resource management.

In conclusion, this literature review provides a comprehensive overview of potential technologies and processes for remanufacturing connecting rod big-end bearings. Further, It summarises potential technologies which could be used for the journal-bearing remanufacturing process. As an example, High-Velocity Oxy-Fuel (HVOF) thermal spray is identified as the most suitable method for journal bearings. The research is not only relevant to the automotive industry in Sri Lanka but also offers valuable insights into sustainable practices in remanufacturing worldwide. This comprehensive understanding of remanufacturing technologies and quality control measures is instrumental in ensuring the reliable and cost-effective performance of these critical components.

This review sets the foundation for future progress in journal-bearing remanufacturing technology and sustainable product recovery opportunities. Further research needs to be performed to investigate the cost-benefit of the process.

REFERENCES

- [01] Matsumoto Dr., M., Ijomah Dr. Remanufacturing. In: Kauffman, J., Lee, KM. (eds) *Handbook Sustainable Engineering*. Springer, Dordrecht. W. (2013), https://doi.org/10.1007/978-1-40208939-8_93
- [02] George Kasabov, 'Project of the Institute for the Study of Human Knowledge (ISHK)', (2022), <https://humanjourney.us/the-changing-world-economy-section/?>
- [03] Capital Reman Exchange (2019), <https://www.capitalremanexchange.com/remanufactured-connecting-rods>
- [04] Samuel Gitukui, 'Cost To Replace Engine Bearings' (2022), <https://www.motorsverso.com/cos-to-replace-engine-bearings>.
- [05] Invest Northern Ireland, (2022), <https://www.nibusinessinfo.co.uk/content/what-products-cbe-remanufactured>.
- [06] ThemeKalia, "The Singapore Bearing Industrial services portfolio", (2011) <https://www.skf.com/group/services/reconditioning-and-customization/industrial-bearings>.
- [07] T.A. STOLARSKI, "Tribology in Machine Design", 5 - Sliding-element bearings, (1990), Pages 174-231., <https://www.sciencedirect.com/science/article/pii/B9780080519678500086>.
- [08] D. Moher, A. Liberati, J. Tetzlaff, and D. G. Altman, (2009), "Academia and Clinician Annals of Internal Medicine Preferred Reporting Items for Systematic Reviews and Meta-Analyses ;," vol. 151, no. 4, pp. 264–269.
- [09] A. M. Silva, D. A. Fields, and L. B. Sardinha, (2013) "A PRISMA-Driven Systematic Review of Predictive Equations for Assessing Fat and Fat-Free Mass in Healthy Children and Adolescents Using Multicomponent Molecular Models as the Reference Method. of Civil and Mechanical Engineering (2017), https://www.researchgate.net/figure/Damaged-Connecting-rod-bearing_fig3_316212220.
- [10] Vanessa M. Smith and Gregory A. Keoleian, The Value of Remanufactured Engines: Life-Cycle Environmental and Economic Perspectives, published on 08 February 2008, Google scholar: <https://onlinelibrary.wiley.com/doi/abs/10.1162/1088198041269463>

IV. CONCLUSION

- [11] SAE Transactions, Vol. 107, Section 5: Journal of Materials & Manufacturing, (1998), <https://www.jstor.org/stable/i40198796>.
- [12] A. Seitz, Peter E. Wells, Business process management journal, Challenging the implementation of corporate sustainability: The case of automotive engine remanufacturing, (2006), Google scholar: <https://www.emerald.com/insight/content/doi/10.1108/14637150610710954/full/html>
- [13] Juan Rodrigo Laguna, A Wear Analysis Carried on Connecting Rod Bearings from Internal Combustion Engines, (2020), <https://www.intechopen.com/chapters/69547>
- [14] McCombes, S. (2022). Sampling Methods | Types, Techniques & Examples. Scribbr. Retrieved March 4, 2023, from <https://www.scribbr.com/methodology/sampling-methods/>
- [15] Nikolopoulou, K. (2022). What Is Purposive Sampling? | Definition & Examples. Scribbr. Retrieved February 27, 2023, from <https://www.scribbr.com/methodology/purposive-sampling/>
- [16] Pradnya Bhuse, Remanufacturing is an Energy Efficient & Cost-Effective Process (2018) <https://www.researchgate.net/publication/323444912>.
- [17] Andrew-Munot, M, Ibrahim R.N. (2013) ; Journal of Mechanical Engineering and Sciences (JMES) ISSN (Print): 2289-4659; e-ISSN: 2231-8380; Volume 4, pp. 488-495
- [18] S. Tsang Mang Kin, S.K. Ong, A.Y.C. Nee, Published by Elsevier B.V. (2014), <http://creativecommons.org/licenses/by-nc-nd/3.0>.
- [19] Brake and front end staff (2016), <https://www.brakeandfrontend.com/cleaning-bearings-tech-tip/>
- [20] TIMKEN, Pit & Quarry (2012), <https://www.timken.com/resources/a-case-for-bearingrepair/>
- [21] Roger L. Oberwiser, Industrial Bearing Service. The Timken Co., Canton, OH, (2004), <https://www.plantengineering.com/>
- [22] Avweld Australasia Pty Ltd, (2022), <https://www.avweld.com.au/about-us>
- [23] A J Sturgeon (TWI Ltd), C Perrin (Glacier Vandervell), D.G. McCartney (Nottingham University), Paper presented at Tribology (2006): Surface Engineering & Tribology for Future Engine and Drivelines, IMechE, London, <https://www.twi-global.com/technicalknowledge/published-papers/development-of-thermal-sprayed-plain-bearings-for-automotive-engine-applications-july-2006#>
- [24] lloyd fedders (2022), https://www.lloydfedders.com/part-store/industrial-marine-enginesparemtu?gclid=EAIAIqObChMIu6DX7_O8_QIVVSQrCh3KMgW EAAAYASAAEgKwsfD_BwE
- [25] Boats, Yacht, outboard motor, PWC and engines manuals (2022), <https://www.downloadboatmanuals.com/motors/mtu/>
- [26] <https://cqlongshine.en.made-in-china.com/product/ofZGqTLAJuWU/China-NTA855-NT855Diesel-Engine-Spare-Parts-Connecting-Rod-Bearing-214950.html>
- [27] Del Din, M., Kassfeldt, E. ; (1999), Wear characteristics with mixed lubrication conditions in a full scale journal bearing, <https://www.sciencedirect.com/science/article/abs/pii/S0043164899001453>
- [28] Hadiseh Karimaei, Hamidreza Chamani, (2010), ICEF2009-14091, pp. 553-565; 13 pages <https://doi.org/10.1115/ICEF2009-14091>
- [29] Manufacturing Process of Connecting Rod Big End Journal Bearing (2020), <https://www.enginebuildermag.com>
- [30] Engine Parts (UK) LTD (1987), <https://www.enginepartuk.net/engine-bearings-conrodmains-thrust-washers-bushes-shells>
- [31] ISO/TS 16949:2016 Quality Management Systems – Particular Requirements for the Application of ISO 9001:2015 for Automotive Production and Relevant Service Part Organizations
- [32] Nanoscience Analytical (2023), <https://www.nanoscience-analytical.com/capabilities/>
- [33] Bose S.K., (2000) “Metal Praying Methods for Alloy Journal Bearings,” Tribology International, vol. 33, no. 10, pp. 845-851,
- [34] Neale, M.J. (1996). Bearings: A Tribology Handbook. Butterworth-Heinemann; 2nd edition.
- [35] Oberg, E., Jones, F.D., Ryffel, H.H., McCauley, C.J. (2004). Machinery's Handbook. Industrial Press Inc. New York, <http://library.uc.edu.kh/userfiles/pdf/19.Machinery%27s%20handbook.pdf>
- [36] Martin Charter, (2007). Remanufacturing and Product Design – Designing for the Seventh Generation. https://www.researchgate.net/publication/237798183_Remanufacturing_an_Product_Design_Designing_for_the_Seventh_Generation
- [37] Alexander E. Mironov, Dr. Iosif Gershman, Dr. Pavel Podrabinnik, (2021). Properties of Journal Bearing Materials That Determine Their Wear Resistance on the Example of Aluminum-Based Alloys, <https://www.mdpi.com/1996-1944/14/3/535>
- [38] Joel Pino Gómez, Fidel E. Hernández Montero, Yenny Villuendas Rey, (2021), “Identification of Babbitt Damage and Excessive Clearance in Journal Bearings through an Intelligent Recognition Approach”, (IJACSA) International Journal of Advanced Computer Science and Applications, Vol. 12, <https://philarchive.org/archive/PINIOB>
- [39] Dr. Florian Summer, Dr. Philipp Bergmann and Dr. Florian Grün (2017), Damage Equivalent Test Methodologies as Design Elements for Journal Bearing Systems, <https://www.mdpi.com/2075-4442/5/4/47>
- [40] A.K. Singh, S.K. Singh (2013), “Investigation of Metal Spray Process for Repair of Connecting Rod Big End Journal Bearing Surface,” International Journal of Engineering Research and Applications, vol. 3, no. 4, pp. 1545-1550
- [41] M.A. Khorrami (2022), “Thermal Spray Coatings: Properties, Processes and Applications”, <https://www.sciencedirect.com/science/article/abs/pii/S0254058422009221>
- [42] Bodycote plc annual report (2022), “Flame spraying”, <https://www.bodycote.com/services/surface-technology/flame-spraying/>
- [43] Bodycote plc annual report (2022), “High Velocity Oxygen Fuel (HVOF) coating”, <https://www.bodycote.com/services/surface-technology/high-velocity-oxygen-fuel-hvof-coating/>
- [44] Bodycote plc annual report (2022), “Plasma spray”, <https://www.bodycote.com/services/surface-technology/plasma-spray/>
- [45] Bodycote plc annual report (2022), “Electric arc wire”, <https://www.bodycote.com/services/surface-technology/electric-arc-wire/>
- [46] Hayden Corporation. Thermal Spray Coating & Laser Cladding in West Springfield, MA, <https://www.haydencorp.com/the-advantages-of-high-velocity-oxygen-fuel-thermal-spraycoating#>
- [47] Jim Gibson (2012), “Performance Perspectives: Connecting Rod Inspection”, <https://www.motor.com/magazine-summary/performance-perspectives-connecting-rodinspection/>
- [48] MAHLE GmbH, Automotive industry company, “ENGINE BEARING: FAILURE ANALYSIS AND CORRECTION” <https://www.mahle-aftermarket.com/media/local-media-north-america/pdfstumbnails/catalogs-and-literature/engine-bearings/ceb-2-1114-engine-bearing-failuresochure.pdf>
- [49] Profilometer / Roughness (2023), KEYENCE INTERNATIONAL (BELGIUM) NV/SA, <https://www.keyence.eu/products/microscope/microscope>
- [50] Don Sapp (2016), Predictive Testing & Inspection (PTSI) to Prevent Operational Interruptions, <https://www.wbdg.org/resources/predictive-testing-inspection-ptsi-preventoperational-interruptions>
- [51] H. N. W. Gunasekara, J. R. Gamage, and H. K. G. Punchihewa, “Remanufacture for sustainability: a comprehensive business model for automotive parts remanufacturing,” Int. J. Sustain. Eng., vol. 14, no. 6, pp. 1386–1395, 2021, doi: 10.1080/19397038.2021.1990437.
- [52] H. Gunasekara, J. Gamage, and H. Punchihewa, “Remanufacture for sustainability: Barriers and solutions to promote automotive remanufacturing,” Procedia Manuf., vol. 43, no. 2019, pp. 606–613, 2020, doi: 10.1016/j.promfg.2020.02.146.

IOT Based Real-Time Portable Weather Data Collecting Station

W M A Sampath

*Department of Electrical and Electronic
Technology
Univesity of Vocational Technology
Rathmalana
amilasamphwijekoon@gmail.com*

K Y R Amaradewa

*Department of Electrical and Electronic
Technology
Univesity of Vocational Technology
Rathmalana
yasmiraveena@gmail.com*

H G A Sampath

*Department of Electrical and Electronic
Technology
Univesity of Vocational Technology
Rathmalana
achinthsampath84@gmail.com*

R L W Koggalage

*Department of Electrical and Electronic
Technology
Univesity of Vocational Technology
Rathmalana
koggalage@yahoo.com*

Abstract— The challenge of obtaining real-time weather data is compounded by the labor-intensive installation and maintenance of wired sensors, necessitating frequent adjustments. To counter this, this study introduces a portable weather data collection station tailored for efficient data collection in rural settings. Using advanced wireless technologies, the station instantly transmits data to predetermined destinations or securely stores it on an online server, eliminating the limitations of wired connections. The project employs the DHT_11 and BMP_180 sensors for precise temperature, humidity, and pressure measurements. The NodeMCU V3 seamlessly transmits the collected data over Wi-Fi to a Google Sheet, ensuring secure data storage. Integration of the MQTT protocol enables efficient communication between the NodeMCU V3 and the designated server, ensuring reliable data transmission. Moreover, the system integrates Google Maps for location tracking and utilizes MATLAB for comprehensive data analysis, enhancing its capabilities for in-depth weather monitoring. This portable weather data collection station streamlines the acquisition of real-time weather information and offers a sustainable solution for monitoring weather conditions, especially in remote regions. By integrating cutting-edge wireless technologies and advanced data management tools, the system meets the escalating demand for accessible and comprehensive weather data, addressing the limitations of traditional wired weather monitoring systems.

Keywords— portable weather station, data collection, location tracking

INTRODUCTION

The Internet of Things (IoT) enables the remote connection and monitoring of real world objects through the internet, offering convenience and efficiency in various fields. One important application of IoT is in obtaining accurate weather information, which can greatly simplify our daily routines. To achieve this, weather stations are utilized.

Weather stations are devices equipped with sensors that collect data related to weather and the environment. There are two types of weather stations: those with their own sensors

and those that retrieve data from dedicated weather station servers. These sensors can include a thermometer for temperature readings, a barometer for atmospheric pressure, a hygrometer for humidity levels, a rain sensor for rainfall measurements, an anemometer for wind speed, among others. Weather stations are also known as weather centers, personal weather stations, professional weather stations, and home weather stations.

Recent technological advancements, such as Bluetooth and Wi-Fi, have enabled wireless connectivity between different devices. By using a Wi-Fi controller board as a micro web server, the need for wired connections between the Wi-Fi board and a computer is eliminated, reducing costs and enabling the board to function independently. The Wi-Fi board requires an internet connection through a wireless router or hotspot, serving as the gateway for communication with the internet. In the context of weather stations, this technology allows for the creation of a system that provides weather data through a NodeMcu, operating via Wi-Fi.

As the world rapidly develops technologically, there is a strong desire to simplify tasks and explore modern equipment and methods. The integration of IoT and weather stations aligns with this motivation, allowing for easy access to real time weather information. This empowers individuals to make informed decisions and better plan their activities. The continuous evolution of technology and the integration of IoT and weather stations will further enhance our lives, making tasks more efficient and providing us with valuable insights into our surroundings.

Significantly, the need for accurate and accessible weather data has become more pronounced at a global scale, especially with the increasing frequency and intensity of extreme weather events attributed to climate change. The ability to access real time and localized weather information has substantial implications for disaster preparedness, agricultural planning, transportation management, and various other sectors. Furthermore, the integration of IoT technology with weather stations not only facilitates data collection but also allows for the seamless transmission and analysis of this data, enabling proactive decision-making in various sectors. This

research aims to explore the integration of IoT technology in weather stations in greater detail, with a focus on its practical implications and potential for addressing pressing environmental and societal challenges.

LITERATURE REVIEW

The system that Snehashish Mandal and Ravi Kishore Kodali [2] proposed is intended to measure temperature, humidity, pressure, and light intensity. We are able to compute additional data factors, including the dew point, by using temperature and humidity. Apart from the aforementioned features, we have the ability to keep an eye on the location's light intensity. We have also made it possible to keep an eye on the room's air pressure. Moreover, we can keep an eye on the rain value. The Nodemcu (12E) Wi-fi module, based on the ESP8266, is the brains of the prototype. The NodeMCU is connected to four sensors: a light-dependent resistor (LDR), a pressure sensor (BMP180), a raindrop module, and a temperature and humidity sensor (DHT11).

The suggested system by Snehashish Mandal and Ravi Kishore Kodali [2] is designed to assess light intensity, pressure, temperature, and humidity. By using temperature and humidity, we can compute additional data elements, such as the dew point. In addition to the elements listed above, we can monitor the amount of light present at the place. We've also made it possible to monitor the air pressure in the space. Additionally, we can monitor the rain value. The brains of the prototype are found in the Nodemcu (12E) Wi-fi module, which is based on the ESP8266. Four sensors are attached to the NodeMCU: a pressure sensor (BMP180), a raindrop module, a temperature and humidity sensor (DHT11), and a light-dependent resistor (LDR).

According to the system designed by Chen Jianyun and Sun Yunfan[3] a method of data acquisition and transmission based on NBiot communication mode is proposed, Introduction of Internet of things technology, Sensor digital and independent power supply as the technical basis, In the construction of Automatic To realize the intelligent interconnection of the automatic weather station, and then to form an automatic weather station based on the Internet of things.

METHODOLOGY

System Block Diagram

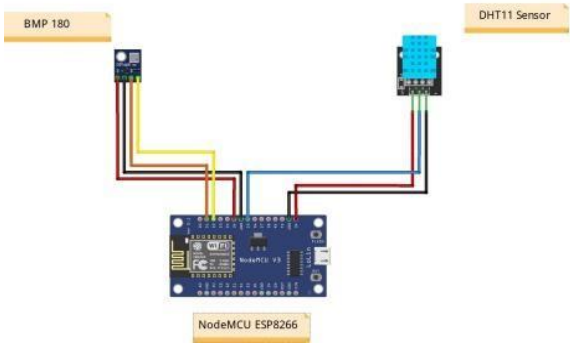
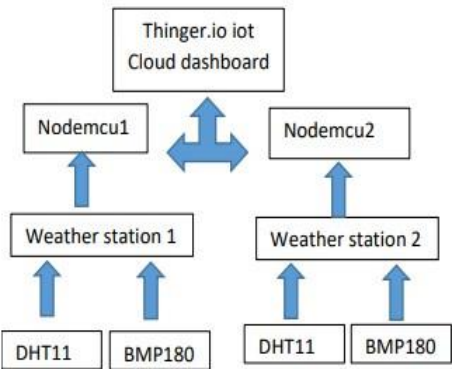


Figure 1- Circuit diagram

COMPONENT LIST

- 1. ESP8266 Node MCU Wifi development board
- Internet
- 2. BMP180 Barometric pressure Sensor
- 3. Jumper wires (female to male)
- 4. Jumper wires (female to female)
- 5. Bread board (Additional)
- 6. USB cable (micro USB)
- 7. Male header pin Covering Box

Main requirement

- Node MCU ESP 8266 BOARD (figure 2)



Figure 2- Nodemcu ESP8266 12E Module

The Node MCU ESP8266 development board comes with the ESP-12E module containing the ESP8266 chip having TENSILICA XTENSA 32-bit LX106 RISC microprocessor. This microprocessor supports RTOS and operates at 80MHz to 160 MHz adjustable clock frequency. Node MCU has 128 KB RAM and 4MB of Flash memory to store data and programs. Its high processing power with in-built Wi-Fi / Bluetooth and Deep Sleep Operating features make it ideal for IOT projects. Node MCU can be powered using a Micro USB jack and VIN pin (External Supply Pin). It supports UART, SPI, and I2C interface.

- **DHT 11 Sensor (humidity and Temperature) (figure3)**

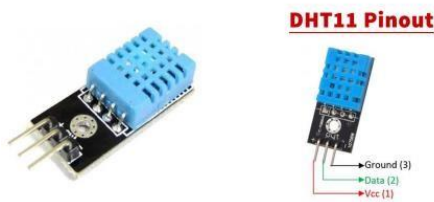


Figure 3- DHT11 Sensor and Pinout

The DHT11 is a basic, low-cost digital temperature and humidity sensor. It uses a capacitive humidity sensor and a thermistor to measure the surrounding air, and spits out a digital signal on the data pin (no analog input pins needed). Connections are simple, the first pin on the left to 3-5V power, the second pin to our data input pin and the rightmost pin to ground.

- **BMP180 (Barometric Pressure, Altitude & Temperature Sensor)**



Figure 4- BMP180 & Pins

The BMP180 is the new digital barometric pressure sensor of Bosch Sensortec, with a very high performance, which enables applications in advanced devices such as smartphones, tablet PCs, and sports devices. It follows the BMP085 and brings many improvements, like the smaller size and the expansion of digital interfaces. The ultralow power consumption down to 3 μ A makes the BMP180 the leader in power saving for your devices. BMP180 is also distinguished by its very stable behavior (performance) with regard to the independence of the supply voltage.

HARDWARE MODELING & SETUP

- Setting up the Thingier.io Dashboard

Here we have used Thingier.io as the IoT platform for our weather station project. That's because it's easy to use Google Maps on Thingier.io to show where weather stations are

located. First, go to <http://www.thingier.io> and create an account and login. After login we can see the interface. First of all, we need to add the devices we use for think.io platform. Then we have add device details.

- Wire Connection

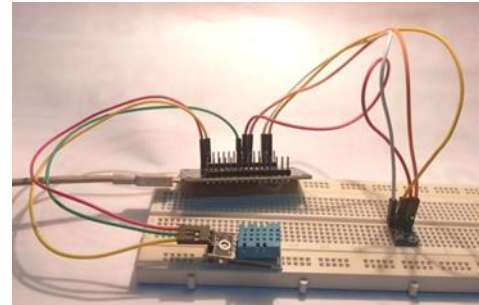


Figure 5- wire connection

Here is the wire circuit we connected for whether station as a protocol. Mainly Nodmcu, humidity sensor and temperature sensor used for that.and also jumper wires and bread board used for that.

ACTUAL DATA

This shows the MWS (Matale Weather station) dashboard and the data obtained from the MWS1 device installed in Matale. Here the data such as temperature, humidity, pressure, altitude and sea level pressure around the weather station is installed and the location of the weather station is shown by Google Map.(figure6)



Figure 6- Weather station Matale Dashboard (Data Resource MWS1)

This shows the CWS (Colombo Weather station) dashboard and the data obtained from the CWS2 device installed in Colombo . This is established in the Ratmalana

area, the surrounding weather data and the location are shown here by Google Map (figure 7).

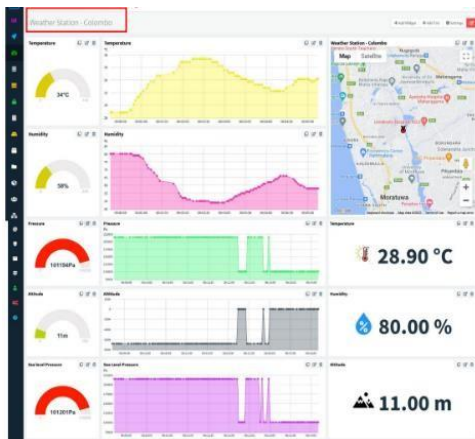


Figure 7- Weather station Colombo Dashboard (Data Resource CWS2)

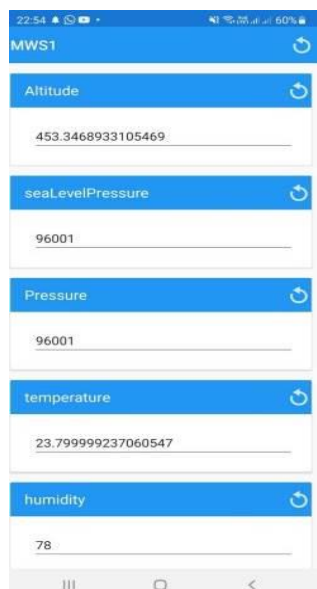


Figure 8- Mobile View COLLECTED DATA

Here data buckets were created to collect weather data. (figure 9)

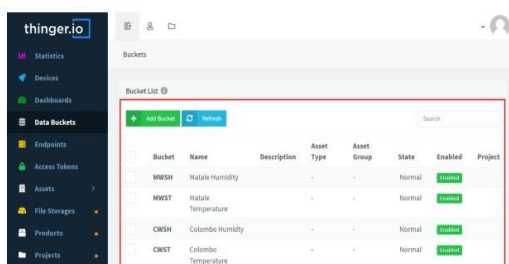


Figure 9- weather data

Here, data buckets have been created to collect weather data separately (figure 10)

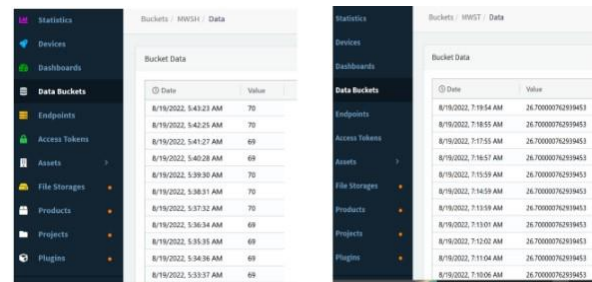


Figure 10- weather data

We have export the data collected here (figure 11) and exported all data files are downloaded as excel sheets.

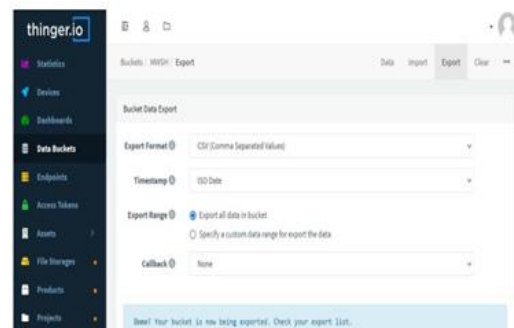


Figure 11- collected data

MATLAB ANALYSIS

The data been collected by the implemented portable weather station. Here connected both devices to the one thinger.io account. A maximum of two devices can be connected to the free account. In data collection, has been decided to put them in four separate buckets. Only 4 buckets are provided in thinger.io free account to collect data. Therefore, initially we had to collect only four types of weather data. We first collected the humidity and temperature of both weather stations in the four buckets.

We first took the data from CWS2 (Colombo weather station) and analyzed it by transferring it to Matlab. Here we collected more than six thousand data.

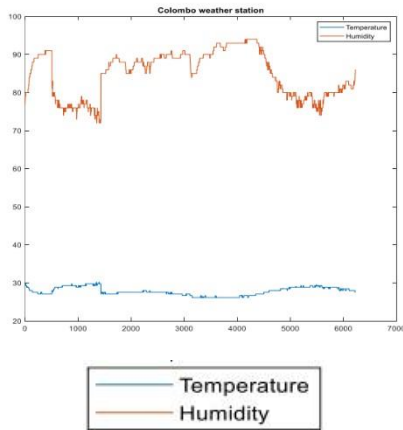


Figure 12- Temperature and humidity data

Temperature and humidity data obtained here are shown separately. Temperature data in orange and humidity in blue (figure 12)

CONCLUSION

In many places, one of the most significant aspects influencing human life is the weather. Thus, understanding the precise weather patterns plays a crucial role in both sustaining and enhancing human life. Even with significant technological advancements in satellite weather monitoring, obtaining precise data in a limited region still presents a challenge. The world has been inspired to use wireless technology for such tasks. By using sensor devices in the environment, we can bring the environment into real life. Then the collected data and analysis results will be available to the user through the Wi-Fi.

By using sensor devices and latest technology in the implemented system it is possible to bring the environment monitoring into real life. By using this portable system, the collected data and analysis results are available to the user in real-time through the Wi-Fi technology.

The smart way to monitor environment an efficient, low cost embedded system is successfully implemented and presented in this paper. It also sent the sensor parameters to the cloud. According to the collected data analysis, it can

successfully collect and transmit data in real-time with no errors.

The system designed and implemented in this project can be used to collect real-time weather information and transmit to required location for monitoring and further analysis to take necessary action. As this system is designed to use wireless technology it can be easily transport and fixed in remote locations as required.

This data will be helpful for future analysis and it can be easily shared to other users also. This model can be expanded to monitor the developing cities and industrial zones for pollution monitoring. By installing such systems in various specific areas, the prevailing weather can be monitored very easily. For example, a system like this can be used to check whether the light and humidity in an industry are favorable for workers. IOT Based systems are very suitable for such activities.

REFERENCES

- [1] A F Pauzi and M Z Hasan "Development of IoT Based Weather Reporting System". 2020.
- [2] Chen Jianyun and Sun Yunfan "Research on Application of Automatic Weather Station Based on Internet of Things" 2018.
- [3] IoT Weather Station using NodeMCU: Monitoring Humidity, Temperature and Pressure over Internet <https://circuitdigest.com/microcontrollerprojects/esp12-nodemcu-based-iotweather-station>
- [4] IoT based weather monitoring system using Nodemcu and Thingspeak <https://srituhobby.com/iot-basedweather-monitoring-system-usingnodemcu-and-thingspeak/>
- [5] Kulkarni, V. A, Satpute G. M "Weather Reporting System Using FPGA : A Review,". 2017.
- [6] Ravi Kishore Kodali and Snehashish Mandal. "IoT Based Weather Station"2018

Design and Development of Electrically Operated Wheelchair

K.G.Sasindu Gimhana
Department of Mechanical &
Manufacturing Technology
University of Vocational Technology
Ratmalana, Sri Lanka
sasinduggamage1997@gmail.com

M.I.T.D. Damith Wijesinghe
Department of Mechanical &
Manufacturing Technology
University of Vocational Technology
Ratmalana, Sri Lanka
dilshandamith534@gmail.com

K.G. Chamith.Gayanjana
Department of Mechanical &
Manufacturing Technology
University of Vocational Technology
Ratmalana, Sri Lanka
kgcgayanjana98@gmail.com

Jayalal Wettasinghe
Department of Mechanical &
Manufacturing Technology
University of Vocational Technology
Ratmalana, Sri Lanka
jayalal@uovt.ac.lk

G.R.Y. Priyankara Senevirathna
Department of Mechanical &
Manufacturing Technology
University of Vocational Technology
Ratmalana, Sri Lanka
yasankapriyankara@gmail.com

Abstract— The prevalence of disability worldwide is about 15% of the global population. Among the various types of disabilities, mobility impairment stands out as the most prevalent, significantly impacting the daily lives of affected individuals. The conventional solution to address mobility limitations has been the traditional manual wheelchair. However, this approach often falls short of providing users with a sense of independence, as continuous assistance from others is necessary. While manual propulsion is an option, it demands considerable physical exertion from the user. The electric wheelchair is an innovative alternative that seeks to address the limitations of traditional manual wheelchairs by offering enhanced mobility and greater independence to users. This study presents the design and development of an electric wheelchair, enriched with a range of user-friendly features, including dedicated storage space for essential medical equipment and adaptable control mechanisms for operation by either hand. The purpose of this research was to enhance the overall functionality and usability of the electric wheelchair, catering to the specific needs and preferences of users with mobility impairments. Through a systematic approach, the wheelchair's design was optimized to accommodate medical necessities while ensuring ease of use and versatility in its control mechanisms.

Keywords—Electric wheelchair, Joystic control, Low-cost wheelchair

I INTRODUCTION

In today's society, disability stands as a significant concern that can curtail individuals' ability to fully utilize their knowledge, talents, and opportunities [1]. Around 15% of the global population, which is equivalent to one billion individuals, face various types of disabilities, with a greater occurrence of disabilities found in developing nations [2]. In situations where an individual has been injured in an accident, is dealing with a condition like palsy, or faces a long-term inability to walk, which may persist until the condition improves, wheelchairs play a crucial role in enabling them to engage in their daily routines and activities. Historically, wheelchairs used to rely on manual propulsion by individuals,

making it quite challenging to cover distances beyond 100 meters [3]. Individuals in need of adaptive tools like electric wheelchairs or assistance from caregivers to carry out their daily tasks find electric wheelchairs to be the most effective solution [4]. Presently, numerous intelligent wheelchair systems have been created through advanced technology; however, the challenge lies in the significant cost associated with these smart wheelchairs. This challenge could be addressed by creating an affordable smart wheelchair. The proposed electric wheelchair aims to provide essential assistance to disabled individuals for performing daily tasks autonomously, particularly focusing on underprivileged individuals who lack the means to afford such high-cost smart wheelchairs.

Over the last couple of decades, a consistent progression has been observed within the domain of electric wheelchairs, facilitating heightened adaptability in their utilization among individuals with disabilities [5]. In this circumstance, it is essential to carry out a comprehensive study of prior research endeavors. Within the body of research, the progression of wheelchair advancements can basically be categorized into two groups: hand-controlled and non-hand-controlled wheelchairs. The latter category proves advantageous for individuals who have incurred the loss of both upper extremities. Hand-controlled wheelchairs mainly rely on joystick controllers for operation [4], [6]–[10], whereas non-hand-controlled variants predominantly harness technologies such as voice recognition, eye movement tracking, head movement tracking, and various gesture recognition methodologies [11]–[14]. However, a majority of initiatives employed costly apparatus and intricate technologies to achieve self-directed navigation and versatile interfacing, accompanied by significant expenses and extensive training requirements. These factors impede the progression of intelligent wheelchairs into the phase of commercial viability [15]. Therefore, the primary objective of this research endeavor was to design and develop a cost-effective electric wheelchair, thereby rendering it financially accessible to individuals with limited economic means, while concurrently

fostering a conducive environment for potential commercial deployment.

H. CUSTOMER PERSPECTIVE

A survey was conducted among prospective customer segments to identify the attributes that should be integrated into the proposed wheelchair design. The principal customer categories encompassed individuals presently employing wheelchairs, medical practitioners, and vendors specializing in medical equipment. Some important points identified from the customer survey are as follows.

- It is necessary to design a control unit which can be controlled by either the left or right hand.
- Even though it is an electric wheelchair, a mechanism should be incorporated to operate the wheelchair manually in the event of a sudden failure.
- There should be some space to place some important medical equipment, such as oxygen tanks, urine bags, etc.

II METHODOLOGY

The devised system has undergone phases of design, fabrication, and evaluation in alignment with the study's objectives. Throughout these processes, input from stakeholders has been solicited, enabling iterative enhancements to be made consistently. Fig. 1 illustrates the block diagram containing all the relevant components.

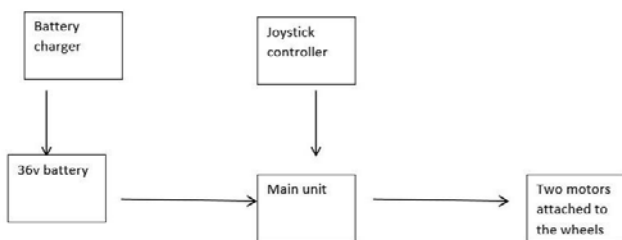


Fig. 5. Block diagram

The joystick controller serves as the interface through which the user imparts necessary commands to the central unit. The primary unit, in turn, transmits control signals to the pair of wheels' associated dual motors. Power is supplied to the central unit via a 12V battery, and the charging replenishment is facilitated by a battery charger.

A. Body specifications

The wheelchair developed under this study has dimensions, including a length of 106 cm, a height of 92 cm, and a seat elevation of approximately 49 cm. The main frame of the wheelchair was built using the Aluminum box bar due to its' light weight. Fig. 2, Fig. 3, and Fig. 4 show the body dimensions, the 3D view of the wheelchair, and the finished version of the developed electric wheelchair, respectively.

Fig. 6. Body dimensions

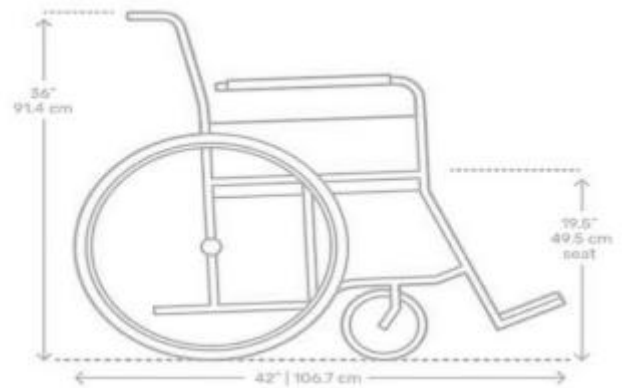


Fig. 7. 3D view

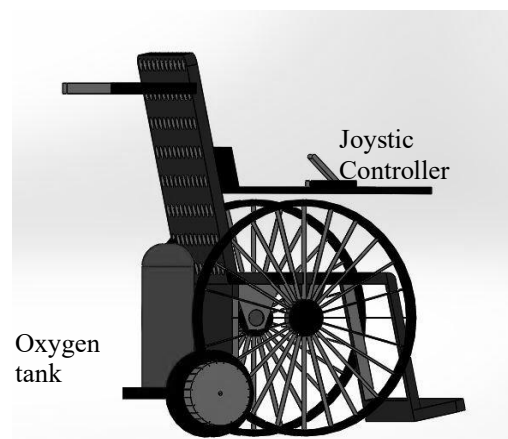


Fig. 8. Finished version

B. Operating system

The wheelchair's navigation is managed via a joystick controller, which encompasses four distinct switches that facilitate the wheelchair's movement in forward, backward, left, and right directions. In the propulsion system, a 36V brushless DC electric motor (BLDC) has been implemented

and selected for its commendable load-bearing proficiency, robust longevity, and minimal maintenance requirements. The modulation of motor velocity is achieved through the integration of a 10k potentiometer, enabling seamless speed adjustment. This integration of components not only ensures precise control and versatility in maneuvering but also emphasizes the judicious selection of components based on their technical attributes.

C. Hub motors

In this design, two magnet-based 250W * 36V hub motors were employed. This choice has been made due to the motors' robust load-bearing capacity, durability over time, and minimal maintenance requirements.

D. Power source

The main power source in the wheelchair is a 36V 2500mA Li-ion Battery being utilized.

E. Wheels and brake system

In this study, the choice has been made to employ a conventional bicycle framework, featuring rear wheels alongside two caster wheels incorporated as the front wheels. A lever-based braking system was used for the wheelchair which ensures the maximum safety.

III TESTING AND RESULTS

The operational electric wheelchair has been introduced and subjected to multiple rounds of testing by a group of individuals with various disabilities. According to the feedbacks given by the users, modifications and improvements were made. Upon the finalization of the electric wheelchair design, comprehensive trials were conducted in both indoor and outdoor environments. The operational capacity of the electric wheelchair extends for approximately one hour following a complete battery charge. Noteworthy ease and effortlessness characterize the operation of this wheelchair. The controller interface offers flexible control from both left and right orientations as necessitated. Considerable attention has been given to accommodating an oxygen tank, optimizing its positioning for minimal height while ensuring effective retention. Additionally, the wheelchair has been engineered to enable manual maneuvering in instances of sudden battery discharge.

Current prices for electric wheelchairs are in the range between LKR 270,000 and LKR 800,000, depending on the features included. If the proposed wheelchair is manufactured locally, the cost of manufacturing will be around LKR 150,000 but it will include many useful features. So, the objective of developing a cost-effective electric wheelchair while incorporating user-friendly and medical requirements has been achieved.

IV CONCLUSIONS

The developed wheelchair possesses the capacity to meet the mobility requirements of individuals who encounter physical limitations. Beyond addressing mobility needs, it also adequately addresses various other medical requisites defined from the customer's perspective. Constructing the wheelchair can be achieved using low cost components readily accessible within the local market. The electric

wheelchair developed in this study represents a significant advancement in mobility technology. This wheelchair offers a dual mode of operation, functioning effectively through battery power or manual maneuvering. By incorporating high-performance motors with a power rating of 36 volts and 2.5 amperes, the wheelchair maintains commendably low power consumption. The utilization of hub motors contributes to its exceptional load-bearing capacity, enabling it to accommodate higher weights with ease. Furthermore, the wheelchair's control mechanism is intelligently designed, allowing users to effortlessly navigate both left and right directions. The endeavor to enhance the electric wheelchair's functionalities is mindful of the prevailing cost dynamics associated with modern electronic devices, which can introduce challenges when incorporating advanced smart features. The central aim of this study is to render the wheelchair an affordable solution, making it accessible to a wider range of users. In striving for cost-effectiveness, it's acknowledged that certain high-end smart functionalities may necessitate careful consideration. In addition, it's important to note that, despite the wheelchair's autonomous capabilities, the mechanical mode of operation may still require external assistance.

ACKNOWLEDGEMENT

The authors wish to thank Department of Mechanical and Manufacturing Technology of University of Vocational Technology for giving the necessary directions to carry out the project.

REFERENCES

- [1] C. Shahnaz, A. Maksud, S. A. Fattah, and S. S. Chowdhury, "Low-cost smart electric wheelchair with destination mapping and intelligent control features," *Int. Symp. Technol. Soc. Proc.*, vol. 2017-Augus, pp. 1–6, 2018.
- [2] "https://www.worldbank.org/en/topic/disability." .
- [3] C. H. Hsiao, M. L. Lee, Y. C. Shen, and F. Lai, "A design of small-area automatic wheelchair," *Conf. Proceeding - IEEE Int. Conf. Networking, Sens. Control*, vol. 2, pp. 1341–1345, 2004.
- [4] Y. Rabhi, M. Mrabet, and F. Fnaiech, "Intelligent Control Wheelchair Using a New Visual Joystick," *J. Healthc. Eng.*, vol. 2018, 2018.
- [5] X. Attali and F. Pelisse, "Looking back on the evolution of electric wheelchairs," *Med. Eng. Phys.*, vol. 23, no. 10, pp. 735–743, 2001.
- [6] J. H. Choi, Y. Chung, and S. Oh, "Motion control of joystick interfaced electric wheelchair for improvement of safety and riding comfort," *Mechatronics*, vol. 59, no. 10080547, pp. 104–114, 2019.
- [7] N. Thongpance and P. Chotikunnan, "Design and Construction of Electric Wheelchair with Mecanum Wheel," *J. Robot. Control*, vol. 4, no. 1, pp. 71–82, 2023.
- [8] Y. Rabhi, M. Mrabet, F. Fnaiech, P. Gorce, I. Miri, and C. Dziri, "Intelligent Touchscreen Joystick for Controlling Electric Wheelchair," *Irbm*, vol. 39, no. 3, pp. 180–193, 2018.
- [9] W. Budiharto, "Intelligent controller of electric wheelchair from manual wheelchair for disabled person using 3-axis joystick," *ICIC Express Lett. Part B Appl.*, vol. 12, no. 2, pp. 201–206, 2021.
- [10] J. W. Park, W. S. Im, D. Y. Kim, and J. M. Kim, "Safe driving algorithm of the electric wheelchair with model following control," *2014 16th Eur. Conf. Power Electron. Appl. EPE-ECCE Eur. 2014*, 2014.
- [11] D. Bai *et al.*, "Design of an eye movement-controlled wheelchair using Kalman filter algorithm," *2016 IEEE Int. Conf. Inf. Autom. IEEE ICIA 2016*, no. August, pp. 1664–1668, 2017.
- [12] G. Marins, D. Carvalho, A. Marcato, and I. Junior, "Development of a control system for electric wheelchairs based on head movements," *2017 Intell. Syst. Conf. IntelliSys 2017*, vol. 2018-Janua, no. September, pp. 996–1001, 2018.

- [13] J. W. Machangpa and T. S. Chingtham, "Head Gesture Controlled Wheelchair for Quadriplegic Patients," *Procedia Comput. Sci.*, vol. 132, no. Iccids, pp. 342–351, 2018.
- [14] M. Fezari, M. Bousbia-salah, and M. Bedda, "Voice and Sensor for More," vol. 12, p. 23000, 2006.
- [15] J. Shen, B. Xu, M. Pei, and Y. Jia, "A Low-Cost Tele-Presence Wheelchair System *," pp. 2452–2457, 2016.

Design and Development of an Efficient Portable Seed Sowing Machine

Pushpasiri P.U.L
Department of Electrical and Electronics Technology
University of Vocational Technology
Colombo, Sri Lanka
pushpasiripul@gmail.com

Amaranatha K.G.B.
Department of electrical and electronics technology
University of Vocational Technology
Colombo, Sri Lanka
kgbhatiya21@gmail.com

Ganegoda D.T.
Department of electrical and electronics
technology
University of Vocational Technology
Colombo, Sri Lanka
ganegodadilsh@gmail.com

Abstract— Sri Lanka, which is an agriculturally active country, should be ready to find solutions to the food crisis in the near future. Accordingly, there is an urgent need to increase the speed of agricultural activities around the country. Even now, various countries have increased the productivity of agricultural activities in their countries by using various research and new technical methods. Considering these facts, the main objective of this study was to find out how technical methods can be used to increase the productivity of seed nursery systems, which are one of the aspects of Sri Lankan agriculture. Accordingly, the areas cultivated by the farmers using seed nursery methods, the types of crops, and the different sowing practices followed by the farmers have also been analyzed. Using the analyzed details, mechatronics concepts were used to develop a low-cost automatic machine with facilities related to seed sowing, fertilizer collection, and water collection. This seed-sowing mechanism is designed so that the mechanism can be easily adjusted according to the size of the seed used for sowing, and separate containers are used for storing fertilizer and water with special equipment. After inserting soil-filled seed trays into the machine and starting the system, the seed tray automatically moves to each stage of the process, and after the process is completed, the nursery trays automatically come out of the machine with higher-quality seeds. As the time taken for this entire process is close to 19 seconds, we were able to increase the sowing productivity. This new machine will also enable farmers to engage in alternative income-generating activities and demonstrate the success of our project objective by convincing farmers that traditional farm machinery can be replaced with low-cost automation systems and new techniques to complete a labor-intensive task more efficiently.

Keywords—agriculture, seed sowing, farm machinery, nursery tray, ATmega 328p microcontroller

I INTRODUCTION

Background

Due to low productivity, declining product quality, and climate change, farmers face a number of challenges and obstacles. Agriculture needs to be continuously developed and shaped through technological innovation so that it can contribute more effectively to the economy. For this,

farming should be made more efficient and easier by introducing methods through new technologies, tools, machinery, and analysis. Here, special attention is paid to maximizing yields in the short term with minimal inputs. For this purpose, the use of machinery and cultivation management can be seen to be more productive than agricultural activities, which are primarily done using human labor.

There are seven major activities in the field of agriculture: soil preparation, sowing, fertilizing, irrigation, weeding, harvesting, and storage [1]. These are intertwined processes and must be done sequentially until the final harvest. Here, energy management, time management, and crop seed management can be identified as the main issues. In agriculture as a whole, there is a diversity of labor that must be employed differently for each task. However, the loss of efficiency when the same task is performed continuously is a major problem in the use of human labor, and it is a problem that affects the entire process. In agriculture, it is always a great advantage to be able to control the above activities through time management and reduce the time taken to harvest. But since human labor is widely used for this, it can be seen that these steps take more time.

The other thing to consider here is seed management. In most plantations, plants or seeds are planted using human labor. For this, it was seen from the observations that more time has to be spent because the labor skill affects the related agricultural process. If the seeds are sown mostly by human labor, there is a higher chance of the seeds not germinating due to excessive accumulation of seeds in the field, contact germs, etc. This has been a huge problem throughout the process. What became clear here was that these problems could be clearly solved using technical and automated methods. The aim is to find the correct answer to the problems mentioned here based on mechatronic technology.

II REVIEWS OF LITERATURE

Many literary studies have been done on the design, construction, and operation of an automated seeding machine. In discussing the information so obtained, some machines describe both automated and semi-automated

methods. A number of factors have been considered for the design, construction, and operation of an automated seeding machine, such as sowing seed, planting seed type, sowing time, the power required for operation, and efficiency, and various relevant information and methods have been found in this literature. In the final report of the data collection survey on Sri Lanka's agriculture sector conducted by the Japan International Cooperation Agency (JICA), many major challenges in Sri Lanka's agriculture sector have been pointed out. According to this report, among the social and economic challenges to the Sri Lankan agricultural sector, it is shown that the decrease in the population of the agricultural workforce has had a great impact. Thus, due to the decrease in the contribution of the agricultural sector to the GDP and the increase in the overall production cost of agricultural products due to the labor shortage and the trend of increasing labor wages, it shows that even if the products comply with the export quality standards in the international market, they are not competitive. It is explained that continuous efforts like breeding new varieties, the introduction of new crops, and the introduction of modern technology are necessary to meet this requirement [2].

According to the research conducted by R. M. S. R. Chamara and the team, it has been shown that the rapid growth of population, depletion of natural resources, climate change, shrinking of agricultural land, and unstable markets make global food systems quite insecure. Therefore, they have shown that modern agricultural and food processing systems should be implemented more effectively and efficiently. It reveals how AI technologies can benefit the global agriculture and food sectors. It examines ways in which AI can solve key problems in Sri Lanka's agriculture sector, such as labor shortages, misuse of agrochemicals, and inefficient research, policy, and administration. In addition, it is shown that the huge potential of this new technology should be rapidly utilized in the journey towards global food security [3].

Pranil V. Sawalakhe and his team explore that the present era is witnessing rapid growth in all sectors of agriculture and is moving towards mechanization. In order to meet future food demand in the agricultural sector, new technologies that do not affect farmers should be implemented. In addition, the impact of soil nature on crop production is discussed [4]. Prashant Kumar S. Pal and his team have studied the potential of rapidly developing industrialization to meet the growing population and their food needs. Accordingly, it explains the possibility of mechanization conserving inputs with greater precision, ensuring better distribution, reducing the quantity required by production in response to demand, and thereby preventing loss or wastage of inputs [5].

According to the Agricultural Development article by Rajan Binayek Pasa of Tribhuvan University, shows that the agriculture sector is the single largest employer in the world. This study emphasizes the importance of technological intervention for agricultural development and shows that the socio-economic conditions of farmers are barriers to the adoption of modern technologies. According to the research conducted using modern and traditional agricultural technologies, this study has revealed that modern technological intervention can increase commercial farming activities and family income, create self-employment, and

generate rural economies in particular, and support the rural development process in general [6]. D. Ramesh and H.P. Girish Kumar have provided brief information on the various types of innovations that have already taken place. The depth of seed placement varies from crop to crop, and it has been shown that seed sowing equipment plays an extensive role in the field of agriculture to achieve maximum yield in different agro-climatic conditions [7].

III METHODOLOGY

Field Survey

This section will detail the field survey conducted to increase the effectiveness of the project and its related matters. Here, a group of farmers carrying out their cultivation activities using various seed nursery methods was targeted. All the farmer members who participated in the survey were from the Welimada area because it is an area where seed nursery methods are widely used.

Since these members were of different knowledge levels, the main objective was to give a general idea about the project and to give an idea about how this project was used among the farmers. For this purpose, a data collection form, which is mentioned in Appendix 01, was created, and their opinions were collected through the form. Their views on current cropping methods, frequency of cropping per year, whether nursery methods are used or not, the problems currently encountered when using nursery trays, reasons for not using them, and facilities that should be available if an automatic machine is introduced for this purpose, are primarily targeted.

However, the summary of findings was somewhat negative and required further investigation and follow-up. The reason is that the farmers do not have a clear idea about the technical process of the project and the use of the project. Therefore, the data provided is somewhat backward in nature. Here, in order to implement the project with essential solutions for cultivation and nursery work, a scoring process was implemented considering the opinions presented by the people who participated in the survey. Accordingly, below is an overview of the mean scores of the survey question related to the main points which were considered.

TABLE II.
MEAN SCORE OF THE SURVEY QUESTION

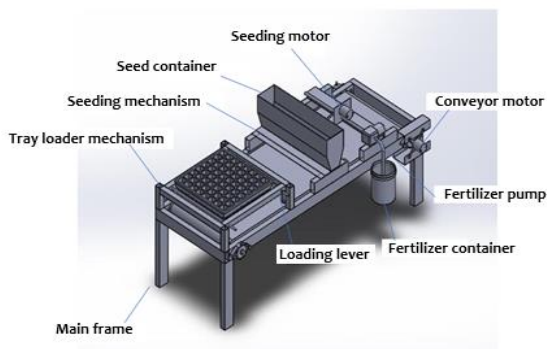
Implementation of the Project

Main Points Related to Survey Question	Overview of the Mean Scores	
	0%	100%
Awareness of the project	52%	
Reliability of operation	28%	
Portability	60%	
Project cost	30%	
Safety in use	44%	
Empowerment	26%	
Final progress	28%	

Conceptual design:

In the conceptual designing step, several key factors were considered when selecting sensor and output circuit devices for the relevant parameters.

Basically, consider the environmental conditions in which the system is expected to be used. Accordingly, the sensors to be used for system automation were selected, and factors such as required accuracy, operating voltage range, speed of response, reliability, and how to deal with the system were also taken into consideration. After selecting the appropriate inputs and outputs like sensors, switches, and motors, we were able to develop the project that had been conceptualized so far using SolidWorks software. It was finally selected and specialized after a multi-faceted quality, simplicity of design, and affordable assessment. Here, when sowing seeds in the nursery, a definite outline of the basic elements was created using the CAD software, taking into account the requirements to be met. Main frame, seeding mechanism, tray loader mechanism, fertilizer pump, seeding motor, conveyor motor, seed container, and fertilizer container can be represent as the major parts of this seed sowing machine.



Solidwork 3D design of the project

Detailed mechatronics design:

The system started by pressing the start push button, and the system stopped by pressing the stop push button. Here, the ATmega328p microcontroller is used to control the whole system. when selecting a microcontroller for the system, low cost and correct operation were considered. Limit switches and proximity sensors are used to get the position signals of the movements and also give the signals about seeding tray load and unload conditions. The relays are used to control DC motors, the water pump, and the buzzer alarm, and those depend on the microcontroller's signal.

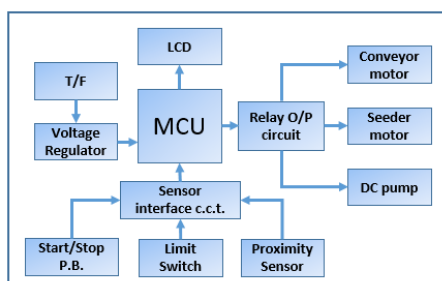


Fig. 9. Microcontroller based control circuit block diagram

Accordingly, ATmega328p microcontroller programming was done using the ATMEL Studio 7 IDE

and, AVR ISP programmer. Here, embedded C was used to program the microcontroller, and the program was also written according to the sequence of the operation. While the nursery disk that lands on the conveyor moves forward, the disk is detected through the sensors installed in the system, and accordingly, the microcontroller works to arrange the time required for fertilizer and seed collection.

IV RESULT AND DISCUSSION



Fig. 10. Portable seed sowing machine

General

Through this seed-sowing project, two main objectives were aimed at being achieved. These are the reduction of time wastage in the sowing process with the introduction of automation and the production of user-friendly and portable machines to obtain high-quality seedlings for field planting.

We were able to see a better result than we thought when considering the first objective. That is time management and minimizing seed waste. When the soil-filled nursery tray is loaded into the machine, it takes less than 19 seconds for the seed sowing and fertilizer application process to come out of the machine. This can be seen as a very advantageous situation. In addition, the seeds do not come into contact with the hands, thus minimizing the damage caused by germs. Gradually, the seeds were sown on the cells of the nursery tray, and it was possible to maintain the seed spacing. It has been shown in practice that the gap between these plants and the plant density affects the quality of the plant and that such disadvantages should be avoided. Accordingly, it was clear that the second objective could also be achieved. After booting the system, the LCD will instruct the user and indicate the nursery disk loading time and unloading time.

This method is very beneficial to all farmers as it can prevent seed wastage and excessive manpower during the sowing process. It also focuses on saving time throughout the entire process. In the design of this system, the seed measurement and sowing mechanism are directly controlled, and a motor-driven system is used. It aims to increase efficiency by minimizing belt and gear systems in general, eliminating cost-increasing complications, and reducing costs. This system provides all the facilities that can be used efficiently. At the end of the process, the

seeding tray reaches the unloading place, and then the alarm buzzer is triggered. Then the user can easily know about it. With this system, a farmer can sow the seeds very easily with a single labor cost. In another way it will be an advantage to him as time, as well as labour, will be saved. It also helped to seed plantation process take place smoothly and without the wasting seeds. At the end of the process, it creates an alarm. Therefore, we can see that this system provides the entire facility, and farmers sow the seeds very easily.

The cost of this machine is around Rs.78,000 which is affordable for a nursery farmer. It is also possible to earn it again using the system.

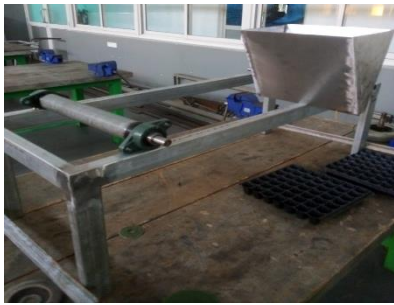


Fig. 11. Seed tray loader and fertilizing mechanism

A comparison between the goals that were expected to be achieved when the system was created and the goals that were achieved after the system was created to achieve those goals are shown in the following table 3.1. Studying this table, it is clear that we have been able to achieve close to the desired goals by designing this portable seed-sowing machine.

TABLE III.
COMPARISON BETWEEN DESIGNED VS DESIRED SYSTEM

Desired system	Designed system
Seed sowing accuracy: 87% or more	We got more than 90% accuracy
Photoelectric sensor detection system if there are no discs.	Achieved and system displayed there is no seeding tray.
preventing seed wastage	Achieved and seeds sow without disease issues.
System suitable for cell distance between 10-50 mm	Achieved and with the small change of seeder mechanism it can be used with different cell distances.
Seed sowing speed: 20-30 discs per hour.	We counted and we can complete more than 100 trays per hour.
Multi-button operating system and sowing is simple, practical and fast	We designed system with simple button operations and therefore the sowing is simple, practical and fast
Low Energy Requirement	Achieved and the whole system power consumed to operate only 60W

Challenges and Recommendations

The system uses a 12-volt and 5-ampere transformer to power it, which can be powered by a 12V battery. It can then be reused by charging the battery with solar power. Instead of the DC motor used for the seed-sowing mechanism, it would be more advantageous to use a motor that can easily control the locations. This is because the sowing gap can be further stabilized.

The positioning of the photo sensors used for the system and the circuits used to detect the sensors emitted by them worked correctly, but it was a bit difficult to locate and adjust the sensors. This is because the range at which the sensor operates is slightly different from the range of the datasheets. However, we were able to keep the activism unchanged.

The project was also adversely affected by the current adverse effects on the market and the economy. Therefore, the shortage of equipment and the high cost of existing equipment also hampered the development of the project. However, we hope to further improve the system, as we have been able to achieve successful results. This seed sowing machine has been upgraded to be very convenient and cost-effective but we hope to develop it in the future considering the following points:

- Solar power can be used to replace the existing power system and thereby familiarize the user with energy management.
- The system can be upgraded to integrate an IoT based system for automatic control and remote control.
- This can be done by adding a software system that can be assembled and used as needed for sowing on a large farm at a minimal cost.
- In addition to the fertilizer currently in use, a mechanical system can be added to fill the soil for the nursery trays.

V CONCLUSION

This seed-sowing machine has great potential to increase planting productivity. Until now, the main method used for sowing seeds on nursery trays in farming was manual sowing. But with the adaptation of this seed-sowing machine, the advantage is greater and the purpose of the nursery tray system will be fulfilled more effectively. Therefore, it is imperative to promote this technology and make it affordable to even small-scale farmers.

The machine can be manufactured locally from raw materials, which minimizes the cost of the entire project, and can be easily manufactured in existing workshops. In addition to the cost of sensors and motors, the cost is very small. So by using this machine, we can sow nursery seeds more flexibly as well as at a lower cost. In addition, another advantage is that the sowing mechanism can be changed according to the nature of the seed. Finally, it can be said that this project has the right answer to the problems of seed nursery work in Sri Lanka.

REFERENCES

- [1]W. K. S. M. Abeysekera, G. A. S. Premakumara, R. D. Ratnasooriya and V. N. Chandrasekharan, "Physicochemical and nutritional properties of twenty three traditional rice (*Oryza sativa* L.) varieties of Sri," *Journal of Coastal Life Medicine*, pp. 343-349, 2017.
- [2]Japan International Cooperation Agency (JICA), "Data Collection Survey on Agricultural Sector in Sri Lanka - Final Report," Japan International Cooperation Agency (JICA), Sri Lanka, September 2019.
- [3]R. M. S. R. Chamara, S. M. P. Senevirathne, S. A. I. L. N. Samarasinghe, M. W. R. C. Premasiri, K. H. C. Sandaruwani, D. M. N. N. Dissanayake, B. Marambe, W. M. T. P. Ariyaratne and S. H. N. P. De Silva, "Role of artificial intelligence in achieving global food security: a promising technology for future," *Sri Lanka Journal of Food and Agriculture*, vol. 06, no. 02, pp. 43-70, 2020.
- [4]P. V. Sawalakhe, A. Wandhare, A. Sontakke, B. Patil, R. Bawanwade and S. Kurjekar, "Solar Powered Seed Sowing Machine," *Global Journal of Advanced Research*, vol. 2, no. 4, pp. 712-717, 2015.
- [5]P. K. S. Pal, R. R. Pal, V. D. Prajapati, Y. R. Pandey and S. Shaikh, "Design and Fabrication of Agricultural Sprayer," *International Journal for Research in Applied Science & Engineering Technology*, vol. 10, no. 4, pp. 358-362, 2022.
- [6]R. B. Pasa, "Technological Intervention in Agriculture Development," *Nepalese Journal of Development and Rural Studies*, vol. 14, no. 1&2, pp. 86-97, December 2017.
- [7]D. Ramesh and H. Girishkumar, "Agriculture SeedSowing Equipments: A Review," *International Journal of Science, Engineering and Technology Research (IJSETR)*, vol. 03, no. 07, pp. 1987-1992, 2014.

e

DEVELOPMENT OF SEMI-AUTOMATIC ERGONOMIC SMART TABLE

K. A.D.H.Kumarasinghe
*Department of Electrical and
Electronics Technolog
University of Vocational
Technology, Sri Lanka*

R.G.D.B. Dissanayake
*Department of Electrical and
Electronics Technology
University of Vocational
Technology, Sri Lanka*

L.Mallikarachchi
*Department of Electrical and
Electronics Technology
University of Vocational
Technology, Sri Lanka*

Eng.S.P.A.R.Suraj Jayathilaka
*Department of Electrical and
Electronics Technology, University
of Vocational Technology, Sri
Lanka*
subjaya2001@yahoo.co.uk

Abstract—The semi-automatic ergonomic smart table provided answers to many of today's questions. The main purpose of creating this table was to do the work of several tables in one table. The ergonomic smart table consists of several features. The table is an equipment that very close to people. It can further develop using the technology. This smart table combined with the electrical, electronic and mechanical system. The table is designed to adjust the height of the table according to the sitting posture by moving the legs up and down. The maximum height of the table is 950mm and the minimum height of the table is 650mm. This mechanism is done by two linear actuators and height can adjust by the screen attached to the table. This smart table can carry 90 kg weight in total. Iron and wood are used as the main raw material in the design of the table. This table attached with the dimensions of 7 inches of screen. The table is intended to be accessed by a central software with an LED screen that can be used as a table tab with Bluetooth Wi-Fi connectivity. The smart table is equipped with the Wi-Fi camera, Hot plate and a wireless charger. The height adjustment mechanism, hot plate, screen and all other functions of the table controlled by the Raspberry pi 4 model B. The user interface was created using QT software for the screen. With the investigation camera, you can see the person working in front of the table from anywhere in the world. Also, you can take a photo and a video with this. A 12v heat element was used for the hot plate and an emergency switch was also connected to it. The Ergonomic Smart table is specially designed for students, but anyone can easily work from the same table without changing the table according to the work done.

Keywords: *LED screen; QT software; Raspberry pi; Wi-Fi camera*

I. INTRODUCTION

A table is a tool that is always closely associated with people's daily activities. The table can be further adapted using technology to further enhance its functional features and make it easier to use. Many people are tempted to work remotely during this pandemic situation. As a result, it is the learning child who suffers the most. The reason for this is that although children are inclined towards education in a

classroom, it is difficult to continue it due to the pandemic situation. The main purpose of making this table is to minimize the damage to education. This portable smart table is the best option for it. Because of this pandemic situation people spending a very difficult time period. This mainly affected the education sector. In this smart table, there is a LED screen accessed by the central software, a calculator combine with the watch, USB. By the use of individual LED screens, students can see the question papers, and books and can answer the questions and check it themselves. Smart table will be designed to move from one place to another and can adjust the height. This will help to fit in the doorways very easily and can be easily moved from one place to another. Wi-Fi technology will be adopted with this smart table to provide better communication for students and people who use it. It designs as a mobile design. Smart table can adjust the angle according to the work done.

II. BACKGROUND STUDY/ REVIEW OF LITERATURE

Importance of the design

Although many things have changed in the world, the only thing that has not changed is education. With the advancement of technology, only the way education is imparted or received in a classroom or outside has changed according to technology. The main aim of educational institutions is to provide a suitable learning environment for the child to acquire knowledge and to motivate the students to develop their abilities. (Maruful Islam, Raman Das, 2017).

Innovations such as smart tables benefit not only from the product features in the redesigned product but also from the technological knowledge of the people who use such devices. Positive attitudes of parents and teachers about working with technology are also important. A portable Smart Table for Interactive Class Room is a combination of both analog and digital technologies. The reason for this is to increase the efficiency of this table. The design is combined with a lot of features. The design of a portable smart table includes with calculator and a clock to see the time and do the calculations. It's a very interesting idea and

we have added these elements to the smart table we have designed and also set an alarm to indicate the different time periods when working. It also includes the touch screen and we have included a touch screen in the design to do the controlling part (Islam and Das, 2017).

III. METHODOLOGY

An ergonomic smart table is designed by combining electrical electronic and mechanical systems. The table is designed to extend from both sides and adjust the angles of the table according to the sitting posture by moving the legs up and down. This smart table can carry 90 kg. iron and wood are used as the main raw material in the design of the table. The ergonomic smart table is attached to the 10 inches screen. This table is intended to be accessed by central software with a LED screen that can be used as a table tab with Bluetooth and Wi-Fi connectivity. The smart table is equipped with a calculator, clock, and hot plate.

The main feature of the ergonomic smart table is the table legs up and down mechanism, which is mounted in two DC motors on either side of the table, and when motor 2 is rotated, the mounting screw rotates and moves the table legs up and down. Table legs vary in height, with a maximum height of 950mm and a minimum height of 650mm. A limit switch is used to activate and operate this mechanism. The motor used here is controlled by a motor control activated by a Raspberry Pi board. The raspberry pi board provides the input signal to the motor control, which in turn provides the input to the motor. An HMI is connected to the Raspberry Pi board and controls the ups and downs of the display interface.

The hot plate mounted on the front of this ergonomic smart table can heat food or liquid to a maximum temperature of 65C. This hot plate consists of a load cell and when the weight on it increases, the hot plate auto-ON. An emergency switch is installed to prevent any accidents.

Section one

All wood generally has poor heat transfer qualities-that is it cools relatively rapidly after being heated and doesn't transfer heat well through conduction. Most metals are electropositive in nature which means they tend to gain the electron. Whereas wood is electronegative in nature it tends to lose electrons. We know that a material that has more electrons can conduct easily, so metals have good conducting properties. That's why metal gets heat faster than wood.

Table surface

Teak wood was used to create the table surface. The main reason for this is the durability and strength of teak wood. Making the table 700mm wide was the first step in creating the table face. The wood was first cut into pieces with a width of 15cm. They were then nailed together to make a width of 700mm. It was then glued again using glue. Then did the first roughing. Then slammed the frame around the table and roughened it again. The table face was then painted with waterproof paint and as a final step, the rough areas were re-roughened and painted.

Section two

When a weight is placed on the surface of the table and on the table, the weight is supported by the legs of the table. Therefore, it should be made possible to bear more weight on the legs.

Lower part of the table

The footed part of the table is made of iron. Because it should be able to carry a mass of 90kg and have a displacement of 300mm. The maximum height of the table is 950mm and the minimum height is 650mm. Meanwhile, the distance is designed to be adjustable to any desired size. Linear actuators are used to change the height of the table relative to these distances in the table. The cross-section between the legs of the table holds the circuits for operating the motor and other table Equipment required to operate the linear actuators.



Figure 1: Minimum height of the table

Features included in the table

The main features of the semi-automatic ergonomic smart table are changing the height of the legs and controlling the activities of the table through a screen. It is also equipped with many additional features such as a wireless charging unit, a heating element, and an investigation camera.

Legs up and down mechanism

The main feature in the ergonomic smart table is the mechanism of legs going up and down, it has two linear actuators mounted on both sides of the table. When the motor rotates, the screw is designed to rotate up and down from the table. The maximum height change of the legs is 950mm and the minimum height is 650mm. This mechanism uses a limit switch to activate and operate it. The process done here is controlled by raspberry pi, which supplies inputs. The raspberry pi board is connected to an HMI. From that display interface can controls the ups and downs mechanism.

Hot plate

The hotplate mounted on the face of this ergonomic smart table can heat food or liquid to a maximum temperature of 65 degrees Celsius. This hot plate consists of a load cell and as the load on it increases, the hotplate automatically turns ON. An emergency switch is installed to prevent any accidents.

Investigation camera

The primary purpose of installing an investigation camera on the desk was because this desk was purposefully created for studying children. This can be used to see if the child is working from the desk when the parents are not at home. The type of camera used here is a Battery Wi-Fi camera. This camera can be used for two hours continuously when fully charged. This device is not connected to any external wires. Only the charging cable is used here. A Wi-Fi connection is sufficient to enable this. If the camera is within that Wi-Fi range, it can be spread anywhere in the world. In addition, video recordings and even a photo of the desk users can be taken here.

Screen

The cloud screen allows you to do all the tasks of exchanging data and searching for something. The user interface used here is created by using the QT software. It can also operate the table top and bottom mechanism. All this is controlled by the raspberry pi board. Because of the pandemic situation, every action has to be done within a certain range of distance. Therefore, this screen helps those who are studying in the classroom or at home to maintain a continuous connection.

Wireless charger

This is an extra function we insert into the table. Charging the phone is the main thing that we want when using the table. From this wireless charger table users can charge their mobile phones without moving to anyplace.



Figure2: Linear actuator with a table arm

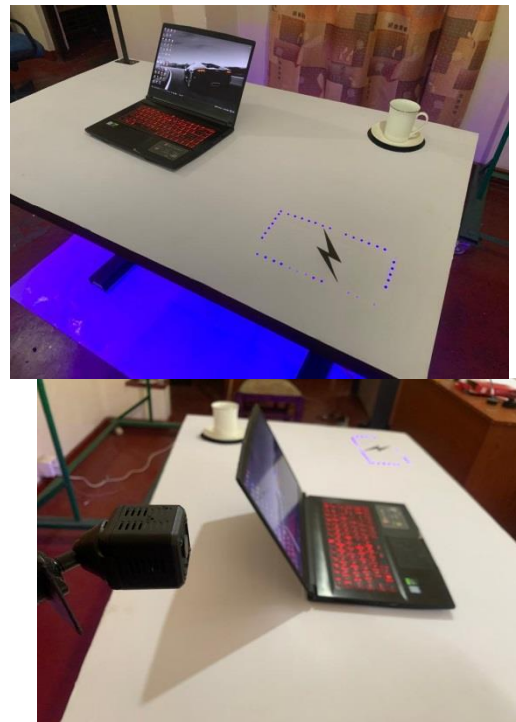


Figure 5: Final view of the table

3. RESULTS AND DISCUSSION

Before manufacturing section 1, it was needed to find a good material. So, the choices depended on different conditions. The first choice was to use metal 'Iron' for the Surface. But the issue was, if the whole part would be made of iron, its weight would be more than 150kg and that might be practically unsuccessful. Next, 'Aluminum' was selected as the manufacturing material as it was less in its weight and had good resistance. Due to the heavy load, it might get buckled in its application. It made us think of another material for the table face and finally, our choice was to use Teak wood to manufacture section 1 (table face). Teak is a fine-grained, durable wood. It stands up extremely well to water and can bear high weight as well as is rich in its look.

Advantages

- Teak wood is harder than other woods like oak, pine, etc.
- It is stable and harder than other varieties of wood.
- Its properties of hardness and durability having no grooves or pockets
- Teak wood is usually cut from quartered logs, so there are fewer chances of these planks being bent due to heat and other diverse conditions.
- It does not fade easily as it absorbs sunlight.
- Teak wood is a highly durable wood.
- Teak wood is dense & compact which makes the wood anti-corrosive.
- Teak wood is solid, light-weight, and resilient material due to which it is made in a number

Disadvantages

- As it is very hard compared to others, it is difficult to cut, give different shapes, and also has a tiring installation process.

4. CONCLUSION(S)/ IMPLICATIONS/ RECOMMENDATIONS & LIMITATIONS

The main purpose of creating the Semi-Automatic ergonomic Smart Table is to make it easier for the students who are studying due to this pandemic situation to study from home apart from the classroom. It has a screen to do study materials with the class teacher, a camera that can monitor where the child is working from, a heater to heat something if needed, and a wireless charge. This is designed to change the height of the table if needed. There are several features that can be added to this. Some of them are adjusting the surface area of the table to make it foldable, and folding the table into smaller sections a desk is something that is always used everywhere. So there are a lot of changes that can be made

For future developments:

- Insert alarm to warn the user to take a break
- Modified table surface with the feature of increasing and decreasing the surface area
- Make it more foldable
- Adjustable foot holder

The project was started to simulate the key parameters related to the tables used by the students to make the initial practices more efficient. This project was mainly focused on students who are carrying out their studies at home due to the pandemic situation. Considering the difficult factors they are facing during the studying through we were done different designs to achieve this task. After going through different designs for the table, the finalized design was selected while retaining manufacturability and project cost. Here we tried to insert all the requirements that students want during their studies. Because when studying teachers have to monitor the student and have to contact each other. This table is the best solution when considering the situation that we are facing nowadays.

REFERENCES

- Maruful Islam, Ramon Das, 2017. A New Approach of Portable Smart Table for Interactive Class Room. Conference Paper March 2017, [online] 6(1), p.11. Available at: <<https://www.researchgate.net/publication/315449145>> [Accessed 2017].
- Cheng, L., Tseng, C. and Lu, C., 2010. Design of Interactive e-Care Dining Table for Smart Kitchen. 2010 International Conference on Computational Aspects of Social Networks,
- Aryal, A., Becerik-Gerber, B., Anselmo, F., Roll, S. and Lucas, G., 2019. Smart Desks to Promote Comfort, Health, and Productivity in Offices: A Vision for Future Workplaces. *Frontiers in Built Environment*, 5.

Smart LP Gas Cylinder Carrier And Safe Regulator

H W C Madhubhashana
Department of Electrical & Electronics
Technology
University of Vocational Technology
Colombo, Sri Lanka
chathuramadu92@gmail.com

H K Wannigama
Department of Electrical & Electronics
Technology
University of Vocational Technology
Colombo, Sri Lanka
hkinstan@gmail.com

M W P I S Thalangama
Department of Electrical & Electronics
Technology
University of Vocational Technology
Colombo, Sri Lanka
prathanaisuri@gmail.com

J K Kanthi
Department of Electrical & Electronics
Technology
University of Vocational Technology
Colombo, Sri Lanka
kanthi.jayaweera@uovt.ac.lk

Abstract—Liquid petroleum gas (LPG) is widely used in households and industries. Gas leakage is a major problem with industrial and residential premises. Another problem is the consumer's unawareness of the daily rate of gas consumption and the remaining gas content in the cylinder. One of the preventive methods to stop accidents associated with the gas leakage is to install a smart gas regulator to identify gas leakage quickly. Our project includes three main parts. The major parts of our project are safety features of the smart gas regulator and weight monitoring system. When a gas leakage is detected, a buzzer is switched on and displays a message on the display unit. At the same time, turn off the main gas supply, turn on exhaust fans and, in a few seconds, the main power supply of the residential area is shut down. Then the owner gets an alert as a message via mobile application. The other component is the staircase climbing gas carriage. Any person who needs to take the filled gas cylinder from ground floor to another floor, it may help to carry the cylinder safely and quickly without any helper. Not only that but also it helps to carry the gas easily in long queues in this crisis situation in the country nowadays. Main purpose of this project is to monitor for gas leakage to avoid fire accidents providing house safety features where security has been an important issue. Not only that but also to design an easily movable carriage for the gas cylinder.

Keywords: Smart Regulator, IoT, Node MCU, Gas Leakage Detector, Data Analytics, Microcontroller

INTRODUCTION

LPG is becoming more popular as a fuel in homes, factories, and automobiles due to its advantages, such as high calorific value, low soot, very little smoke, and low environmental impact. LPG is a non-polluting fuel. Liquefied petroleum gas is used in both home and industrial applications all over the world. It is often used in the home for cooking and heating. In Sri Lanka, LPG is used by the majority of the population instead of other combustibles. It is primarily used in the kitchen for cooking in the home, but it is also utilized in a variety of industrial activities like gas cutting, gas welding, metallurgical industries, steel plants, glass cutting, pharmaceutical industries, and many more. One of the most important items in today's world is a gas

cylinder. The newest global trend is to incorporate technology into our homes and workplaces, creating a more intelligent environment. Everyday activities are becoming increasingly simple. People are increasingly adopting the smart home concept, and the gas cylinder is one of the most significant items in our kitchen. The project's goal is to develop an intelligent gas cylinder. Here, in this project it is expected not only to make the gas cylinder smarter but also to improve its ease of use and safety. And also to smart the regulator, which is the main part that connects to the gas cylinder. The existing regulator can only manually cut off the gas supply and only provides gas under controlled pressure. Some regulators have pressure gauges, which reduce cylinder pressure to delivery or outlet pressure in one step. Many people only check when the gas is finished. Most people are not aware of it.

The smart gas regulator designed in our project computes how much gas is consumed daily and how much is remaining in the tank. Further, it provides an estimation of how many days we can use it, relative to how much gas is left inside the cylinder.

Fig. 1. Initial design

In the case of emergency, it will promptly cut off the gas supply and notify the user via SMS when a gas leakage happens. After being filled with gas, a domestic 12.5 kg gas cylinder typically weighs around 28 kg. It weighs more than the maximum amount that a person can carry safely. For this reason, Our objective is to produce a safe handling carrier with a wheel system (Fig. 1).

II AIM AND OBJECTIVES

The aim of the project is to design a safe and smart system for LPG gas consumers. It will detect the gas leakage, identify daily gas consumption, identify the balance gas content in the cylinder and introduce a safe

staircase climbing carrier for carrying the gas cylinder from ground level to an upper floor.

The specific objectives of the project are:

To design a safe LPG regulator which can detect a gas leakage and activate safety precautions.

To design a weight monitoring mechanism for the cylinder.

To design an easily movable carrier for the gas cylinder.

III PROBLEM IDENTIFICATION

Sri Lankan domestic gas market is currently experiencing a major crisis in terms of supplying LP gas cylinders to meet consumer demand and the set standards. Many incidents of gas leakages and explosions have been reported during the past few months. Another major complaint was that the level of gas leak detection smell (Ethyl Mercaptan) was not adequate to identify the leaking. In addition to that, several explosions of gas cookers were also reported. The damages due to these explosions and related fires were massive. This situation has made Sri Lanka the highest number of gas-related accidents in its history last year.

Possible failures in the quality inspection process of LP gas cylinders, distribution of irregular gas-related equipment by gas distributors and lack of knowledge of consumers on the safe use of LPG are two other identified problems.

Government involvement was a mandatory requirement to protect the consumers as around 400 explosions and gas leak occurrences were reported by the first week of December 2021. A great number of observations of leaking gas cylinder valves have also been reported.

There are four major causes into which the reported accidents and incidents can be categorized:

- (a) Explosions of gas in buildings and residences
- (b) Gas cooker explosions which happened suddenly
- (c) Significant gas leaks and the ensuing damage to the regulator and hoses
- (d) Minor leaks from the cylinder valve, regulator, or hoses.

The number of accidents reported within a single week far exceeded the average number of gas-related incidents recorded for an entire year earlier. There must be a terrible mistake that caused all these damages. Unconfirmed reports now suggest that some of these gas explosion events may have resulted in deaths.

IV SCOPE AND LIMITATIONS

A Scope

In this project, it was planned to provide a solution for household consumer. However, this can be extended easily for some commercial sectors also.

B Limitations

- Weight of the empty gas cylinder is not similar in every tank. This was a common problem for the 2.5kg, 5kg, 12.5kg gas cylinders. According to that reason we have to get the average weight of the cylinder.

V PRODUCT SPECIFICATIONS

- Give smart details to the user to calculate the amount of gas remaining and how many days' user can use it.
- Gas leakage detection system is to detect the malfunctioning of the pressurized gas system in order to prevent the accumulation of the gasses so that the explosion does not happen.
- Auto cut off gas valve, turn ON buzzer and exhaust fan is done at the time of leakage. LPG leakage is detected by the sensor and the information is sent to the user via 'GAS PET' app.
- Its special function is the ability to quickly switch off the main power supply in the situation of an emergency gas leak.

VI METHODOLOGY

The methodology consists of several activities that have been performed in order to ensure that the project can be completed successfully.

- Development of a data flow diagram (Fig. 2)
- Real time system design

In this part, the progress of designing this project will be discussed in detail. Therefore, this chapter deals with the design and construction of the actual system. The system can be categorized into two parts as:

- A. Hardware Development
- B. Software Development

Fig. 2 Flow Diagram of the System

A Hardware Development

Fig. 3 Schematic diagram of the system

B Software development

The computer code is created using the Arduino IDE (Integrated Development Environment), which is then uploaded to the actual board. The open-source Arduino IDE environment makes it simple for users to create code and program the AT Mega 328 IC. The Arduino IDE is relatively easy to use.

We can categorically declare that being compatible with the Arduino IDE is currently one of the primary requirements for a new microcontroller board. The Arduino

IDE has gained a lot of useful capabilities over time, and we can now manage third-party libraries and boards from the IDE while retaining the ease of programming the board.

An Integrated Development Environment (IDE) and the core libraries make up the Arduino IDE software. The Java-based IDE was created using the Processing development environment. Both C and C++ are used to create the core libraries. The Arduino IDE's main window is used to program code for our project.

The Proteus Design Suite is a proprietary software tool suite used primarily for electronic design automation. The program is primarily used by technicians and electronic design engineers to develop schematics and electronic prints for printed circuit board production. It is a collection of software tools for schematic, simulation, and PCB design. We can design schematics and simulate circuits in real-time using the application ISIS. Real-time simulation is made possible by the simulation's provision for human involvement. ARES is used to design PCBs. It offers the option to show the result as a three-dimensional depiction of the created PCB with all of its components. The designer of the product can also produce 2D drawings.

The library of ISIS has a wide range of materials. Sources, measurement and analysis tools like oscilloscopes, voltmeters, and ammeters, signal generators, monitoring, switches, displays, probes for real-time circuit parameters, loads like motors and lamps, discrete components like resistors, inductors, capacitors, and analog and digital components like resistors, capacitors, inductors, and transformers are all included.

As well as surface mount and whole package PCBs, Ares can design PCBs with up to 14 inner layers. It is integrated with different component footprints, including those of ICs, transistors, headers, connectors, and other discrete parts. The PCB Designer has the option of using either automatic or manual routing. From the ISIS diagram, the area schematic can be automatically transferred.

Fig. 4 Electrical systems and circuit Design

Android Studio software is used to create the mobile app Gas Pet. The official integrated development environment (IDE) for creating Android applications is called Android Studio. It integrates the code editing and developer tools from the "IntelliJ IDEA", a Java integrated development environment.

Android Studio utilizes an emulator, a build system based on "Gradle" and code templates to facilitate application development within the Android operating system. One or more modalities with source code and resource files are present in every Android Studio project. Modules for Google App Engine, libraries, and Android apps are some of these modalities. To update running applications with new code and resources, Android Studio employs a feature called Instant Push. A code editor offers code completion, refraction, and analysis in addition to helping the developer write code. The APK file is then created from applications

created in Android Studio and submitted to the Google Play Store.

VII THEORETICAL DESIGN AND CALCULATIONS

In this chapter the calculations of the project are described. The final hardware design of the system and the outcome of the measurements and its analysis are discussed.

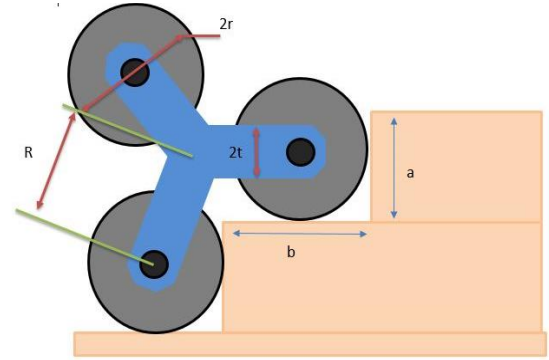


Fig. 5 Design of Tri-Star Frame and Wheels

Rise (a) = 0.15 m

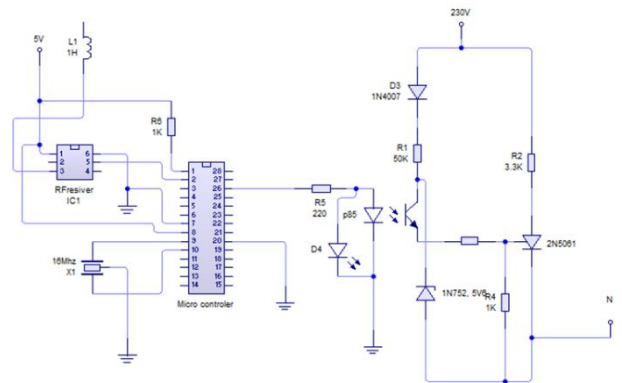
Tread (b) = 0.28 m

Radius of Wheel (r) = 0.1016 m

$$R = \sqrt{\frac{a^2 + b^2}{3}} = 0.1833 \text{ m}$$

The minimum value of the radius of regular wheel (rmin) to prevent the collision of the holders to the stairs is derived as follows,

$$r_{\min} = \frac{6Rt + a(3b - \sqrt{3}a)}{(3 - \sqrt{3})a + (3 + \sqrt{3})b} = 6.67 \text{ cm}$$



$$r_{\max} = \sqrt{\frac{a^2 + b^2}{2}} = 22.46 \text{ cm}$$

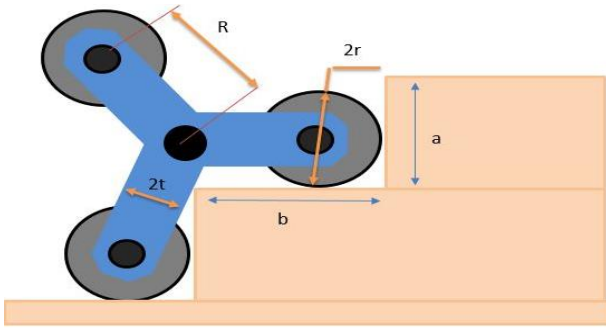


Fig. 6 Design of Tri-Star Frame and Wheels (Min)

The maximum value radius of the radius regular wheels (r max) to prevent the collision of the wheels together.

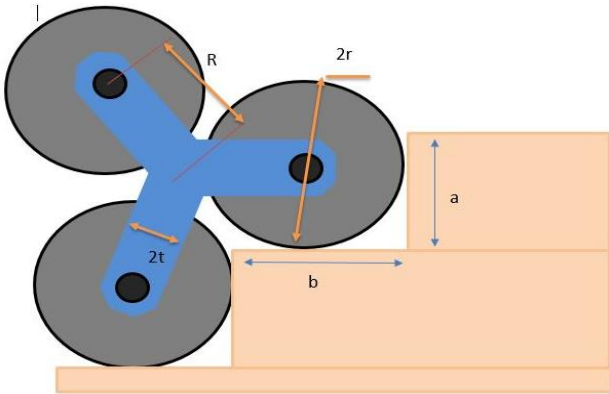


Fig. 7 Design of Tri-Star Frame and Wheels (Max)

Sensing unit

The output of the sensor is measured in volt V0

Rs = sensor resistance

RL = load resistor value in ohms from the MQ5 data sheet

$$\frac{0.653 + 0.657 + 0.671 + 0.666 + 0.669}{5} = 0.6632mv$$

The sensor operation with current of 0.17mA

$$V = IR \text{----- 1}$$

$$R = \frac{0.6632mV}{0.17mA} = 3.9017\Omega$$

From the data sheet Range is 10KΩ to 60KΩ. therefore at minimum valve $R_0 = 3.9017 \Omega * 10K\Omega = 40K\Omega$

Also from the Mq5 data sheet,

$$R_s = (V_c - V_o) \times \frac{RL}{V_0} \text{----- 2}$$

$$R_s = (5 - V_0) \times 20000/V_0$$

$$R_s = (100000 - 20000V_0)/V_0$$

The data sheet provides a graph for LPG concentration in ppm versus R_s/R_0 . The ppm versus R_s/R_0 curve was fitted for the values provided which gives;

$$R_s/R_0 = 18.446 \times (LPG \text{ ppm})^{-0.421}$$

Average voltage of out put

$$\frac{0.653 + 0.657 + 0.671 + 0.666 + 0.669}{5} = 0.6632mv$$

The sensor operation with current of 0.17mA

$$V = IR$$

$$R = \frac{0.6632mV}{0.17mA} = 3.9017\Omega$$

$$R_s = (V_s - V_o) \times \frac{RL}{V_0}$$

The output of the sensor is measured in volt V0

Rs = sensor resistance

RL = load resistor value in ohms from the MQ5 datasheet

From the data sheet Range is 10KΩ to 60KΩ. therefore at minimum valve $R_0 = 3.9017 \Omega * 10K\Omega = 40K\Omega$

Also, from the Mq5 data sheet,

Then,

$$LPG \text{ ppm} = \left[\frac{\frac{R_s}{R_0}}{18.446} \right]^{-\frac{1}{0.421}}$$

$$LPG \text{ ppm} = \left[\frac{\frac{(100000 - 20000 V_0)/V_0}{R_0}}{18.446} \right]^{-\frac{1}{0.421}}$$

$$LPG \text{ ppm} = \left[\frac{\frac{(100000 - 20000 V_0)}{R_0 \times V_0}}{18.446} \right]^{-2.3753}$$

$$LPG \text{ ppm} = \left[\frac{(1)}{\frac{(100000 - 20000 V_0)}{18.446 \times R_0 \times V_0}} \right]^{2.3753}$$

$$\text{Where } R_0 = 40k\Omega \text{ LPG ppm} = \left[\frac{(1)}{\frac{(100000 - 20000 V_0)}{18.446 \times 40000 \times V_0}} \right]^{2.3753}$$

$$+ \text{ error of percentage} = 10.4\%$$

- error of percentage

$$\text{Indicated weight the empty cylinder} = 12.5kg$$

$$\text{Actual maximum weight of the empty cylinder} = 12.2kg$$

$$- \text{ error of percentage} = (12.5 - 12.2)/12.5 * 100\%$$

$$- \text{ error of percentage} = 2.4\%$$

VIII RESULTS AND DISCUSSION

- Testing of gas leakage monitoring system & weight of load cell was carried out successfully with ATMEGA 328.
- The weight was placed on the stand for the load cell and its readings were tabulated (Table 1). The reading given by the load cell is given in kilograms.

Table 1 The summarized results

Test Condition	LED	Buzzer	Solenoid Gas Valve	LCD Display
No gas leakage	OFF	OFF	OFF	Display amount of LPG and pressure.
Low gas leakage Level (below threshold)	OFF	OFF	Not activated	Display gas content low
High Level gas leakage (above threshold)	ON	Sound alarm	Activates	Display danger! Gas leakage detected.

- The gas sensor was tested and the corresponding results were tabulated (Table 2). Data was sent to the cloud. When the gas leakage is detected, the LED glows and the buzzer is turned on simultaneously.

Table 2 LPG Detection time Chart

Distance From Burner	Detection	
	Time (s)	Gas Concentration (ppm)
0.15m	23	1024
0.3m	39	953
0.5m	46	350
0.7m	58	307
0.9m	69	290
1.1m	84	268
1.3m	99	268
2.5m	200	252

- The data is sent to the Google firebase by the gas sensor and load cell with the help of Node-MCU.
- The sensor senses when there is any leakage and sends the message to the customer's mobile app, which also turns on the buzzer simultaneously and cuts off the main gas supply through the solenoid valve.

It makes a minor percentage of errors when the content of gas cylinder weights are varying. But the positive error percentage of the system is 10% and the negative error percentage is 4%. Hence, we considered the error of percentage is negligible in this project.

It may cause errors when the system is used in different climatic conditions. For example, when this system was used in cool climate areas like Nuwara Eliya, Badulla, it indicated low pressure and low temperature. When it was used in the northern part of the country it made high temperatures and gas pressure incensed. So we set a safety point that varies with the temperature for the safety of the consumer. It can cause some errors in the upper safety point of the pressure. However a proper calibration is needed.

When the gas cylinder is placed on the stand, it should be kept at the center correctly. Else it will make load reading errors when reading the remaining gas amount.

IX CONCLUSION

The gas leakage detection system was proposed, designed and tested for home safety and industrial applications. With this proposed system, parameters such as gas leakage and LP gas weight can be monitored and also controlled by the modules, such as when gas leakage is detected, exhausted fans will be on automatically to send gas outside of the space.

The weight monitoring system was proposed and designed in this project to identify the remaining gas content in the cylinder so that consumers can easily get an idea of when to replace it.

The main aim of this project is to detect gas leakages and prevent hazardous situations. This system supports in identifying gas leakage and automatically shutting down the main gas supply and the main power supply. Not only that, but also the system sends an SMS to the consumer via the 'GAS PET' mobile application. A mobile carriage helps to move the gas cylinder easily from the basement level to the upper floors without facing any health and safety issues.

As a conclusion, this gas leakage monitoring system, weight monitoring system, and gas cylinder movable carriage were successfully designed and developed. By testing the system prototype model, it was verified that when a small amount of gas is introduced near the gas sensor, the system detects the leakage and suddenly activates its indicators.

REFERENCES

- [1] Amatul Munazza, Rupa Tejaswi, Tarun Kumar Reddy and Saranga Mohan, 2020. "IoT based gas leakage monitoring system using FPGA". Journal of xi'an university of architecture & technology, 9(1006-7930), p. 10.
- [2] Beliraya A., october 2017, "GSM based gas leakage detection system using arduino", International journal of engineering technology science and research, 4(2394 – 3386), p. 3.

- [3] Dr Tukkoji, Sanjeev Chetana and A N Kumar, April 2020, “LPG gas leakage detection using IoT”, “International journal of engineering applied sciences and technology”, 4(2455-2143), p. 7.
- [4] Falohun A Salice Oke, 2016, “Dangerous gas detection using an integrated circuit and mq-9”. International journal of computer applications, 135((0975 – 8887), p. 6.
- [5] Hasibuan M S, 2019, “Intelligent LPG leak detection tool with SMS notification”, Industrial engineering, politeknik lp3i medan, indonesia, p. 9.
- [6] I. Juvanna and Meenakshi , 2014 Feb, “Gas level detection and leakage”, International journal of computer science and mobile computing, 3(2320-088x), p. 5.
- [7] Kalpana Murugam, 2020, “Intelligent gas booking and leakage system”, 3c tecnología. Glosas de innovación aplicadas a la pyme., issue 2254-4143, p. 13.
- [8] Khan M., 14 November 2020, “Sensor-based gas leakage detector system”, Engineering proceedings, p. 6.
- [9] Lokesh Chandak, Aditya Kolhe1, Sathak Shirke and Prof. Suresh Kurumbanshi, 2020, “IoT based LPG cylinder monitoring system”, International journal of innovative research in electronics and communications, 7(2349-4050), p. 7.
- [10] M Anusha and V Nagesh, 2020, “IoT based LPG leakage detection and booking”, International journal for modern trends in science and technology, 6(2455-3778), p. 5.
- [11] Arijit Banik, Bodhayan Aich and Suman Ghosh, 2018. “Microcontroller based low cost gas leakage”, Emerging trends in electronic devices and computational techniques (edct), p. 3.
- [12] Nasir, S. Z., 2017. *theengineeringprojects.com*. [Online] Available at: <https://www.theengineeringprojects.com/2017/08/introduction-to-atmega328.html> (accessed September 8, 2021)
- [13] P. Kanaka Maha Lakshmi, P. S. G. Aruna Sri and P. Gopi Krishna, April 2019, “An IoT based LPG leakage sensing, International journal of innovative technology and exploring engineering (ijitee), 8(2278-3075), p. 7.
- [14] R Naresh Naik, P Siva Nagendra Reddy, S Nanda Kishore and K Tharun kumar Reddy, Jul.-Aug 2016, Arduino based ILPG monitoring & automatic cylinder booking with alert system. Iosr journal of electronics and communication engineering (iosr-jece), 11(2278-8735), p. 7.
- [14] Shashi Kumar, Pranita Padole, Shweta Salve, Aditya Sachdev and Prof. M.p. wankhade5, 2018 apr. Smart LPG monitoring & automatic gas booking system. International research journal of engineering and technology (irjet), 5(2395-0072), p. 4.
- [15] Sushil Kumar Paridda, Aankit Pratik Kumar Pani, 2016 “Innovative design and simulation of gas level”. International journal of industrial electronics and electrical engineering, 4(2347-6982), p. 3.
- [16] Skogestad S, Postlethwaite, i., 2001, “Multivariable feedback control”, S.I.:john wiley & sons.
- [17] Unnikrishnan, M. Et al., March 2017, “LPG monitoring and leakage detection system”. International conference on wireless

Emerging Trends in ICT and Media Technology for Resilient Industries

Ensuring Resilient Software-Defined Networking Infrastructure Against Advanced Persistent Threats

W.U.Chamodya
Department of Network Technology
University of Vocational Technology
Ratmalana, Sri Lanka
net20b126@uovt.ac.lk

Abstract—This research delves into the intersection of Software-Defined Networking (SDN) and the challenge posed by Advanced Persistent Threats (APTs). We navigate the realm of APT detection and mitigation within SDN environments, which present unique vulnerabilities. By unraveling the foundational principles of SDN, we establish a comprehensive understanding of its evolution, architectural components, and applications. Concurrently, we dissect the intricacies of APTs, revealing their stealthy nature and Command and Control (C & C) mechanisms. The fusion of SDN and APTs highlights the imperative for robust defenses. We scrutinize the vulnerability landscape born from SDN's programmability, addressing the exploitation of flow entries, control plane compromise, and an array of attack vectors. Despite the scarcity of SDN-specific APT models, we analyze broader APT detection and SDN defense models. This paper propels the discourse forward, identifying potential research avenues and advocating for interdisciplinary collaboration to ensure the resilience of SDN infrastructure against relentless APT attacks.

Keywords— Software Defined Network, Advanced Persistent Threats, Network Infrastructure Resilient

I INTRODUCTION

This research explores the intricate relationship between SDN (Software-Defined Networking) and APTs (Advanced Persistent Threats). It begins by laying the groundwork for SDN, tracing its evolution, and highlighting its potential across various industries.

Simultaneously, it acknowledges the growing threat of APTs in cybersecurity, detailing their sophisticated methods and emphasizing the importance of understanding these threats for effective defense strategies.

The study then investigates the vulnerabilities that arise from the convergence of SDN and APTs, focusing on potential attack vectors such as flow entry exploitation, control plane manipulation, and various other tactics.

Despite the lack of specific APT security models for SDN, the research draws insights from broader APT detection and defense models. It critically reviews existing studies, highlighting their strengths and limitations.

The conclusion advocates for the development of tailored SDN-specific APT models, stressing the need for collaborative efforts between SDN and cybersecurity experts. The ultimate goal is to fortify SDN infrastructures against APT attacks for resilient networks.

The following sections are covered: Section II delves into SDN, Section III examines APTs, Section IV scrutinizes APTs' influence on SDN, Section V encompasses a review of past researches, while Section VI outlines future pathways and engenders discussion.

II SOFTWARE DEFINED NETWORK

o What is a SDN

A software-defined network (SDN), as the name suggests, refers to a network that is defined by software in a programmable way. In traditional network architecture, three primary planes define network operations: the Control Plane, Data Plane (Forwarding Plane), and Management Plane. These three primary planes are tightly combined in Traditional Network Architecture, which can lead to issues related to network management, flexibility, and scalability. To overcome the challenges faced in traditional networks, the SDN concept has been introduced. In the SDN architecture, the data plane and control plane of the traditional architecture have been decoupled to enhance the flexibility, manageability, scalability, and security of the network.

o SDN Principals and Architectural Components

SDN provides a high-level overview of its principles and architecture, which are subsequently summarized briefly and then elaborated in greater detail:

o Decoupling of the control plane and data plane

The fundamental principle of SDN is to decouple the control plane from the data plane while centrally managing and configuring network device policies. In traditional architectures, network operations had to be performed individually on each separate device by network administrators [5].

o Network Programmability

SDN introduces a novel network architecture that allows computer networks to configure network behavior and resources by abstracting the underlying infrastructure [2]. This capability empowers network operators and software developers to design, implement, and deploy a wide range of network applications, services, and even complex

protocols, both from traditional and legacy networks [2], [6], [7].

○ *Logically Centralized Control*

SDN enables logically centralized control and management through a controller, which is the core element of the SDN architecture. The controller acts as a bridge between SDN applications and the Datapath. Logically centralized control enhances network management, facilitates policy implementation, and supports other network operations more effectively than traditional legacy network architectures [5], [8].

○ *Abstraction*

The abstraction of SDN enables applications to operate and communicate with the network without necessitating an in-depth understanding of the underlying hardware, protocols, or topology [9]. It involves simplifying and generalizing network information and functions, which are then presented to SDN applications by the SDN controller. This abstraction allows for the separation of the control plane from the data plane, facilitating dynamic network configuration to meet specific requirements [9], [10].

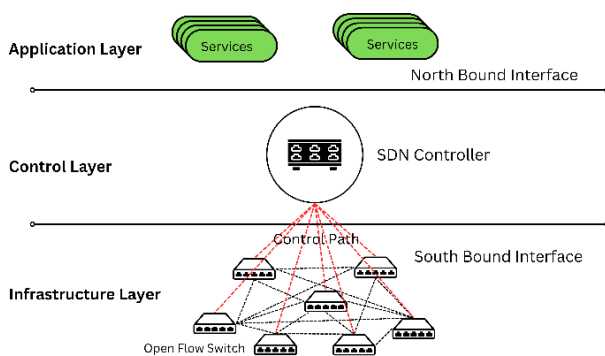


Fig.1. SDN Architecture

As depicted in Fig. 1, the Software Defined Network Architecture is structured into three distinct layers: the Application Layer, the Control Layer, and the Infrastructure Layer. These layers are interconnected through both the Southbound Interface (SBI) and the Northbound Interface (NBI), enabling seamless communication among them. Here's a concise overview of these planes and interfaces:

○ *Application Layer:*

This layer comprises SDN applications that are utilized to request or configure the underlying SDN infrastructure. It is the plane where applications and services define network behavior. The management capabilities of this application layer have obviated the need for dedicated firewalls as appliances or load balancers [11], [12].

○ *Control Layer:*

The Control Layer represents the SDN controller, which consists of SDN software and functions as the network's brain. The controller communicates with the application layer and the infrastructure layer through standard protocols to control forwarding devices [13]. It acts as a bridge between the application and infrastructure layers. Administrators use the SDN controller to manage the entire network, including policies, and to monitor traffic flow [12].

○ *Infrastructure Layer:*

The Infrastructure Layer constitutes the underlying network of forwarding devices, including switches and routers. This layer manages the flow of traffic between hosts and destinations, guided by policies and rules defined in the application layer and overseen by the SDN controller in the control layer [12],[13]. Additionally, the layer processes data within the network, interconnecting all networking devices, and supports standard protocols for seamless communication between devices [14].

○ *Northbound and Southbound Interface:*

These two interfaces are making the connectivity between the different layers of the SDN architecture.

The Northbound interface serves as the connection between the Application and the Controller. It is not standardized and utilizes different languages or APIs for communication, such as Java, Python, and REST. These languages and APIs are commonly used, allowing applications to interact with the SDN [15],[16].

The Southbound Interface serves as the connection between the controller and the physical networking hardware. The southbound interface is standardized with the OpenFlow protocol, which enables the establishment of connections between controllers, switches, and other network components. Additionally, in 'closed SDN' solutions, SNMP and CLI can be implemented [15], [16].

III ADVANCED PERSISTENT THREATS

○ *What is a APTs ?*

Advanced Persistent Threat (APT) refers to a type of cybersecurity threat that is posed by highly advanced adversaries, such as state sponsored or sophisticated terrorist groups. These adversaries possess significant expertise and resources and aim to establish a lasting presence within targeted organizations. Unlike traditional attackers with limited capabilities, APTs seek to impede various aspects of organizational missions by exploiting vulnerabilities in information systems [17].

The objective of the assailant commonly revolves around infiltrating the intended system, extracting relevant information about the target using compromised systems. After breaching the target's system, they maintain a low profile to accumulate the desired data before transmitting it to the entity funding the attack. Advanced Persistent Threat (APT) incidents typically encompass multiple compromised nodes, in contrast to conventional attacks which usually involve only one [18].

Unlike traditional cyber-attacks, APT attacks are highly challenging to detect due to the attackers' utilization of sophisticated and stealthy techniques. They employ a range of tactics, including social engineering, exploiting vulnerabilities, encrypting traffic, concealing malware, deleting logs, and continually changing their tactics. These strategies enable APTs to infiltrate and maintain a covert presence within the network [18],[19].

○ *The Anatomy of APTs*

APT attacks are well-planned and highly organized, aiming to maximize the probability of successful infiltration. In [18], A. Alshamrani et al. explain that there are different phases or steps that an attacker goes through to execute an APT attack. However, it's important to note that

not every attack necessarily follows these exact steps or phases.

Reconnaissance - The initial step APT attackers take involves acquiring knowledge about the target. The more they uncover about the target, the greater their chances of achieving success.

In the context of SDN, APTs can use stealth scans to gather information that underpins further attacks [23], such as the port scan to obtain information about the key nodes of the target network, discovering the running applications in the victim network (e.g., defense tools or network balancing) and DDoS attacks. Their adoption of some APT characteristics makes stealth scans hard to detect. With the help of an insider, the attackers can bypass the front-line defenses and access the targeted network [20], [23].

Establishing a Foothold - At this phase, they have effectively gained entry into the target's computer system and/or network.

In the context of APT attacks within an SDN environment, establishing a foothold involves exploiting SDN vulnerabilities to infiltrate the network. This includes exploiting flow entries and occupying flow tables over an extended period. Such activities create an opportunity for subsequent attacks. This process entails sending attack packets containing authentic IP addresses to activate dormant flow entries. These entries can then be utilized for communication in subsequent attacks [20], [21].

Progressing Laterally - Once inside the system, their objective is to identify nodes containing sensitive data or serving as critical components of the organization's infrastructure. This requires advancing further into the network.

In this stage, attackers extend their access within the network components of the SDN environment, including the SDN controller, switches, and other applications. They achieve this by leveraging compromised credentials or exploiting vulnerabilities present in the initially affected node [24].

This lateral movement strategy empowers attackers to:

- Evade and postpone detection and removal efforts by security systems or administrators, effectively concealing their activities by shifting between different nodes.
- Attain or escalate their privileges and authorizations on network components, thereby gaining access to more sensitive data or critical functions within the network.
- Fulfill their malicious objectives or goals on the network, which could involve data theft, service disruption, or even infrastructure destruction [25], [26].

Data Extraction - When attackers' objective is to obtain the organization's data, the process of retrieving and transmitting this data to the attackers' command and control center falls within this stage.

Exfiltration empowers APT attackers to transfer and pilfer the data or information they have gathered or accessed from various network components, such as the SDN controller, switches, or applications. They employ diverse tools and

methods to circumvent network security systems or administrator oversight [27].

This process grants attackers the ability to:

- Exploit or utilize the acquired data or information for their own gain, including activities like selling, blackmailing, or reserving it for future attacks.
- Inflict damage on the reputation or credibility of the network owner or operator by exposing secrets, vulnerabilities, or weaknesses.
- Disrupt or even dismantle the network's functionality or performance by actions such as deletion, encryption, or alteration of data or information.

Concealment - An APT attack can be deemed successful and comprehensive only when the identities of the attackers and the entity supporting the attack remain hidden and untraceable. This requires the attackers to eliminate any traces that could be linked back to them.

- *Command and Control (C & C) Communication*

The Command and Control (C&C) phase plays a pivotal role in APT attacks. In this phase, attackers exercise control over, or issue commands to, compromised systems within the target environment. At least one system within the target environment must establish communication with an external server on the Internet, depending on the chosen C&C protocol. Furthermore, the exfiltration of sensitive data from the target environment, which is often the primary objective of APT campaigns, is an integral part of the C&C phase [28].

Examining command and control communication in APT attacks within the SDN environment entails understanding how attackers utilize command and control (C2) techniques to communicate with compromised systems in a network, as well as comprehending how SDN can either be susceptible or resilient to such attacks [28], [29], [30].

As referenced in [30], C2 constitutes the sixth phase of the cyber kill chain, wherein the attacker has successfully implanted their management and communication APT code into the target network. C2 can be carried out using various protocols, including DNS, HTTP, or TCP.

IV APTs AND THEIR IMPACT ON SDN

The title APT is one of the main security threats to SDN [20]. This section delves into the specific vulnerabilities that APTs exploit within SDN environments, showcasing the intricate ways in which these stealthy threats can manipulate the programmability of SDN to achieve their objectives.

- *Programmability and Vulnerability in SDN*

SDN is a new network framework that can be controlled and defined by software programming. The programmability of SDN allows network administrators to manage the network more efficiently and flexibly. However, this programmability also introduces new vulnerabilities to the network. With centralized control of SDN, the network is more vulnerable to encounter APTs than traditional networks. Attackers can exploit the centralized control of the network to launch attacks on the controller or data plane. They can modify the actions of the

flow table, change the forwarding path, and focus on sensitive hosts to transfer important asset data out through tampering flow.

In addition to APTs, other security threats and issues such as malicious traffic attacks and Distributed Denial of Service (DDoS) are also of great concern in SDN. Therefore, it is important to develop effective security mechanisms to protect SDN from these vulnerabilities.

○ Exploiting Flow Entries

In SDN, flow entries are used to manage network traffic [21]. A flow entry is a set of rules that define how packets should be processed by the SDN switches. It includes information such as the packet's source and destination addresses, the actions to be taken on the packet, and the priority of the rule. Exploiting flow entries refers to the long-term occupation of flow tables, which can be used as a prerequisite for APT attacks [20], [21].

○ Compromising the control plane

The centralized control of SDN renders the network more susceptible to APTs compared to traditional networks [20]. If the control plane is compromised, an attacker can potentially commandeer the entire network by impersonating the SDN controller. Unlike a targeted attack on a router, in SDN, the infrastructure layer relies solely on the control plane, making its reliability contingent upon the security of the controller. This vulnerability is even more severe [20], [22].

Moreover, apart from APTs, unauthorized access to the controller can result in security breaches and various attacks, including but not limited to controller hijacking, Denial-of-Service (DoS) and Distributed Denial-of-Service (DDoS) attacks, as well as the introduction of fake traffic or flow rules [22].

○ More Attack vectors on SDN environment

There are numerous potential attack vectors within an SDN environment, especially with regard to APT attacks. Figure 2 illustrates the SDN architecture along with its potential attack vectors, highlighted in red.

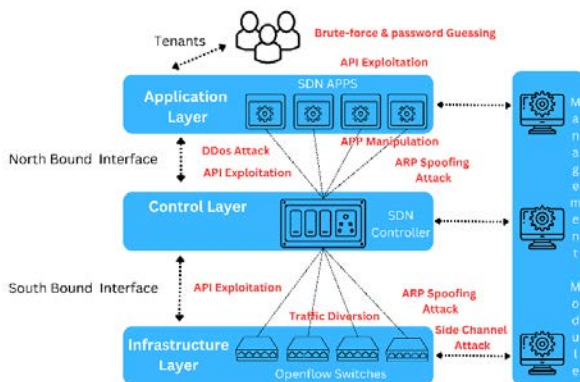


Fig. 2. SDN Attack Vectors

○ ARP Spoofing Attack

ARP spoofing is a type of attack that enables an attacker to impersonate another computer on the network by sending fake ARP packets. This can lead to other attacks, such as Man-in-the-Middle (MitM) attacks, where the attacker can

intercept or modify the traffic between two legitimate hosts [31],[32].

○ Side Channel Attack

A side-channel attack is an exploitation method that leverages the physical characteristics of a computer system, such as timing, power consumption, sound, or electromagnetic radiation, to deduce the confidential information being processed by the system [33].

In the realm of SDN, a timing side-channel attack can be executed by an attacker who measures the delay between transmitting a packet to the controller and receiving a response. This delay can unveil the controller's workload or the network topology, potentially leading to other attacks or inducing network congestion [34].

○ API Exploitation

API exploitation refers to an attack that specifically targets the application programming interfaces (APIs) used for communication between the controller and network devices or applications in SDN [35, 36]. In this type of attack, an attacker manipulates, abuses, or compromises the APIs to gain unauthorized access or control over network resources and functions. This unauthorized access can result in various security issues such as data leakage, denial of service, or network misconfiguration [30], [35].

○ DDoS Attack

A Distributed Denial of Service (DDoS) attack involves inundating a target with substantial volumes of malicious traffic, aiming to disrupt its regular operations or degrade its performance. In the realm of SDN, a DDoS attack can have repercussions across the data plane, control plane, or control plane bandwidth. This impact is achieved by overwhelming the resources or overloading the communication channels of the network devices or the controller [37], [38], [39].

○ Traffic Diversion Attack

A traffic diversion attack aims to redirect the network traffic from its intended destination to a malicious host or a black hole. An attacker can perform a traffic diversion attack by capturing or modifying the control plane traffic between the SDN controller and the network devices, or by injecting fake or malicious forwarding rules. A traffic diversion attack can cause data leakage, denial of service, or network misconfiguration [40].

○ APP Manipulation

An application layer manipulation attack focuses on the application layer of SDN, which is responsible for automating interactions with network devices through the SDN controller using APIs [10], [40]. In this type of attack, an assailant exploits vulnerabilities within an application to achieve unauthorized access or control over network resources and functions. Additionally, they can cause malfunctions, interruptions, or eavesdropping. Moreover, the application layer can serve as a launching pad for other attacks on the SDN network [30].

○ Brute-force and Password Guessing

Brute-force and password guessing attacks involve attempting various passwords to gain access to a system or account without prior knowledge of the legitimate credentials [51], [52]. Such attacks can occur on non-SDN elements. Through password guessing or brute-force

methods, unauthorized users might potentially gain access to the SDN [50].

V RESEARCH REVIEW: APT DETECTION AND MITIGATION MODELS AND TECHNIQUES IN SDN

○ *SDN Based Models*

There aren't many research articles on APT detection for SDN [20]. While there are some studies on threat mitigation models and detection systems against APT, as well as overall threat mitigation techniques for the SDN environment, there is a lack of focus specifically on APT detection within the SDN environment. In this section, we emphasize researches on APT detection in SDN and also cover some general models for APT detection and SDN security. We provide a comprehensive summary of these studies and compare the different models.

○ *A two-phase detection method against APT attack on flow table management in SDN by Xinfeng He and Shuchao Sun [21]*

A two-phase detection method for APT attacks on flow table management in SDN is proposed to reduce the computation overhead on the controller and improve detection efficiency and accuracy compared to current networks. This model proposes the principle that the latent flow entry corresponding to the APT attack flow occupies the flow table and suggests a method for preliminarily filtering out suspicious flow entries. Finally, the B-P neural network method is employed to further detect suspicious flow entries based on the selected five-dimensional features. The two-phase detection method effectively identifies APT attacks on flow table management while avoiding excessive consumption of controller resources.

○ *The model is divided into two main phases:*

Pre-detection Phase: This initial phase plays a crucial role in reducing the computational load on the controller. It accomplishes this by proactively identifying suspicious flow entries within the SDN switch. This identification process takes into consideration the frequency of packet occurrences.

Detection Phase: In this subsequent phase, the focus shifts to the detection of potential threats. To achieve this, a set of five-dimensional features is carefully chosen based on the attributes of packets' behavior in terms of both their volume and frequency. These features, designated as ABP, FEID, APS, ATEM, and duration, stem from the TMAF method for identifying APT attacks within the flow table management framework of SDN.

These five features are meticulously chosen to align with the distinct attributes of attack packets. ABP, for instance, pertains to the average count of packets that find a match per second. This particular metric gives us insight into the loading characteristics of packets. On the other hand, FEID, which represents the unique flow entry identifier, assists in differentiating regular flow entries from hidden ones.

Another vital feature, APS, captures the average size of packets, serving as an important criterion for distinguishing between normal and malicious packets. ATEM, denoting the average time between matched packets, serves as an indicator of the packet arrival frequency. Lastly, the

duration attribute captures the lifespan of flow entries, which proves invaluable in discerning between typical flow entries and those that are potentially latent or hidden.

Afterward, the analysis continues through the utilization of a Back-Propagation (B-P) neural network on the controller. The B-P neural network, known as a feedforward architecture, comprises nodes within its input and output layers, along with one or more hidden layers. What sets this network apart is its remarkable capability for nonlinear mapping. Particularly when dealing with substantial datasets, the B-P neural network showcases a more pronounced classification effect in comparison to algorithms such as support vector machines.

Notably, the model parameters of this neural network are trained and then stored. This serves the crucial purpose of detecting latent flow entries that might otherwise go unnoticed.

The significance of this model lies in its capacity to alleviate the controller's workload while simultaneously enhancing the efficiency and accuracy of detection, setting it apart from existing networks.

The authors have meticulously assessed this model through a series of experiments, yielding outcomes that underscore the advantages of the TMAF approach. These results demonstrate a reduction in the controller's computational burden, coupled with heightened efficiency and precision in detecting potential threats. To substantiate this, the CPU utilization of the controller is scrutinized across both attack scenarios and regular network conditions. This analysis involves a comparison of CPU resource consumption during the flow entry extraction process using TMAF, alongside Bayesian network [41] and the factorization machine-based technique [42].

Moreover, the evaluation encompasses crucial metrics like detection accuracy, precision, and recall. This evaluation framework showcases that the proposed method outperforms its counterparts in identifying APT attacks.

It's important to acknowledge that the evaluation of the proposed method takes place within the context of a single controller. Future research endeavors are expected to explore the applicability of the method in scenarios involving multiple controllers. Additionally, the recalibration of the pre-detection threshold is recognized as an essential step to adapt the approach for diverse network environments beyond SDN.

○ *The APT Detection Method in SDN by Jia Shan-Shan, Xu Ya-Bin [20]*

In their research, Jia Shan-Shan and Xu Ya-Bin introduce an APT detection approach leveraging the Hidden Markov Model (HMM). The aim is to effectively address the multi-stage nature of APT within the context of SDN. The authors propose an APT detection method grounded in HMM, which not only achieves accurate APT identification in SDN but also minimizes resource overhead.

By employing the HMM framework, the researchers succeed in pinpointing distinct stages of APT progression. This entails establishing an APT detection model centered on the HMM concept. Crucially, the sequential steps of an APT are encapsulated as internal states within the HMM structure. Each individual step is then associated with an observable linked to its corresponding action.

Consequently, the APT detection model built upon HMM captures the intricate interplay between attack behaviors and the evolving stages of APT. This model demonstrates a robust capability to accurately identify APT instances while imposing minimal memory overhead.

However, the study acknowledges certain limitations stemming from the experimental environment and detection parameters. The proposed approach operates on the assumption that an attacker's behavior adheres to the predefined APT model, which might not always hold true. It's important to note that the method may prove less effective against APTs employing novel attack methods or exhibiting distinct patterns. Consequently, the authors recommend exploring alternative attack behaviors and devising identification techniques to effectively counter the multifaceted and diverse array of APT strategies.

- *The APT Detection Method based on Attack Tree for SDN by Shan-Shan Jia, X Ya-Bin*

In this paper, authored by Shan-Shan Jia and X Ya-Bin, an enhanced version of APT detection is presented, building upon their previous work. The authors introduce a novel methodology aimed at effectively identifying APTs within SDN contexts, employing the concept of attack trees. This approach involves a comprehensive exploration of the APT attack process specific to SDN, culminating in the creation of an APT attack model grounded in the principles of attack trees. By correlating the discerned attack behaviors via multiple detection techniques, the trajectory of the attack is deduced.

The core objective of this research is to introduce an APT detection approach finely tuned for SDN environments, harnessing the power of attack trees to precisely identify potential APT occurrences within the SDN domain. The paper endeavors to establish an APT attack model based on the structural framework of attack trees. Subsequently, a meticulous analysis of interconnected attack behaviors originating from diverse detection methodologies is conducted, facilitating the identification of the attack pathway. This identified pathway is then aligned with the APT attack model, enabling the assessment of APT presence within the SDN landscape. Furthermore, an additional aim of this study is to showcase the heightened accuracy of the proposed method in APT detection within SDN, complemented by a reduction in operational overhead.

The Authors introduce an innovative APT attack model centered on the attack tree paradigm, adeptly describing the protracted and multifaceted nature of APTs within SDN. Constructing the attack tree is a result of scrutinizing the intricate APT process within SDN. This model encompasses distinct stages of an attack, encompassing reconnaissance, infiltration, and exfiltration. The attack tree serves as a visual representation of these stages and their interrelationships. The paper additionally employs the Baum-Welch algorithm within the Hidden Markov Model (HMM) to train historical APT data, extracting transition probabilities to gauge Attack Type correlations. The correlation degree and corresponding weight of various attributes (k attributes) contribute to the computation of the attack path. The ultimate alignment of the determined attack path with the established APT attack model is pivotal in adjudicating the existence of an APT within SDN.

Presenting an original APT detection method grounded in the attack tree concept for SDN, this paper asserts that its approach surpasses existing methodologies in terms of precision and operational efficiency. It is important to note that the paper acknowledges certain limitations in detecting attack behaviors arising from experimental conditions and detection settings. To address these limitations, the paper advocates for an exploration of alternative attack behaviors and the development of identification strategies to effectively tackle the intricate and diverse nature of APTs. This implies that forthcoming research could focus on refining the proposed method by accounting for diverse attack behaviors and devising more potent identification techniques. Moreover, the effectiveness and efficiency of the proposed method could be subjected to further evaluation across varied experimental environments and detection scenarios, thereby validating its real-world applicability.

- *Detecting Stealthy Scans in SDN using a Hybrid Intrusion Detection System by Abdullah Alqahtani, John Clark [23]*

The paper introduces a novel approach - a hybrid Network Intrusion Detection System (NIDS) - designed to spot covert scans aimed at SDN networks with the intention of reconstructing flow rules. This innovative model seamlessly combines two primary machine learning techniques: signature-based and anomaly-based detection. This dual approach effectively minimizes error rates.

The central goal of this research is to present a versatile Network Intrusion Detection System (NIDS) that can effectively identify hidden scans that target SDN networks, aiding in the reassembly of flow rules. By capitalizing on two fundamental Machine Learning (ML) detection methods - namely, signature-based and anomaly-based detection - this model successfully curtails error rates. The ultimate aim is to provide a pragmatic and potent solution for detecting internal breaches and Advanced Persistent Threats (APTs).

The proposed model outlined in this study constitutes a hybrid Network Intrusion Detection System (NIDS) that proficiently harnesses two primary Machine Learning (ML) detection methodologies. These methodologies serve the purpose of exposing surreptitious scans that target SDN networks and contribute to the restoration of flow rules. The two pivotal techniques employed encompass signature-based detection and anomaly-based detection.

In the realm of signature-based detection, the model employs XGBoost, a supervised learning algorithm, to differentiate between ordinary and malicious network traffic, relying on pre-established signatures. On the other hand, the anomaly-based detection employs the One-Class Support Vector Machine (OC-SVM), an unsupervised learning algorithm, to map out normal network behavior, subsequently spotting deviations from the established norm.

This innovative model's efficacy is gauged through the assessment of a comprehensive dataset, encompassing both benign and malicious activities. The evaluation results portray the proposed model as a high-performing solution, yielding remarkable accuracy, recall, precision, and F1-score. This collective performance underscores the model's proficiency in spotting hidden scans that aim at SDN networks, facilitating the reconstruction of flow rules.

However, the proposed model is not exempt from potential limitations. The evaluation process is carried out on a limited dataset, raising concerns about its adaptability to alternate datasets and real-world scenarios. Moreover, the computational resources required for processing extensive network traffic might pose challenges for certain organizations. The model's susceptibility to generating false positives or negatives is also a point of consideration, as this could lead to unnecessary alerts or missed detections. It's important to note that the model's effectiveness might be compromised in instances of zero-day attacks, which involve hitherto unknown threats devoid of established signatures or patterns.

Additionally, the authors recommend avenues for future work in this domain. This includes the development of history-based features, evaluated either over the network's complete operational lifespan or within a recent timeframe. Furthermore, exploring alternative Machine Learning (ML) techniques, like deep learning, holds promise for enhancing detection accuracy and mitigating false positives and negatives. Evaluating the model using diverse datasets and real-world scenarios to gauge its effectiveness and versatility remains crucial. Furthermore, investigating other attack types, such as denial-of-service attacks, and devising new detection methods for their identification are pertinent. Similarly, delving into other network architectures, such as cloud-based networks, and innovating fresh detection approaches for thwarting attacks targeting these systems, are avenues worthy of exploration. In conclusion, the paper introduces various future directions that can not only refine the proposed model but also extend its utility to various scenarios and network frameworks.

- *The SDN-microSENSE architecture proposed by Grammatikis et al. presents a novel approach to SDN-based resilient smart grids.*

The authors of this paper have proposed the SDN-microSENSE architecture, aiming to enhance the resilience of the Smart Grid by leveraging SDN technology. In the introduction of the paper, they discuss the evolution of the Industrial Internet of Things (IIoT) and its impact on conventional Electrical Power and Energy Systems (EPES), leading to the emergence of the Smart Grid (SG). The Smart Grid offers benefits such as customer choices, pervasive control, self-monitoring, and self-healing. However, it also introduces privacy and cybersecurity risks that can have devastating consequences, particularly from cyber threats like Advanced Persistent Threat (APT) attacks. As previously mentioned, this paper discusses several cyber threats, such as APT attacks, that have affected SDN-based Smart Grid solutions and the energy sector worldwide. The authors have highlighted that the energy sector, including EPES, has been targeted by APTs, resulting in severe consequences like blackouts and disruptions in Ukraine and other incidents.

The SDN-microSENSE architecture presents a novel approach aimed at enhancing the resilience of the Smart Grid (SG) through the utilization of SDN technology. The paper's objective is to address challenges by introducing the SDN-microSENSE architecture, which employs SDN technology to bolster the resilience of Electrical Power and Energy Systems (EPES) and the SG across three primary

tiers: risk assessment, intrusion detection and correlation, and self-healing.

The risk assessment tier is responsible for evaluating potential risks and vulnerabilities within the SG system. The intrusion detection and correlation tier employ advanced mechanisms for detecting and correlating security events and alerts, thereby providing early warnings of potential cyber threats. The self-healing tier focuses on implementing mitigation and energy management actions to ensure the seamless operation of the SG system.

The SDN-microSENSE architecture tackles cybersecurity and privacy concerns associated with the SG, particularly those tied to legacy Industrial Control Systems (ICS) and Supervisory Control and Data Acquisition (SCADA) systems. The authors also introduce honeypots that simulate communication protocols used in the SG, such as IEC-61850, IEC-60870-5-104, and ModbusTCP, in order to gather information about potential cyber attackers. This architecture builds upon existing research and solutions in the field of SG security, including threat modeling, intrusion detection, and the use of SDN technology.

While this paper primarily focuses on enhancing resilience against cyber threats in the energy sector using SDN, the authors do not discuss potential drawbacks of their architecture. Instead, they highlight challenges in implementing SDN architecture. Although SDN offers advantages in terms of security and network management, it also introduces certain challenges that require careful management for successful adoption and implementation.

The authors delve into SDN Implementation Considerations due to the various challenges and factors involved in implementing SDN-microSENSE:

Technology Requirements: SDN technologies like OpenFlow may necessitate the upgrade or replacement of intermediary network equipment.

Compatibility and Integration: Challenges can emerge from vendor-specific implementations that deviate from standards, potentially leading to compatibility and integration issues within the network.

Specialized Knowledge: The paper mentions that IT personnel need specialized knowledge in SDN to troubleshoot network issues arising from SDN control.

Unforeseen Complications: While SDN offers benefits in network management, it might introduce unforeseen technical and managerial complications, potentially resulting in increased financial costs during adoption.

- *Honeypot Detection Strategy against Advanced Persistent Threats in Industrial Internet of Things: A Prospect Theoretic Game by Wen Tian, Miao Du, Xiaopeng Ji, Guangjie Liu, Yuewei Dai, and Zhu Han*

This paper introduces a novel approach for bolstering the security of industrial Internet of Things (IIoT) devices against APT attacks. Instead of a dense technical jargon, we propose a fresh strategy that hinges on a dynamic bounded rational honeypot-APT game model within the realm of IIoT. This approach not only outperforms existing defenses, but it also brings clarity to the management of IIoT device security.

At its core, this strategy is deeply intertwined with the concept of SDN. The proposed model leverages SDN to oversee honeypots, gather data, and discern APT attacks in a more effective manner. We also delve into the vulnerability of SDN, which is essentially the heart of sensitive data storage and business interaction, and offer a remedy to counter APT attacks.

Our model stems from the intriguing prospect theory, which orchestrates a dynamic tussle between attack and defense maneuvers. This framework involves two pivotal players – the defender and the attacker – each optimizing their strategies to gain an upper hand. The defender's goal is to maximize utility through smartly-timed honeypot data collection and analysis, while the attacker seeks to optimize their own utility by strategically timing their attacks. We introduce the Prelec function and value function to encapsulate bounded rationality, lending depth to the model.

To validate our approach, we executed experiments using Network Simulator version 2. While the results demonstrated our strategy's robustness, it's important to acknowledge some limitations that warrant discussion. The use of simulation-based evaluation through Network Simulator version 2 might not perfectly replicate real-world scenarios, thus demanding a cautious interpretation of the results. Additionally, the experiment was conducted on a relatively smaller scale, potentially limiting the applicability of findings to larger networks.

Another pertinent limitation arises from the assumption that both the attacker and defender possess complete information about each other's strategies. Real-world situations often deviate from such assumptions. Furthermore, our model does not account for the broader impact of attacker actions on network performance, which holds significance in practical scenarios. Lastly, the presumption of rational decision-making by both attacker and defender might not always hold true in the real world.

In conclusion, proposed model showcases promising potential, yet further exploration is imperative to ascertain its viability in real-world settings. Addressing the aforementioned limitations and delving deeper into real-world applicability are crucial aspects for future research. We foresee an exciting avenue of investigation into multi-defender and multi-attacker collaboration under bounded rationality within the IIoT landscape. This next phase would entail understanding how these entities can cooperate to enhance the security of IIoT devices against APT attacks, all while embracing the dynamic interplay outlined by the prospect theory.

- *Defense against advanced persistent threat through data backup and recovery by Lu-Xing Yang et al [49]*

The authors of this paper have introduced an innovative strategy to counter Advanced Persistent Threats (APTs) by leveraging Data Backup and Recovery (DBAR) techniques. This approach aims to surpass the traditional methods of APT defense that focus on detection and repair.

The main essence of this paper revolves around presenting a fresh defense strategy against Advanced Persistent Threats (APTs) using Data Backup and Recovery (DBAR) techniques. The goal is to overcome the limitations of the conventional APT defense, which relies on detection

and repair, by creating a more powerful and efficient alternative. Furthermore, the study delves into the challenge of devising a cost-effective DBAR approach, framing it as a problem in differential game theory. The ultimate objective is to identify a DBAR strategy that effectively balances cost and performance, drawing on the concept of Nash equilibrium.

Within this study, the authors propose a systematic approach to identify a cost-effective DBAR strategy for countering advanced persistent threats (APTs). The effectiveness of this strategy is evaluated by assessing potential losses an organization might suffer due to APT incidents and network downtime resulting from implementing a DBAR strategy. By translating the pursuit of an affordable DBAR strategy into a differential game-theoretic context, the authors formulate and derive the optimal approach. The resulting DBAR strategy, derived from this optimal approach, aligns with Nash equilibrium principles, thus showcasing cost-effectiveness. Through comprehensive comparative experiments, the authors validate the effectiveness of the DBAR strategy arising from the optimal approach. This underscores the practicality of their proposed methodology in establishing a cost-effective DBAR strategy for APT defense.

The proposed DBAR-centric defense mechanism against APTs can seamlessly integrate with the framework of software-defined networking (SDN), effectively bolstering organizational data against APT attacks. The DBAR strategy model proves valuable in identifying an economical defense approach, guided by Nash equilibrium. This approach extends beyond APT defense to address diverse cybersecurity challenges including smart grid security, blockchain security, and privacy protection. This study introduces a novel perspective on APT defense, providing organizations with tools to safeguard their data against APT threats.

Highlighting the importance of data backup and recovery methods in disaster recovery for APT defense, this paper establishes a theoretical foundation for the development of more potent and efficient APT defense mechanisms in the future. As such, the practical implications of this paper are of considerable value for organizations aiming to secure their data against APT attacks and for researchers dedicated to advancing APT defense mechanisms.

- *Although the research doesn't explicitly outline the paper's limitations, certain potential drawbacks can be inferred:*

The authors do not directly address the potential drawbacks or limitations of the DBAR model; instead, they mention possible limitations. The proposed DBAR-based APT defense strategy might not universally apply to all types of organizations or network setups. The methodology for identifying a cost-effective DBAR strategy might not be universally applicable to all APT attack scenarios or network configurations. Implementing the model's methodology might require significant computational resources and time to determine the optimal DBAR strategy. It might not encompass all factors influencing the cost-effectiveness of the DBAR strategy.

The methodology of the DBAR model might not readily adapt to the ever-changing landscape of APT attacks and network environments. It cannot guarantee complete prevention of APT incidents or complete data recovery. Implementing and maintaining the proposed methodology could necessitate a certain level of technical expertise and might not address all cybersecurity concerns organizations could face.

○ General Models

The studies mentioned above delve into the realm of Advanced Persistent Threats (APTs) and Software-Defined Networking (SDN), each offering unique perspectives. In this section, we will explore these research articles, discussing their enhancements and limitations. Rather than focusing on specific articles, we will discuss these studies in a more general context.

Upon analyzing these articles, it becomes evident that there is substantial potential for improvement through the application of Machine Learning (ML) and Deep Learning (DL) techniques. In studies [43], [44], and [45], researchers have presented distinct ML and DL approaches to fortify networks against APT attacks. Notably, these models do not exclusively address their application within the SDN environment. Additionally, research into DL and ML strategies for combating cyber threats is not limited. A comprehensive survey of ML and DL integration within SDN settings has been presented in [46].

In [43], the primary focus is on promptly detecting APT attacks. This study employs a variety of machine learning methodologies, including the C5.0 decision tree, Bayesian network, and deep learning models. The NSL-KDD dataset is utilized to identify and classify APT attacks using machine learning techniques. With a dataset comprising 148,517 samples—125,973 for training and 22,544 for testing—the deep learning model stands out for its timely detection capabilities. Achieving an impressive accuracy rate of 98.85% and a false positive rate of 1.13%, this model's automatic multi-layered feature extraction proves to be highly effective.

Moving on to [44], this research introduces a method for detecting Control and Command (C&C) servers within APT attacks, hinging on network traffic analysis driven by machine learning. The identification of C&C servers is pivotal in APT attack prevention. This method employs various network traffic features, such as byte count over time, TCP SYN packet percentage, and inter-arrival time ratios, to discern patterns associated with C&C server communication.

In [45], a novel approach to APT attack detection is proposed, founded on the analysis of network traffic using a combined deep learning model. This approach amalgamates deep learning networks—multilayer perceptron (MLP), convolutional neural network (CNN), and long short-term memory (LSTM)—to detect signs of APT attacks within network traffic. The detection process encompasses IP feature extraction and APT attack IP classification. Remarkably, the combined deep learning models exhibit remarkable proficiency, yielding accuracy levels between 93% and 98% for APT attack detection based on network traffic. Notably, the study underscores the

necessity of a robust dataset encompassing a substantial number of flows and IPs, along with balanced average flow distribution, to optimize deep learning model performance.

Furthermore, we encounter studies exclusively centered on SDNs. In [47], authors propose an architecture for malware analysis utilizing Software-Defined Networking (SDN) to dynamically adapt the network environment based on malware actions. This architecture harnesses SDN's adaptability to reconfigure network settings in response to malware activities, thereby enhancing the detection and analysis of sophisticated malicious software.

Turning to [48], this paper introduces a secure distributed model leveraging blockchain technology to facilitate cyber threat intelligence sharing among diverse stakeholders within SDN networks. This model guarantees unalterable record-keeping and immutable logic through blockchain and smart contract integration. The proposed model has been realized using the Hyperledger Fabric open-source permissioned blockchain platform.

V FUTURE DIRECTIONS AND DISCUSSION

The journey of research we've embarked upon in the preceding sections unveils the remarkable progress made in the quest to enhance the resilience of Software-Defined Networking (SDN) infrastructure against the ever-evolving landscape of Advanced Persistent Threats (APTs). While these studies have provided valuable insights and innovative approaches, it's evident that achieving a comprehensive defense against APT attacks within SDN environments remains a complex challenge. Despite the significant advancements, the current models and strategies are not without limitations and complexities that require thoughtful consideration.

The research papers we've explored present various strategies for mitigating APT attacks within the SDN domain, such as TMAF [21], HMM [20], and NIDS [23], each designed to counter these threats. However, applying these models in real-world situations often encounters computational demands that could strain network resources when implemented at scale. While these models demonstrate effectiveness in controlled environments, adapting them for practical deployment necessitates addressing real-world obstacles while maintaining scalability and efficiency.

One overarching observation throughout these studies is the limited focus on dedicated research exclusively targeting APT attacks within SDN environments. In many cases, the focus leans towards general approaches to APT detection or safeguarding against conventional cyber threats. The secretive and sophisticated nature of APT attacks, often orchestrated by state-sponsored adversaries, emphasizes the urgency of adopting strategies that go beyond traditional cybersecurity approaches.

As our research journey continues, future directions for ensuring resilient SDN infrastructure against APTs come into view:

Real-World Implementation and Validation: A recurring theme in these studies is the intended implementation of proposed models and strategies in real-world operational settings. Bridging the gap between research and practical application is crucial to confirming

the effectiveness and adaptability of these approaches under genuine conditions.

Strengthening Resilience and Adaptability: The next phase involves enhancing the resilience of detection and mitigation models to cover both known and emerging APT attack vectors. Overcoming challenges related to false positives and false negatives while accommodating evolving threat tactics is of utmost importance.

Integration of Machine Learning (ML) and SDN: An exciting avenue is the integration of Machine Learning and Deep Learning techniques with Software-Defined Networking. By applying ML algorithms to analyze network traffic and predict potential threats, combined with SDN's flexibility, a proactive defense approach can be established.

Promoting Collaborative Defense: APT threats often transcend organizational boundaries. The future entails creating frameworks that enable secure sharing of threat intelligence and collaborative defense efforts, enhancing collective resilience while respecting privacy.

Synthesis of Comprehensive Security Strategies: The way forward involves crafting comprehensive security strategies that blend traditional network security practices with innovative methods. By incorporating AI-driven detection, SDN's dynamic adaptability, and the agility of threat intelligence sharing, a robust defense mechanism against APT threats can be formed.

Establishing Standardized Evaluation Frameworks: Setting up benchmarking standards and unified evaluation criteria for APT detection and mitigation models can facilitate objective comparisons and drive continuous improvement.

Nurturing Industry-Academia Collaboration: Achieving the vision of resilient SDN infrastructure against APTs requires close collaboration among researchers, cybersecurity experts, and industry stakeholders. Such partnerships will align solutions with practical challenges and real-world conditions.

In conclusion, the journey to safeguard SDN infrastructure against APT attacks is an ongoing and dynamic pursuit. The progress made through existing research is promising, but this journey demands persistent exploration, innovative methodologies, and collaborative efforts. Given the multidisciplinary nature of this challenge, combining research insights, industry involvement, and cybersecurity expertise becomes essential in building strong defenses against the elusive and sophisticated APT threats within SDN environments.

REFERENCES

- [1] Tourrilhes, P. Sharma, S. Banerjee, and J. Pettit, "SDN and OpenFlow Evolution: A Standards Perspective," *Computer*, vol. 47, no. 11, pp. 22–29, Nov. 2014, doi: 10.1109/MC.2014.326.
- [2] N. McKeown et al., "OpenFlow: enabling innovation in campus networks," *ACM SIGCOMM Comput. Commun. Rev.*, vol. 38, no. 2, pp. 69–74, Mar. 2008, doi: 10.1145/1355734.1355746.
- [3] M. Casado, M. J. Freedman, J. Pettit, J. Luo, N. McKeown, and S. Shenker, "Ethere: taking control of the enterprise," *ACM SIGCOMM Comput. Commun. Rev.*, vol. 37, no. 4, pp. 1–12, Oct. 2007, doi: 10.1145/1282427.1282382.
- [4] N. Gude et al., "NOX: towards an operating system for networks," *ACM SIGCOMM Comput. Commun. Rev.*, vol. 38, no. 3, pp. 105–110, Jul. 2008, doi: 10.1145/1384609.1384625.
- [5] "TR_SDN_ARCH_1.0_06062014.pdf." Accessed: Aug. 11, 2023. [Online]. Available: https://opennetworking.org/wp-content/uploads/2013/02/TR_SDN_ARCH_1.0_06062014.pdf
- [6] "What is Software-Defined Networking (SDN)? - Ciena." <https://www.ciena.com/insights/what-is/What-Is-SDN.html> (accessed Aug. 11, 2023).
- [7] A. Lopes, M. Santos, R. Fidalgo, and S. Fernandes, "A Software Engineering Perspective on SDN Programmability," *IEEE Commun. Surv. Tutor.*, vol. 18, no. 2, pp. 1255–1272, 2016, doi: 10.1109/COMST.2015.2501026.
- [8] "Software-Defined Networking (SDN) Definition - Cisco." <https://www.cisco.com/c/en/us/solutions/software-defined-networking/overview.html> (accessed Aug. 11, 2023).
- [9] K. Gurbani, M. Scharf, T. V. Lakshman, V. Hilt, and E. Marocco, "Abstracting network state in Software Defined Networks (SDN) for rendezvous services," in 2012 IEEE International Conference on Communications (ICC), Ottawa, ON, Canada: IEEE, Jun. 2012, pp. 6627–6632. doi: 10.1109/ICC.2012.6364858.
- [10] "Software defined Networking(SDN) - GeeksforGeeks." <https://www.geeksforgeeks.org/software-defined-networking/> (accessed Aug. 11, 2023).
- [11] Haleplidis, K. Pentikousis, S. Denazis, J. H. Salim, D. Meyer, and O. Koufopavlou, "Software-Defined Networking (SDN): Layers and Architecture Terminology," Internet Engineering Task Force, Request for Comments RFC 7426, Jan. 2015. doi: 10.17487/RFC7426.
- [12] "What is Software-Defined Networking Definition, Layers, and How Does it Work? - zenarmor.com." <https://www.zenarmor.com/docs/network-basics/what-is-software-defined-networking-sdn> (accessed Aug. 11, 2023).
- [13] "What Is SDN? How Does It Differ from NFV? - Huawei." <https://info.support.huawei.com/info-finder/encyclopedia/en/SDN.html> (accessed Aug. 11, 2023).
- [14] "What is Software Defined Networking? SDN Explained – BMC Software | Blogs." <https://www.bmc.com/blogs/software-defined-networking/> (accessed Aug. 11, 2023).
- [15] "Data centre networking: SDN fundamentals | Ubuntu." <https://ubuntu.com/blog/data-centre-networking-sdn-fundamentals> (accessed Aug. 11, 2023).
- [16] "Northbound vs Southbound (and east vs west) Explained - Topio Networks." <https://www.topionetworks.com/topics/northbound-vs-southbound-and-east-vs-west-5d0792ae843bac3622b63ff8> (accessed Aug. 11, 2023).
- [17] Joint Task Force Transformation Initiative, "Managing information security risk :: organization, mission, and information system view," National Institute of Standards and Technology, Gaithersburg, MD, NIST SP 800-39, 2011. doi: 10.6028/NIST.SP.800-39.
- [18] Alshamrani, S. Myneni, A. Chowdhary, and D. Huang, "A Survey on Advanced Persistent Threats: Techniques, Solutions, Challenges, and Research Opportunities," *IEEE Commun. Surv. Tutor.*, vol. 21, no. 2, pp. 1851–1877, 2019, doi: 10.1109/COMST.2019.2891891.
- [19] "What is an APT Attack and How to Stop It?" <https://phoenixnap.com/blog/apt-attack> (accessed Aug. 12, 2023).
- [20] Shan-Shan and X. Ya-Bin, "The APT detection method in SDN," in 2017 3rd IEEE International Conference on Computer and Communications (ICCC), Chengdu: IEEE, Dec. 2017, pp. 1240–1245. doi: 10.1109/CompComm.2017.8322741.
- [21] He and S. Sun, "A two-phase detection method against APT attack on flow table management in SDN," *J. Supercomput.*, Apr. 2023, doi: 10.1007/s11227-023-05281-5.
- [22] M. Rahouti, K. Xiong, Y. Xin, S. K. Jagatheesaperumal, M. Ayyash, and M. Shaheed, "SDN Security Review: Threat Taxonomy, Implications, and Open Challenges," *IEEE Access*, vol. 10, pp. 45820–45854, 2022, doi: 10.1109/ACCESS.2022.3168972.
- [23] H. Alqahtani and J. A. Clark, "Detecting Stealthy Scans in SDN using a Hybrid Intrusion Detection System".
- [24] "What Are APTs? Advanced Persistent Threats Explained – BMC Software | Blogs." <https://www.bmc.com/blogs/advanced-persistent-threats/> (accessed Aug. 13, 2023).

- [25] "What is Lateral Movement? – CrowdStrike." <https://www.crowdstrike.com/cybersecurity-101/lateral-movement/> (accessed Aug. 13, 2023).
- [26] "Lateral movement: Challenges, APT, and Automation." <https://www.cynet.com/network-attacks/lateral-movement-challenges-apt-and-automation/> (accessed Aug. 13, 2023).
- [27] "Impacket and Exfiltration Tool Used to Steal Sensitive Information from Defense Industrial Base Organization | CISA." <https://www.cisa.gov/news-events/cybersecurity-advisories/aa22-277a> (accessed Aug. 13, 2023).
- [28] M. Ussath, D. Jaeger, Feng Cheng, and C. Meinel, "Advanced persistent threats: Behind the scenes," in 2016 Annual Conference on Information Science and Systems (CISS), Princeton, NJ, USA: IEEE, Mar. 2016, pp. 181–186. doi: 10.1109/CISS.2016.7460498.
- [29] "The Cyber Kill Chain Explained." <https://www.forbes.com/sites/forbestechcouncil/2018/10/05/the-cyber-kill-chain-explained/?sh=14f1f14d6bdf> (accessed Aug. 13, 2023).
- [30] N. Alhaj and N. Dutta, "Analysis of Security Attacks in SDN Network: A Comprehensive Survey," in Contemporary Issues in Communication, Cloud and Big Data Analytics, H. K. D. Sarma, V. E. Balas, B. Bhuyan, and N. Dutta, Eds., in Lecture Notes in Networks and Systems, vol. 281. Singapore: Springer Singapore, 2022, pp. 27–37. doi: 10.1007/978-981-16-4244-9_3.
- [31] S. Buzura, M. Lehene, B. Iancu, and V. Dadarlat, "An Extendable Software Architecture for Mitigating ARP Spoofing-Based Attacks in SDN Data Plane Layer," *Electronics*, vol. 11, no. 13, p. 1965, Jun. 2022, doi: 10.3390/electronics11131965.
- [32] Ubaid, R. Amin, F. Bin, and M. Muwar, "Mitigating Address Spoofing Attacks in Hybrid SDN," *Int. J. Adv. Comput. Sci. Appl.*, vol. 8, no. 4, 2017, doi: 10.14569/IJACSA.2017.080474.
- [33] "What is a Side Channel Attack? (with Examples)." <https://www.comparitech.com/blog/information-security/side-channel-attack/> (accessed Aug. 13, 2023).
- [34] Shoaib, Y.-W. Chow, and E. Vlahu-Gjorgievska, "Preventing Timing Side-Channel Attacks in Software-Defined Networks," in 2021 IEEE Asia-Pacific Conference on Computer Science and Data Engineering (CSDE), Brisbane, Australia: IEEE, Dec. 2021, pp. 1–6. doi: 10.1109/CSDE53843.2021.9718377.
- [35] "us-15-Hizver-Taxonomic-Modeling-Of-Security-Threats-In-Software-Defined-Networking-wp.pdf." Accessed: Aug. 13, 2023. [Online]. Available: <https://www.blackhat.com/docs/us-15/materials/us-15-Hizver-Taxonomic-Modeling-Of-Security-Threats-In-Software-Defined-Networking-wp.pdf>
- [36] "apigee-api-management-for-sdn-ebook.pdf." Accessed: Aug. 13, 2023. [Online]. Available: <https://cloud.google.com/files/apigee/apigee-api-management-for-sdn-ebook.pdf>
- [37] T. E. Ali, Y.-W. Chong, and S. Manickam, "Machine Learning Techniques to Detect a DDoS Attack in SDN: A Systematic Review," *Appl. Sci.*, vol. 13, no. 5, p. 3183, Mar. 2023, doi: 10.3390/appl13053183.
- [38] S. Abdulkarem and A. Dawod, "DDoS Attack Detection and Mitigation at SDN Data Plane Layer," in 2020 2nd Global Power, Energy and Communication Conference (GPECOM), Izmir, Turkey: IEEE, Oct. 2020, pp. 322–326. doi: 10.1109/GPECOM49333.2020.9247850.
- [39] N. Z. Bawany, J. A. Shamsi, and K. Salah, "DDoS Attack Detection and Mitigation Using SDN: Methods, Practices, and Solutions," *Arab. J. Sci. Eng.*, vol. 42, no. 2, pp. 425–441, Feb. 2017, doi: 10.1007/s13369-017-2414-5.
- [40] Y. Maleh, Y. Qasmaoui, K. El Gholami, Y. Sadqi, and S. Mounir, "A comprehensive survey on SDN security: threats, mitigations, and future directions," *J. Reliab. Intell. Environ.*, vol. 9, no. 2, pp. 201–239, Jun. 2023, doi: 10.1007/s40860-022-00171-8.
- [41] Chen, X., et al. "Research on low-rate DDoS attack of SDN network in cloud environment." *Tongxin Xuebao* 40.6 (2019): 210-222.
- [42] W. Zhijun, X. Qing, W. Jingjie, Y. Meng, and L. Liang, "Low-Rate DDoS Attack Detection Based on Factorization Machine in Software Defined Network," *IEEE Access*, vol. 8, pp. 17404–17418, 2020, doi: 10.1109/ACCESS.2020.2967478.
- [43] Hassannataj Joloudari, M. Haderbadi, A. Mashmool, M. Ghasemigol, S. S. Band, and A. Mosavi, "Early Detection of the Advanced Persistent Threat Attack Using Performance Analysis of Deep Learning," *IEEE Access*, vol. 8, pp. 186125–186137, 2020, doi: 10.1109/ACCESS.2020.3029202.
- [44] Do Xuan, Cho, Lai Van Duong, and Tisenko Victor Nikolaevich. "Detecting C&C server in the APT attack based on network traffic using machine learning." *International Journal of Advanced Computer Science and Applications (IJACSA)* 11.5 (2020).
- [45] Do Xuan and M. H. Dao, "A novel approach for APT attack detection based on combined deep learning model," *Neural Comput. Appl.*, vol. 33, no. 20, pp. 13251–13264, Oct. 2021, doi: 10.1007/s00521-021-05952-5.
- [46] Md. R. Ahmed, S. Islam, S. Shatabda, A. K. M. M. Islam, and Md. T. I. Robin, "Intrusion Detection System in Software-Defined Networks Using Machine Learning and Deep Learning Techniques –A Comprehensive Survey," preprint, Dec. 2021. doi: 10.36227/techrxiv.17153213.v1.
- [47] M. Ceron, C. B. Margi, and L. Z. Granville, "MARS: An SDN-based malware analysis solution," in 2016 IEEE Symposium on Computers and Communication (ISCC), Messina, Italy: IEEE, Jun. 2016, pp. 525–530. doi: 10.1109/ISCC.2016.7543792.
- [48] M. Hajizadeh, N. Afraz, M. Ruffini, and T. Bauschert, "Collaborative Cyber Attack Defense in SDN Networks using Blockchain Technology," in 2020 6th IEEE Conference on Network Softwarization (NetSoft), Ghent, Belgium: IEEE, Jun. 2020, pp. 487–492. doi: 10.1109/NetSoft48620.2020.9165396.
- [49] L.-X. Yang, K. Huang, X. Yang, Y. Zhang, Y. Xiang, and Y. Y. Tang, "Defense Against Advanced Persistent Threat Through Data Backup and Recovery," *IEEE Trans. Netw. Sci. Eng.*, vol. 8, no. 3, pp. 2001–2013, Jul. 2021, doi: 10.1109/TNSE.2020.3040247.
- [50] "9 Types of Software Defined Network attacks and how to protect from them - RouterFreak." <https://www.routerfreak.com/9-types-software-defined-network-attacks-protect/> (accessed Aug. 13, 2023).
- [51] "Brute Force: Password Guessing, Sub-technique T1110.001 - Enterprise | MITRE ATT&CK®." <https://attack.mitre.org/techniques/T1110/001/> (accessed Aug. 13, 2023).
- [52] "What is Password Guessing Attack? - GeeksforGeeks." <https://www.geeksforgeeks.org/what-is-password-guessing-attack/> (accessed Aug. 13, 2023).

Aspect Based Sentiment Analysis on Nepali Language Tweets related to COVID-19

Bijaya Parajuli

Gandaki College of Engineering and Science, Pokhara University
Pokhara, Nepal
bijaya02003@gces.edu.np

Bidur Devkota

Gandaki College of Engineering and Science, Pokhara University
Pokhara, Nepal
<https://orcid.org/0000-0001-5901-3971>

Sujan Tamrakar

Gandaki College of Engineering and Science, Pokhara University
Pokhara, Nepal
sujan@gces.edu.np

Abstract—Public sentiments and opinions concerning COVID-19, a highly infectious disease, were disseminated across several online platforms. Quantifying the sentiment and the related aspects expressed would help not only gauge the level of anxiety in the public but also provide useful directions to the authorities. This study performs Aspect Based Sentiment Analysis on COVID-19 related Nepali language tweets by focusing on identifying aspects and estimating the sentiment related to them. By focusing on both sentiment and the target it provides a more detailed understanding of opinions and attitudes expressed in the text. However, one of the challenges was the absence of a well-labeled aspect dataset for the Nepali text related to COVID-19. In this paper, a publicly available tweet dataset was collected and preprocessed. Next, aspect words and sentiment words were obtained by POS tagging then COVID-19 related aspect dataset was established. The aspect dataset is passed to the machine learning and deep learning models (such as SVM, GRU, and BiLSTM) to estimate the polarity of the COVID-19 tweets. Promising results were obtained with F1 scores of 0.73, 0.78, and 0.77 respectively for SVM, GRU, and BiLSTM. This study significantly contributes to the research domain by developing an aspect dataset related to COVID-19 for the Nepali language and verifying its usefulness by implementing machine learning and deep learning models for Aspect-Based Sentiment Analysis.

Keywords—COVID-19, Nepali language, tweets, aspect based sentiment analysis, SVM, GRU, BiLSTM.

I. INTRODUCTION

Throughout history, there have been many infectious disease outbreaks that have significantly impacted the human population, causing both loss of lives and damage to economies. COVID-19 (Coronavirus Disease 2019), a global health crisis that emerged at the end of 2019, has not only altered everyday lives but has also remarkably influenced public discourse [1]. In today's world, online social media platforms such as Twitter¹ (recently renamed to X), Google², and Facebook³ can be easy and effective means for understanding sentiments through posts related to the COVID-19 pandemic[2]. As the pandemic was entirely new and the virus was highly contagious, various governments attempted different measures to control its spread.

Tweets have been a publicly accessible medium for sharing and learning about various situations, news, and events that occur in our daily lives. It caters to an unprecedented amount of user-generated content which has been successfully used for various applications such as urban studies [17], pandemic and disaster [2,18], tourism and hospitality industry [4,17], and so on. During the

COVID-19 pandemic, people worldwide posted their thoughts as tweets in various languages. Many Nepali people have also composed tweets in their native language sharing their thoughts, feelings, and emotions in response to COVID-19.

Sentiment analysis, often referred to as opinion mining, is the process of determining the emotional tone or attitude expressed in a piece of text. This is a Natural Language Processing (NLP) technique that identifies whether the sentiment behind a text is positive, negative, or neutral [2]. Numerous studies have been conducted on sentiment analysis; however, aspect-based sentiment analysis remains a domain with areas that are yet to be extensively researched [4, 16].

This study utilized the NepCOV19Tweets [3] dataset to predict the sentiments of Nepali Language tweets. Most research on sentiment analysis often focuses on categorizing text into positive or negative sentiments [6,7]. Instead of just labeling the text as positive, negative, or neutral, this study aims to find out what specific aspect is related to that sentiment. This deeper look is called 'Aspect-Based Sentiment Analysis' (ABSA) [15]. Aspect words are usually nouns or noun phrases that represent the subject matter of the sentence and sentiment words can be adjectives or verbs that convey emotions or opinions [19]. Based on the sentiment words associated with each aspect, ABSA classifies the sentiment as positive, negative, or neutral.

This paper contributes by developing COVID-19 related ABSA dataset by performing Parts Of Speech (POS) tagging on Nepali tweets. Next, verify the usefulness of the dataset by performing the aspect-based sentiment analysis on it using machine learning and deep learning models.

1 <https://twitter.com/>

2 <https://google.com/>

3 <https://www.facebook.com/>

II. RELATED WORKS

Early studies have focused on popular languages such as English, Spanish, French, etc., but there is limited research on low-resource languages like Nepali [6,7]. This gap becomes even more pronounced when considering the scarcity of research specifically addressing tweets in the Nepali language pertaining to COVID-19. In this section, we will explore the groundwork laid by other researchers in this fascinating field.

Shahi et al. [3] proposed a method by identifying HybridFeature (FastText + TF-IDF) to represent Nepali COVID-19 related tweets for the sentiment classification and evaluated the classification performance of nine machine learning models (LR, KNN, NB, DT, RF, ETC, AdaBoost, MLP-NN, and SVM). The SVM-based model was the best-performing classifier with an overall 72.1% classification accuracy. This paper has limitations and suggests the use of other feature extraction methods and deep learning models to improve the performance. The authors in [6] proposed an aspect-based sentiment analysis on Nepali text. This study used SVM and Naive Bayes algorithms for sentiment classification. Feature extraction was done by manual labeling and TF-IDF was used to compute the importance of the words. The Bernoulli Naive Bayes classifier performed better yielding an accuracy of 77.5%. Sentiment classification was done only in the positive and negative classes. Likewise, the authors [7] used a pre-train multilingual BERT model for the aspect term extraction and a BiLSTM model for the sentiment classification for abusive Nepali text and achieved an accuracy of 81.6%.

Nemes et al. [9] introduced the Recurrent Neural Networks (RNN) model to classify COVID-19 related English tweets as positive or negative. Naseem et al. [10] tested traditional machine learning classifiers like SVM and Naive Bayes, as well as deep learning models like Bi-LSTM. They represented general English language tweets using embeddings such as FastText, GloVe, word2vec, and BERT. The fine-tuned BERT model achieved the highest accuracy of 92.90%.

The authors [5] use BERT models to analyze Twitter sentiment on vaccination and vaccine types during the COVID-19 pandemic in several countries. English and Turkish tweets were collected from the US, UK, Canada, Germany, Spain, Italy, France, and Turkey. The result showed that BERT models can be used effectively for this task.

Pathak et al. [21] introduced two ensemble models leveraging multilingual BERT (i.e. mBERT-E-MV and mBERT-E-AS) for aspect-based sentiment analysis in Hindi. By transforming ABSA into a sentence-pair classification task and fine-tuning pre-trained BERT models, these ensembles were tested on the III-Patna Hindi Reviews dataset, spanning various domains. The proposed model achieved accuracy up to 78.09%.

Dutta and the team [22], performed ABSA of India-specific COVID-19 tweets, utilizing the multi-criteria

decision-making technique alongside a bi-directional gated recurrent unit model. Employing a rigorous 10-fold cross-validation for validation and testing, the model has shown promising results, yielding an accuracy of 82.35% for the lockdown period dataset and 83.33% for the unlock period dataset. However, the research has identified gaps, notably the omission of sentiment analysis from emojis and the lack of identification of psychological impacts and hate speech within the tweets. Addressing these gaps in future research could provide a more comprehensive understanding of public sentiment during the pandemic.

Pasupa et al. [24] perform a comparative analysis using a dataset comprised of 1115 sentences from Thai children's tales, each classified to express negative, neutral, or positive emotions. It explores the efficacy of three deep learning models which are Convolutional Neural Network (CNN), Long Short-Term Memory (LSTM), and Bidirectional LSTM (BiLSTM) through a 10-fold cross-validation mechanism. Results indicate that the CNN model tops with an F1 score of 0.817, followed by Bi-LSTM and LSTM with 0.805 and 0.793, respectively. Notably, the study discovered that integrating word embedding, POS-tagging, and semantic features enhances model performance.

A recent study [25] investigates sentiment analysis on a dataset of 4035 Nepali tweets related to COVID-19. It benchmarks three models: NB, SVM, and LSTM using a 10-fold cross-validation approach. Among the models, LSTM outperforms the rest, achieving an accuracy of 79% along with precision and recall at the same level, culminating in an F1 score of 0.79. However, the study acknowledges limitations, such as the relatively small dataset size, the absence of pre-trained word embeddings, and the lack of testing across different Nepali text genres.

The research [26] delves into the classification of 12,241 manually annotated Nepali tweets into eight discussion topics using two language models, mBERT and MuRIL, with a 10-fold cross-validation method. Results indicated that MuRIL, tailored to the Nepali language family, excelled with an F1 score of 0.840 when applied to the full dataset, surpassing mBERT which scored 0.823 on the same dataset size. Despite its insights, this study was limited to only two models and did not explore hybrid architectures or other Nepali text forms.

In previous research, ABSA has primarily been conducted in English and other languages, with only a limited number of studies focusing on the Nepali language [6,7,25]. Notably, there is a significant gap in the existing literature concerning ABSA applied to COVID-19 data in the Nepali language. Additionally, the experimental findings indicate that the proposed multi-task framework consistently outperforms single-task frameworks across all experiments. Previous work [3] suggested the use of deep learning models for Nepali language datasets for sentiment analysis tasks.

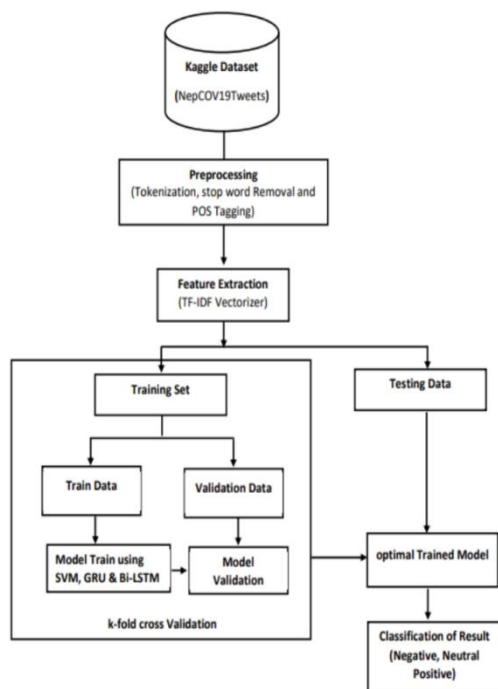


Figure 1: Proposed model

Figure 1 shows the framework used for aspect based sentiment analysis on Nepali language texts. First, preprocessing of the NepCOVID9Tweets dataset was done. The features were extracted using the TF-IDF vectorizer, and the data was divided into training and testing subsets. Next, the data were fed into three different models SVM, GRU, and BiLSTM. Finally, the models predicted the tweet sentiment as positive, negative, or neutral.

A. Datasets Used

The NepCOV19Tweets [3] dataset was utilized, as it is publicly available and well-suited for our aspect-based sentiment analysis in the academic paper. This dataset consists of tweets from Feb 11, 2020, to Jan 10, 2021. There are a total of 33,247 tweets in that dataset. Out of these tweets, 14,957 are positive, 13,546 are negative and the rest 4,744 are neutral in terms of their sentiments. Some examples of the tweets are listed below:

-कोभिड सङ्क्रमणमा आयुर्वेदीय विश्लेषणात्मक दृष्टिकोण र जडिबुटी (Neutral)कोभिड सङ्क्रमणमा आयुर्वेदीय विश्लेषणात्मक दृष्टिकोण र जडिबुटी -कोभिड सङ्क्रमणमा आयुर्वेदीय विश्लेषणात्मक दृष्टिकोण र जडिबुटी (Neutral)(Neutral)-कोभिड सङ्क्रमणमा आयुर्वेदीय विश्लेषणात्मक दृष्टिकोण र जडिबुटी (Neutral)

-भारत र रुसले करोड डोज कोभिड खोप दिने (Positive)भारत र रुसले करोड डोज कोभिड खोप दिने -भारत र रुसले करोड डोज कोभिड खोप दिने (Positive)(Positive)-भारत र रुसले करोड डोज कोभिड खोप दिने (Positive)

-बाँकेमा कोभिड संक्रमित पुरुषको मृत्यु (Negative)बाँकेमा कोभिड संक्रमित पुरुषको मृत्यु -बाँकेमा कोभिड संक्रमित

[illegible]

224

enhanced version of the NLTK stopwords list. Such terms were added to the NLTK stopwords list during the enhancement process.. Furthermore, these remaining terms such as मा, ले, को were addressed by an enhanced version of the NLTK stopwords list. Such terms were added to the NLTK stopwords list during the enhancement process.

C. Feature Extraction

It is the process of selecting or transforming important information from raw data for use in machine learning. In this research, the TF-IDF vectorizer [23], which transforms text into numeric representation, was used for feature extraction. TF-IDF quantifies the importance of a word in a specific document relative to a collection of documents, emphasizing words that are unique to a particular document.

D. Algorithms

In this study, three renowned algorithms from machine learning and deep learning domains, specifically SVM, GRU, and Bi-LSTM, were employed for the ABSA model formulation.

Support Vector Machine [12] was preferred for its proficiency in managing linguistic features effectively and its resistance to overfitting, making it a suitable choice for ABSA, especially considering the limited availability of Nepali datasets.

Additionally, the Gated Recurrent Unit [13] was integrated for its ability to capture long-term dependencies without imposing significant computational demands. GRU's design, featuring update and reset gate mechanisms, proved well-suited for the nuances of the Nepali language, contributing to its value for sentiment analysis.

Bidirectional Long Short-Term Memory [13] was also adopted for its capability to consider the context from both preceding and following tokens, ensuring a comprehensive understanding of sentiment for each aspect. The bidirectional nature of this algorithm is advantageous for navigating the complexities of Nepali syntax and semantics, making it a strong choice for aspect-based sentiment analysis. These algorithm selections, based on their specific strengths in handling linguistic complexities, played a pivotal role in the success of the research.

IV. RESULTS AND DISCUSSION

The newly developed aspect dataset utilized the tweets availed by the NepCOV19Tweets dataset. A total of 5019 tweets (2464 negative, 1208 neutral, and 1347 positive) were processed to label aspect words, and sentiment words along with the related polarity. Since the original dataset had relatively high negative sentiments compared to the other two classes, the newly generated aspect dataset also contains a high number of negative tweets. To balance the dataset before applying the learning algorithms we use SMOTE[27]. SMOTE is specifically designed to tackle imbalanced datasets by generating synthetic samples for the minority class.

Table II displays the best performance achieved by the GRU model, with an F1 score of 0.78. This result was obtained using an 80:20 split ratio, a batch size of 128, a dropout rate of 0.2, 20 epochs, and a learning rate of 1e-3. Notably, this result was slightly superior to the BiLSTM model, which achieved an F1 score of 0.77 under the same parameters. Also, The SVM model result was obtained with an F1 score of 0.73 at 70:30 data split with these optimal parameters: C=10, coef=0.0, degree=2, gamma='scale', kernel='RBF'. Figures 2,3,4 and 5 show the accuracy and loss curves during the training and validation of the GRU and BiLSTM model.

In these experiments, a learning rate of 1e-5 was also tested, which significantly slowed down the model's learning process. If not trained for a sufficient number of epochs, the model might not reach its optimal solution, resulting in suboptimal performance. In our case, the positive class occasionally had a very low F1 score, or even zero, when the epochs were insufficient.

Similarly, increasing the number of epochs, means the models are trained for longer, which improves performance. A higher learning rate like 1e-3 allows the model to make larger updates during training and provide a better solution faster. However, a learning rate that is too high may cause the training to diverge, which means the model's performance may get worse. In that scenario, 1e-3 seems to be the best learning rate. Thus, both models GRU and BiLSTM performed better with a learning rate of 1e-3 than 1e-5, which may be because the higher rate enabled more

effective learning from the training data.

TABLE II. F1 SCORES

	SVM	GRU	Bi-LSTM
Unbalanced	0.70	0.76	0.75
Balanced	0.73	0.78	0.77

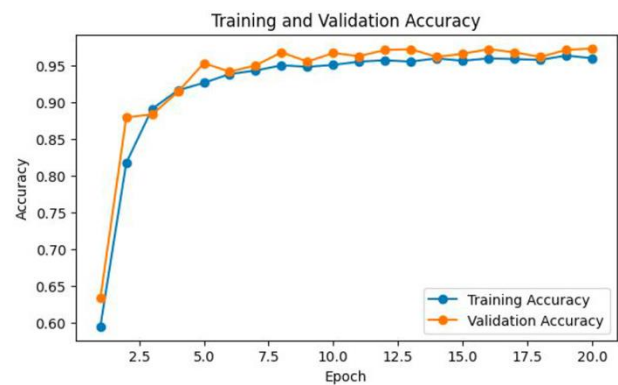


Figure 2: GRU Training and Validation Accuracy Curve

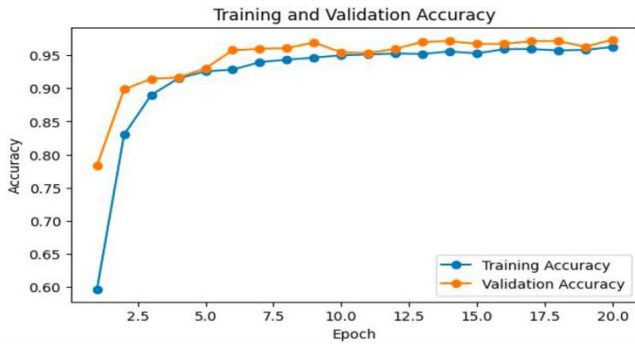


Figure 3: Bi-LSTM Training and Validation Accuracy Curve

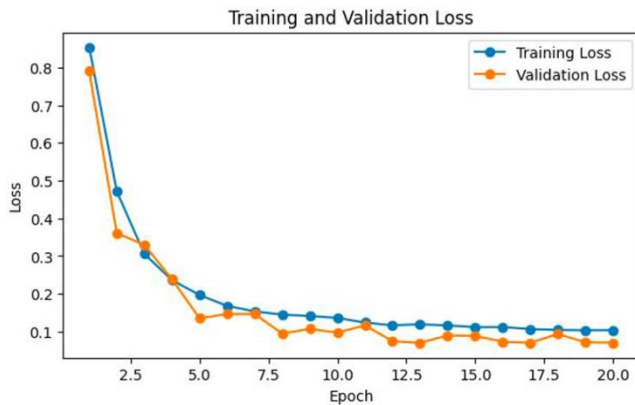


Figure 4: GRU Training and Validation Loss Curve

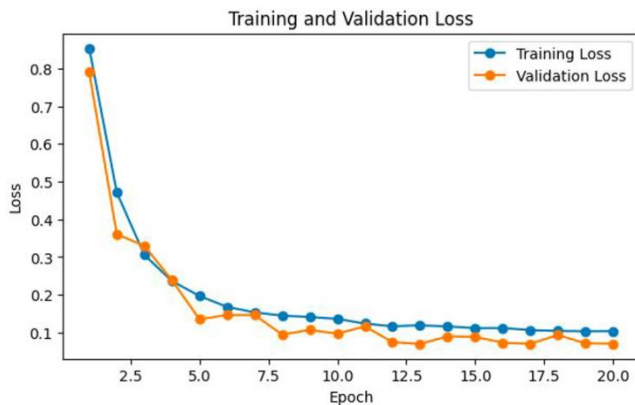


Figure 5: Bi-LSTM Training and Validation Loss Curve

We added about 5,000 POS tags, which is a big step for this language study. This will open new horizons for further researchers as not many researchers have explored and examined the Nepali language at this level. The newly generated aspect dataset was developed by using POS tag data and was trained in both models GRU and BiLSTM, which provide the F1 score of 0.78 and 0.77. The GRU model [28] works well for figuring out feelings in Nepali text because it is simple yet effective at understanding the flow and meaning of words over long sentences. It is also less likely to overfit, which means it won't get confused by limited or messy data. Although it is similar to the Bi-LSTM model, GRU has some small

differences that make it handle information better in certain situations, like when the data is not clean. This simplicity is a good match for the complex Nepali language. GRU has expertise in understanding the impact of word order on sentiment allowing us to select the appropriate model for the experiment.

The obtained results by both models are comparable because both models are recurrent neural networks that are designed to capture the long-range dependency and relationship in sequence data. Similarly, both models have the same gating mechanisms and parameter tuning [14] so they provide a similar result.

V. CONCLUSIONS AND FUTURE WORKS

This study focuses on the development of a new dataset for sentiment analysis of Nepali social media posts. To enrich the dataset, POS tagging was incorporated, and the aspect identification process was improved. Tokenization was performed using the NLTK library, complemented by text preprocessing tools for stemming.

Among the models evaluated, GRU model worked the best, getting an average F1 score of 0.78. While previous research has explored aspect-based sentiment analysis for English and other languages [5,22,24,25], this study represents a significant effort in applying ABSA methodologies to COVID-19 related data in the Nepali language. Existing literature has primarily focused on product reviews[20] and abusive language detection[7]. In contrast, this research centers on the public health concern of COVID-19, highlighting its contemporary relevance.

The study has produced promising results and marks a notable advancement. However, there are areas with potential for further exploration in the Nepali language. Future research could focus on expanding the vocabulary and broadening the tag sets to enhance existing models. Additionally, the integration of reinforcement learning methodologies may offer a more streamlined training process.

REFERENCES

- [1] A. Ather, B. Patel, N. B. Ruparel, A. Diogenes, and K. M. Hargreaves, "Coronavirus Disease 19 (COVID-19): Implications for Clinical Dental Care," *J. Endod.*, vol. 46, no. 5, pp. 584–595, May 2020, doi: 10.1016/j.joen.2020.03.008. [Online].
- [2] Schouten, K., Frasinca, F.: Survey on aspect-level sentiment analysis. *IEEE Transactions on Knowledge and Data Engineering*, 28(3), pp. 813-830 (2015).
- [3] T. Shahi, C. Sitaula and N. Paudel, "A Hybrid Feature Extraction Method for Nepali COVID-19-Related Tweets Classification", *Computational Intelligence and Neuroscience*, vol. 2022, pp. 1-11, 2022. Available: 10.1155/2022/5681574.
- [4] A. S. Shafie, N. M. Sharif, M. A. Azmi Murad, and A. Azman, "Aspect extraction performance with POS tag pattern of dependency relation in aspect-based sentiment analysis," 2018 Fourth International Conference on Information Retrieval and Knowledge Management (CAMP), 2018. doi:10.1109/infrkm.2018.8464692.
- [5] I. Aygun, B. Kaya, and M. Kaya, "Aspect-based Twitter sentiment analysis on vaccination and vaccine types in COVID-19 pandemic with Deep Learning," *IEEE Journal of Biomedical and Health Informatics*, vol. 26, no. 5, pp. 2360–2369, 2022. doi:10.1109/jbhi.2021.3133103.

- [6] S. Tamrakar, B. Bal and R. Thapa, "Aspect Based Sentiment Analysis of Nepali Text Using Support Vector Machine and Naive Bayes", Technical Journal, vol. 2, no. 1, pp. 22-29, 2020. Available: 10.3126/tj.v2i1.32824.
- [7] Oyesh Mann Singh; Sandesh Timilsina; Bal Krishna Bal; Anupam Joshi, "Aspect Based Abusive Sentiment Detection in Nepali Social Media Texts", 2020
- [8] C. Sitaula, A. Basnet, A. Mainali, and T. Shahi, "Deep Learning-Based Methods for Sentiment Analysis on Nepali COVID-19-Related Tweets", Computational Intelligence and Neuroscience, vol. 2021, pp. 1-11, 2021. Available: 10.1155/2021/2158184.
- [9] L. Nemes and A. Kiss, "Social media sentiment analysis based on covid-19," Journal of Information and Telecommunication, vol. 5, no. 1, pp. 1–15, 2021.
- [10] U. Naseem, I. Razzak, M. Khushi, P. W. Eklund, and J. Kim, "COVIDSenti: a large-scale benchmark twitter data set for COVID-19 sentiment analysis," IEEE Transactions on Computational Social Systems, vol. 8, no. 4, pp. 1003–1015, 2021.
- [11] Arora, G., "Natural Language Toolkit for Indic Languages- iNLTK latest documentation. Retrieved March 7, 2019, <https://nltk.readthedocs.io/en/latest/index.html>.
- [12] C. Cortes and V. Vapnik, "Support-vector networks," Machine Learning, vol. 20, no. 3, pp. 273-297, 1995.
- [13] S. Hochreiter and J. Schmidhuber, "Long short-term memory," Neural Computation, vol. 9, no. 8, pp. 1735-1780, 1997.
- [14] J. Chung, C. Gulcehre, K. Cho, and Y. Bengio, "Empirical Evaluation of Gated Recurrent Neural Networks on Sequence Modeling," arXiv preprint arXiv:1412.3555, 2014.
- [15] A novel fusion-based deep learning model for sentiment analysis of COVID-19 tweets Mohammad Ehsan Basiri a,*, Shahla Nemati a, Moloud Abdar b, Somayeh Asadi c, U. Rajendra Acharya
- [16] K. Schouten, F. Frasincar, Survey on aspect-level sentiment analysis. IEEE Transactions on Knowledge and Data Engineering, 28(3), 2015, pp. 813-830
- [17] A. Iranmanesh, and S. A. Mousavi. "Insights from the relationship between urban form, social media, and edu-tourism." Current Issues in Tourism 26.15, 2023, pp 2559-2574.
- [18] K. Wang, N.S. Lam, and V. Mihunov. "Correlating Twitter use with disaster resilience at two spatial scales: A case study of Hurricane Sandy." Annals of GIS 29.1, 2023, pp 1-20.
- [19] A. S. Shafie, N. M. Sharif, M. A. Azmi Murad, and A. Azman, "Aspect extraction performance with POS tag pattern of dependency relation in aspect-based sentiment analysis," 2018 Fourth International Conference on Information Retrieval and Knowledge Management (CAMP), 2018.
- [20] H.T. Ismet, T. Mustaqim, and D. Purwitasari, Aspect Based Sentiment Analysis of Product Review Using Memory Network. Sci. J. Inform. 9(1), 2022, pp 73-83.
- [21] A. Pathak, S. Kumar, P. Roy, and B.-G. Kim, "Aspect-based sentiment analysis in the Hindi language by ensembling pre-trained mBERT models," Electronics, vol. 10, no. 21, p. 2641, 2021. doi:10.3390/electronics10212641
- [22] R. Dutta, N. Das, M. Majumder, and B. Jana, "Aspect based sentiment analysis using multi-criteria decision-making and deep learning under COVID-19 pandemic in India," CAAI Transactions on Intelligence Technology, vol. 8, no. 1, pp. 219–234, 2022. doi:10.1049/cit2.12144
- [23] "Sklearn.feature_extraction.text.TfidfVectorizer," scikit-learn.org/stable/modules/generated/sklearn.feature_extraction.text.TfidfVectorizer.html (accessed Nov. 5, 2023).
- [24] K. Pasupa and T. Seneewong Na Ayutthaya, "Thai sentiment analysis with Deep Learning Techniques: A comparative study based on word embedding, pos-tag, and sentic features," Sustainable Cities and Society, vol. 50, p. 101615, 2019. doi:10.1016/j.scs.2019.101615
- [25] [M. Tripathi, "Sentiment analysis of Nepali COVID-19 tweets using NB, SVM and LSTM," September 2021, vol. 3, no. 3, pp. 151–168, 2021. doi:10.36548/jaicn.2021.3.001.
- [26] R. Adhikari, "COVID-19-related Nepali Tweets Classification in a Low Resource Setting," Proceedings of the 29th International Conference on Computational Linguistics, Oct. 2022.
- [27] "Smote#," SMOTE - Version 0.11.0, https://imbalanced-learn.org/stable/references/generated/imblearn.over_sampling.SMOTE.html (accessed Jan. 7, 2023).
- [28] K. Acharya and S. Shakya, "Named-entity based sentiment analysis of Nepali news media texts," in Proceedings of the 6th Workshop on Natural Language Processing Techniques for Educational Applications, pp. 114-120, 2020.

E-Commerce Website for Astrology Services: Bridging Tradition with Technology

S.Y.Randimal
University of Vocational Technology
Ratmalana, Sri Lanka
yasihot@gmail.com

H.A.Seneviratne
Dept of Multimedia and Web
Technology
University of Vocational Technology
Ratmalana, Sri Lanka
helawikum@gmail.com

Janith Wijekoon
University of Vocational Technology
Ratmalana, Sri Lanka
jawije92@gmail.com

Kosala Kasthuriarachchi
University of Vocational Technology
Ratmalana, Sri Lanka
kosalancc2@gmail.com

Abstract— This research aims to bridge the gap between ancient wisdom and modern convenience by developing an e-commerce website tailored to astrology services. Our study explores user preferences, engagement, and overall user experience of the website. Results from user preference surveys shed light on the diverse needs and expectations of users regarding astrology e-commerce websites. The survey highlighted a strong interest in personalized birth charts and horoscope readings, as well as an emphasis on accurate astrological information. Participants expressed a desire for educational content, interactive tools such as birth chart generators, and community features like discussion boards. Data security and privacy emerged as key concerns, with users emphasizing the importance of secure payment processing and responsible data usage. The architecture of the astrology e-commerce website blends agile development methodologies resulting in a user-friendly interface and seamless navigation. The testing phase ensures the website's reliability through comprehensive functional testing, compatibility checks, and white box testing. Further, the integration of augmented reality and the exploration of personalization algorithms were recommended to enhance user engagement and customization. The research also underscores the significance of evaluating user experience and engagement levels. This involves assessing navigation, responsiveness, aesthetics, and the impact of interactive features. By gaining a deeper understanding of user interactions, preferences, and satisfaction, iterative improvements can be implemented to align the website more closely with user needs. In conclusion, this research contributes to the evolving landscape of astrology in the digital age by bridging tradition with technology. By creating an astrology e-commerce website that caters to user preferences and needs, while focusing on user experience and engagement, the study opens new avenues for enhancing the accessibility and relevance of astrology services in the modern era.

Keywords— Astrology, E-commerce, Agile methodology, Website development

INTRODUCTION

Astrology, a practice weaving celestial phenomena into human destinies, has spanned cultures for centuries, shedding light on personal growth, relationships, and life paths. In the digital age, a new era for astrology emerges as tradition blends with technology, reshaping its accessibility and relevance. E-commerce platforms play a pivotal role, bridging ancient wisdom and modern convenience to make astrological insights and services effortlessly available.

E-commerce's impact on astrology is multi-dimensional. It revolutionizes astrology, breaking free from time and place constraints. This empowers diverse individuals to engage with astrology at their convenience and unites global seekers and practitioners. This infusion democratizes astrological wisdom, expanding its reach and granting a wider audience access to guidance and self-discovery.

The creation of an astrology-focused e-commerce website stems from user expectations, technological advancements, and evolving astrological practices. As digital platforms become integral to modern lifestyles, astrology adapts, enhancing accessibility. This e-commerce portal not only unites ancient wisdom with modern preferences but also crafts an immersive experience for practitioners and seekers alike.

E-Commerce in the Digital Age

The proliferation of e-commerce platforms has ushered in a new era of consumer engagement, reshaping traditional paradigms of commerce and interaction. E-commerce, defined as the buying and selling of goods and services through digital channels, has become an indispensable facet of modern living [1]. As consumers increasingly seek convenience, accessibility, and personalized experiences, businesses across industries are compelled to leverage e-commerce platforms to reach their target audience effectively [2]. The marriage of e-commerce and service sectors, including astrology, holds the promise of democratizing access to insightful offerings, enriching user experiences, and transcending geographical boundaries.

Online Astrology Services: Trends and User Preferences

The digital transformation has not bypassed the realm of astrology, a discipline rooted in ancient practices yet primed for modern reinterpretation. Online astrology services have witnessed a surge in popularity, capturing the attention of a digitally connected audience seeking guidance and self-discovery [3]. A study by Gupta and Islam [4] underscores the growing trend of users engaging with astrology via digital platforms, highlighting the convenience and discretion offered by online consultations. The study also indicates that users appreciate the flexibility of accessing astrological insights without geographical constraints, illustrating the potential for e-commerce-driven astrology to fulfill a latent demand.

Integration of Technology and Tradition in Astrology

The integration of technology and tradition in astrology presents a nuanced landscape, where ancient wisdom is harmonized with contemporary tools and methodologies. Technological advancements enable the creation of dynamic and interactive astrological experiences, augmenting traditional practices with personalized insights [5]. The incorporation of artificial intelligence (AI) algorithms for horoscope analysis and predictive modeling exemplifies the potential synergy between tradition and technology, culminating in enhanced accuracy and relevance [6]. This intersection heralds an era where astrology is not merely transposed onto digital platforms but undergoes a metamorphosis that enhances its accessibility and usability.

E-commerce Platforms in Astrology

The landscape of astrology-centric e-commerce platforms presents a diverse array of services catering to astrological needs. Existing platforms offer a spectrum of services, ranging from horoscope consultations to personalized birth chart readings. However, upon critical examination, several key aspects emerge:

User Interface and Experience: While some platforms offer intuitive interfaces, others lack user-friendly designs, leading to potential usability issues. Navigational complexities and cluttered layouts hinder seamless user experiences.

Service Diversity: Variation exists in the scope of services provided. While some platforms focus solely on basic horoscope readings, others delve into intricate astrological analyses, providing a wider range of offerings.

Data Security Measures: Concerns arise regarding the robustness of data security protocols. Limited transparency about data handling practices poses a significant issue, potentially impacting user trust.

Manual and Automated Astrology Solutions

The dichotomy between manual and automated astrology solutions highlights distinct advantages and limitations within the field:

Manual Solutions: Traditional astrologers offer personalized consultations based on expertise and intuition. While these services provide a human touch, they are often limited by availability, subjectivity, and scalability.

Automated Solutions: Digital platforms integrating algorithms for horoscope generation and predictive models offer scalability and accessibility. However, concerns linger regarding the accuracy and personalized nature of these automated readings.

Digital Tools Specific to Astrology Services

Digital tools tailored for astrology services encompass a broad spectrum of offerings:

Horoscope Generation and Interpretation Tools: These tools vary in accuracy and depth of interpretation. While some provide comprehensive insights, others lack depth and fail to capture nuanced astrological nuances.

Educational Content and Community Features: Some platforms integrate educational resources and community engagement features. However, the quality, relevance, and interactivity of these resources differ significantly.

Critique and Identified Gaps

Upon critical analysis, notable gaps and areas for improvement across existing platforms and solutions become apparent:

User-Centric Approach: Limited emphasis on user preferences and personalized experiences within existing platforms fails to cater comprehensively to diverse user needs.

Integration of Technology: While some platforms incorporate technology, such as AI, its potential to enhance accuracy and user engagement remains largely untapped.

Data Security and Transparency: The lack of transparent data handling practices raises concerns about user privacy and trust in these platforms.

Hence the principal aim of this research is to conceive and actualize an e-commerce website dedicated to offering astrology services. This overarching objective is complemented by a set of specific research goals, which encompass: firstly, the identification of user preferences and essential needs pertaining to an e-commerce platform and secondly, the design, development, and testing phases for the website with data security options.

METHODOLOGY

This section outlines the research design, website development approach, data collection methods, usability testing process, and ethical considerations employed to investigate the development and implications of the e-commerce website for astrology services.

Research Design

To comprehensively explore the multifaceted dimensions of the e-commerce website's development and user engagement, a mixed-methods research approach was adopted, encompassing both qualitative and quantitative elements. This approach facilitated a holistic understanding of user experiences, preferences, and the technical intricacies of the platform.

User Requirement survey

Initially In obtaining the user requirements, preferences a background analysis of stakeholders(n=45) were performed as, understanding user preferences and addressing their concerns are pivotal for enhancing the effectiveness and appeal of the website. Hence a survey was performed explore customer views on barriers to finding astrologers, problems faced by renowned astrologers, and their willingness to engage in online meetings for astrological consultations. Sample was selected based on convenience sampling method

Website Development Approach

The website development process was characterized by a meticulous selection of technologies, frameworks, and design principles to ensure a seamless and enriching user experience. Notable components of the website development approach included:

Technologies and Frameworks Used: The website was constructed using HTML, CSS, and JavaScript, with an emphasis on robust frameworks such as Bootstrap for responsive design and user interface consistency.

Front-End and Back-End Considerations: The front-end was developed using HTML and CSS, while the back-end relied on PHP for server-side scripting and interaction with the database.

Integration of Payment Gateways and Security Measures: The e-commerce aspect was enhanced through the integration of secure payment gateways, ensuring the confidentiality and integrity of user transactions.

Usability Testing Process: Rigorous usability testing sessions were conducted to assess the effectiveness of interactive features, navigation, and overall user experience. Participants' interactions were observed and recorded, and their feedback was subsequently analyzed.

Ethical Considerations

The research was conducted in adherence to ethical guidelines to ensure the well-being and privacy of participants. Informed consent was obtained from all participants, and their identities were anonymized to maintain confidentiality.

RESULTS AND DISCUSSION

User Preferences and Needs for an Astrology E-Commerce Website

The survey results provide valuable insights into the preferences and needs of users for an astrology e-commerce website. (Table 1) In terms of Product and Service Preferences, the strong interest in personalized birth charts (90%) and horoscope readings (84%) highlights the appeal of individualized content. Users also value accurate astrological information, as reflected by their preference for detailed product descriptions (56%). In terms of Website Functionality, the majority of respondents expressed a preference for a search bar (56%), indicating the importance of efficient navigation. Additionally, a significant portion of users (71%) expects the website to offer educational content,

primarily in the form of articles. This highlights the demand for informative resources that enrich the user experience. Notably, an overwhelming majority (84%) expressed interest in interactive tools such as birth chart generators and compatibility calculators, suggesting a desire for engaging and personalized features. The inclusion of social features, such as a community forum (62%), is also noteworthy, indicating the potential for fostering a sense of community among users.

Regarding Payment and Security, respondents' high prioritization of secure payment processing and data protection (93%) underscores the significance of trust and security in online transactions. While a substantial proportion of users (62%) are comfortable providing personal information for customized astrological services, a noteworthy 38% remain cautious. This suggests the need for transparent data usage policies and a balance between customization and privacy.

In terms of Mobile and Accessibility, the majority of users (60%) expect to access the website primarily from mobile devices, emphasizing the importance of mobile-responsive design. The demand for accessibility features (44%) indicates a growing awareness of inclusivity, with users expressing a desire for the website to accommodate individuals with disabilities.

TABLE II. USER PREFERENCES AND NEEDS FOR AN ASTROLOGY E-COMMERCE WEBSITE

Section	Question	Number of Responses	(%)
Product and Service Preferences	What types of astrological products are you interested in?		
	- Birth Charts	40	89%
	- Horoscope Readings	35	78%
	- Astrological products such as crystals, Rings	26	58%
	- Astrology Books	20	44%
	Are there any specific astrology-related services you would like to see offered?		
	- Personalized Readings	37	82%
	- Compatibility Reports	33	73%
	- Horoscope Consultations	29	64%
	- Online Astrology Courses	25	56%
Website Functionality	How important is it for the website to provide accurate and detailed astrological information?		
	- Very Important	45	100%
	How do you envision navigating through the website?		
	- Search Bar	25	56%
	- Categories	15	33%
	- Filters	5	11%
	Do you expect the website to provide educational content about astrology?		
	- Articles	32	71%
	- Videos	18	40%
	- Tutorials	15	33%

	<i>Would you like the website to offer interactive tools, such as birth chart generators.</i>		
	- Yes	38	84%
	- No	7	16%
	<i>Are there any social features you would like to see?</i>		
	- Community Forum	28	62%
	- Discussion Boards	12	27%
	- No Social Features	5	11%
	<i>How important is a personalized user account/dashboard?</i>		
	- Very Important	28	62%
	- Important	15	33%
	- Neutral	2	4%
Payment and Security	<i>What payment methods do you prefer?</i>		
	- Credit/Debit Card	32	71%
	- Bank Transfer	25	56%
	- Other (Specify)	5	11%
	<i>How important is it for the website to have secure payment processing and data protection?</i>		
	- Very Important	42	93%
	- Important	3	7%
	<i>Are you comfortable providing personal information?</i>		
	- Yes	28	62%
	- No	17	38%
Mobile and Accessibility	<i>Do you expect to access the website primarily from a desktop/laptop or a mobile device?</i>		
	- Desktop/Laptop	18	40%
	- Mobile Device	27	60%
	<i>How important is it for the website to be mobile-responsive and accessible on different...</i>		
	- Very Important	35	78%
	- Important	9	20%
	- Neutral	1	2%
	<i>Are there any accessibility features you would like the website to have?</i>		
	- Yes	20	44%
	- No	25	56%

System Design and Development-Design and Technical Aspects

The development of the astrology website employs an agile model, chosen for its adeptness in expeditious execution. Agile modeling constitutes a methodology for designing and documenting software systems based on industry best practices. It comprises a set of guiding principles that are adaptable to software development projects. This approach asserts that each project necessitates a distinctive treatment, advocating the customization of existing methods to optimally align with project requisites. The crux of agile methodology entails segmenting tasks into manageable time boxes, facilitating the delivery of specific features within designated release intervals.

The creation of the website's user interface (UI) leverages Bootstrap CSS and JavaScript. Bootstrap, a robust toolkit, amalgamates HTML, CSS, and JavaScript resources to craft web pages and applications. As an open-source initiative hosted on GitHub, it was initially conceived by and for web developers. The web development and database establishment stages necessitate the utilization of PHP and the MYSQLI software for back-end operations. The core of PHP programming is employed, thereby facilitating user inputs. To enhance interactivity, JavaScript and the jQuery library are employed. Additionally, standard coding practices are adhered to, incorporating the use of server-side scripting and web RPC, bolstered by the North Face software.

Furthermore, the system architecture incorporates APIs for SMS gateways. These APIs encompass Sandbox, Payhere, and Google API, facilitating seamless integration and communication. The SMS API enables the integration of client messages into the system framework, promoting effective interaction amongst astrologers, customers, and administrators. The system is underpinned by a secure domain, utilizing Ready Line and employing SSL protocols to bolster data security.

Operational Workflow of the System

1) *Astrologer Profiles and Registration:* Astrologers possess individual profiles and gain access to new services upon logging into the astrology website. Registration entails user login and the issuance of an OTP code sent to the customer's mobile number to authenticate system access.

2) *Customer Selection and Service Exploration:* Customers have the liberty to select astrologers of their choice and peruse the array of services presented on the website. The customer's chosen astrologer profile is juxtaposed with the available services to facilitate informed decision-making.

3) *Service Selection and Customization:* After selecting an astrologer profile, customers proceed to choose services that align with their requirements and preferences.

4) *Service Form Submission:* Customers engage with the selected service by completing a service form, inputting relevant information to cater to their specific needs.

5) *Document Attachment:* Customers are afforded the opportunity to attach pertinent documents, such as Horoscope

6) *Submission and Payment*: Following the attachment of documents, customers can submit the form. Payment methods are made accessible, guiding customers through the payment process. Successful payment completion yields a reference number.

8) *Live Meetings and Document Sharing:* Customers interact directly with astrologers through live meetings or voice documents, fostering a personalized experience. Document sharing, including Horoscope copies, ensures astrologers have access to all requisite materials.

10) *Admin-Mediated Service Connection*: To maintain control and quality, only administrators facilitate the connection between customers and astrologers for service provisioning.

12) *Astrologer-Customer Interaction:* Customers schedule meetings with astrologers to discuss solutions. Astrologers leverage documents and voice recorders to guide customers through handling their concerns. Upon completion, administrators are notified of task finalization.

14) *Customer Acknowledgment:* Customers receive notifications from administrators, informing them that all tasks have been satisfactorily completed, ensuring transparency and satisfaction.

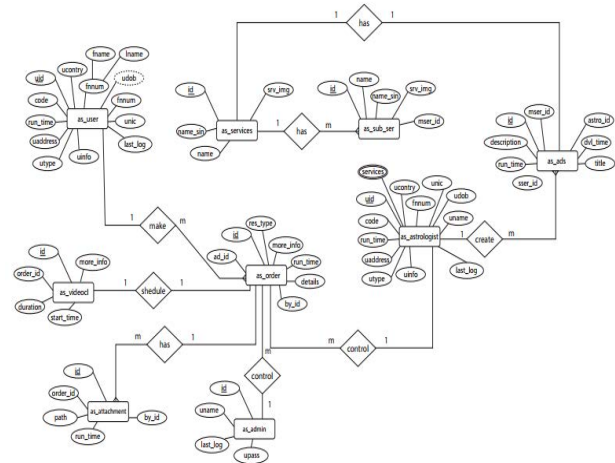
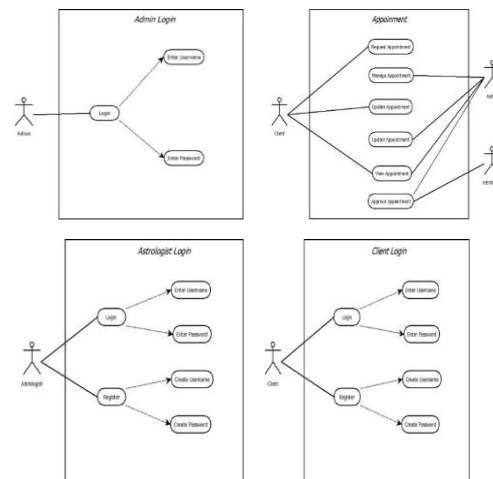


Fig. 12. ERD diagram of Website



case diagrams

Fig. 13. Use

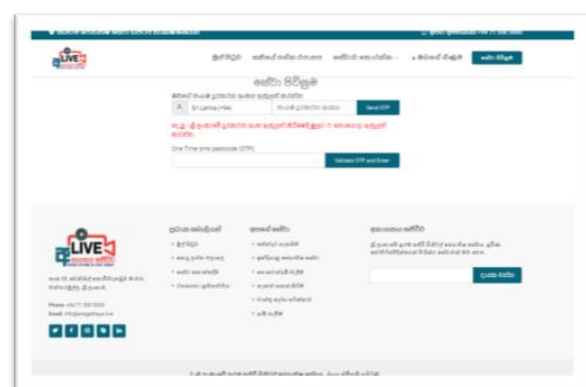


Fig. 14. Login page

User Interface (UI) Design and User Experience (UX) Principles

User interface design was rooted in user-centric principles, aiming to provide an intuitive and visually appealing experience. The user experience was further enriched by strategically placed interactive elements that fostered engagement.

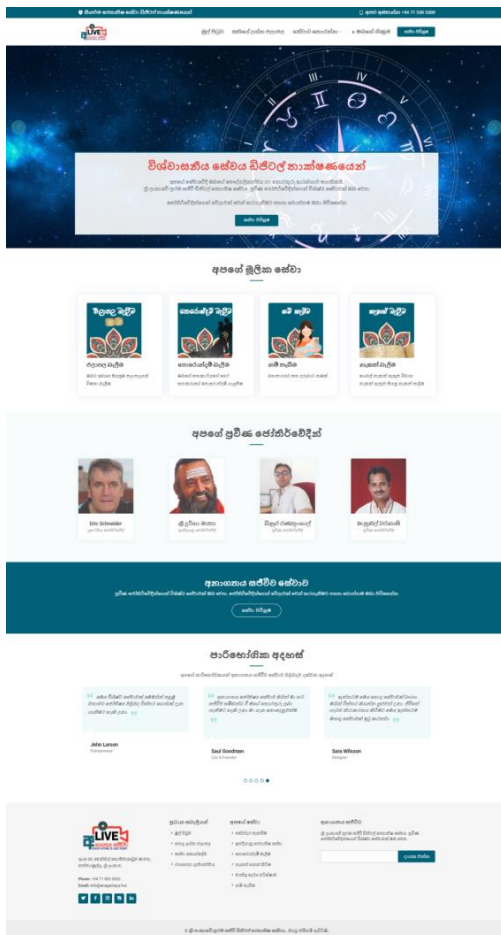


Fig. 15. Home page of the website



Fig. 16. Other pages of the website

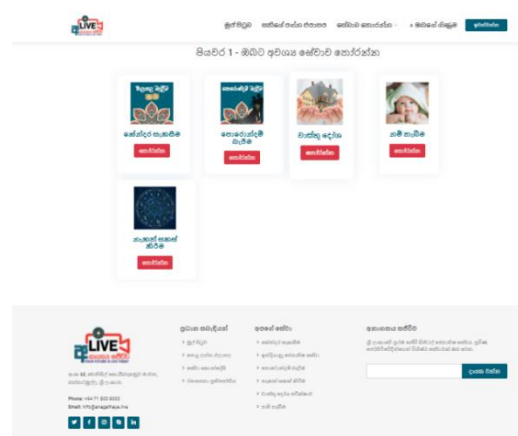


Fig. 17. Other pages of the website

Testing Phase for the Astrology Website

15) Functional Testing and Compatibility Checks:

Broken Links: All links within the website were thoroughly tested, and no broken links were found. Users can navigate seamlessly between different sections without encountering any dead ends.

Compatibility: The website was tested on various devices, browsers, and screen sizes. It exhibited consistent and responsive behavior across all tested scenarios, ensuring a user-friendly experience for visitors regardless of their chosen device or browser.

Code Validation: The code was validated using industry-standard validators. The HTML, CSS, and JavaScript

code adhered to best practices, ensuring compatibility with different browsers and compliance with web standards.

Site Speed: Load times were assessed using performance testing tools. The website demonstrated fast loading times, contributing to a smooth user experience and minimizing potential user frustration caused by slow loading pages.

16) White Box Testing for Structural Integrity:

Internal Code Structure: The internal code structure was thoroughly analyzed to ensure that it matched the specifications and design. All functions and components were tested to confirm that they executed as intended and produced the expected outcomes.

Code Coverage: The white box testing approach allowed us to achieve a high level of code coverage. Internal operations were exercised extensively, guaranteeing that all code paths were thoroughly tested.

17) Comprehensive Scenario Testing:

Scenario Coverage: Extensive scenario testing was conducted to cover a wide range of user interactions and system behaviors. Various scenarios, including edge cases and boundary conditions, were tested to identify potential vulnerabilities and unexpected behaviors.

Permutation and Combination: Testing at the source code level allowed for the examination of different permutations and combinations of inputs. This approach enabled the detection of any unforeseen issues that might arise from complex interactions between system components.

18) Synergy of Testing Approaches:

Black Box Testing: Black box testing validated the external functionality of the website. User interactions, navigation, and input validations were thoroughly tested to ensure that users can interact with the website seamlessly.

Alpha Testing: Alpha testing was performed to evaluate the website from an end-user perspective. Usability aspects, such as intuitive navigation and overall user experience, were assessed to ensure that the website meets user expectations.

CONCLUSION

In conclusion, this research bridges tradition and technology through an astrology-focused e-commerce website. The contemporary digital landscape's fusion of tradition and technology has prompted transformative shifts,

with astrology embracing e-commerce platforms for enhanced accessibility and relevance. E-commerce's multifaceted significance revolutionizes astrology by removing time and location barriers, democratizing access, and fostering a global community. The website's rationale aligns with user demands and technological progress, creating a seamless experience that unites ancient wisdom and modern convenience. Survey insights underscore strong interest in personalized services, accurate information, and mobile responsiveness. The website's development adheres to agile methodology, incorporating Bootstrap, PHP, JavaScript, and APIs for optimal functionality. The operational workflow ensures efficient astrologer-customer interaction. The comprehensive testing phase guarantees quality and user-friendliness. Ultimately, this research advances astrology into the digital era, enriching user experiences and contributing to the evolving landscape of online platforms.

Further research could enhance the astrology e-commerce website's effectiveness by focusing on user experience, engagement, and personalization. Evaluating interactions, preferences, and satisfaction would offer insights. Evaluating navigation, responsiveness, aesthetics, and interactive features' impact on engagement can provide quantitative and qualitative user experience evaluations. Advanced algorithms could offer tailored astrology insights, utilizing machine learning for horoscopes and compatibility reports. Augmented reality integration holds potential for immersive online astrology experiences. Longitudinal studies tracking user behavior over time could uncover astrology's role in personal growth. These research directions can lead to iterative improvements aligning with user needs and preferences.

REFERENCES

- [16] Rayport, Jeffrey F., and Bernard J. Jaworski. Cases in e-Commerce. McGraw-Hill Higher Education, 2001.
- [17] Chaffey, D. (2019). Digital marketing: Strategy, implementation and practice. Pearson UK.
- [18] Campion, N. (2018). The New Age in the Modern West: Counterculture, Utopia, and Prophecy from the Late Eighteenth Century to the Present Day. Bloomsbury Publishing.
- [19] Gupta, S., & Islam, M. A. (2020). An Empirical Analysis on the Factors of Digital Astrology Services Adoption. Journal of Digital Banking, 4(4), 330-340.
- [20] McConnell, K. (2021). Astrology and Technology: Charting a New Frontier. Astrological Association of Great Britain..
- [21] Fenton, S. (2019). Data-Driven Astrology: Using Artificial Intelligence to Enhance the Craft. Flare Publications.

Catalyzing Data Efficiency: A Process Support System for Colombo Consumer Price Index (CCPI)

G. H. K. N. Peeris

*Faculty of Information Technology
University of Vocational Technology
Ratmalana
kanishkanp@gmail.com*

K. M. N. Madhubhashini

*Faculty of Information Technology
University of Vocational Technology
Ratmalana
npmadhubhashini936@gmail.com*

N. S. R. Pathirana

*Faculty of Information Technology
University of Vocational Technology
Ratmalana
sewwandiruwanpathirana@gmail.com*

H. A. Seneviratne

*Faculty of Information Technology
University of Vocational Technology
Ratmalana
helawikum@gmail.com*

Abstract—This research outlines the development of an advanced remote data collection system to enhance the calculation of the Colombo Consumer Price Index (CCPI) in Sri Lanka. The current CCPI estimation process relied on labor-intensive, manual data collection from 14 centers in Colombo, necessitating a modernized approach to streamline operations within the Prices and Wages Division. The study aimed to scrutinize the existing workflow, establish an efficient conceptual framework, create an information system to optimize CCPI calculations, prioritize data security, and develop a customizable CCPI calculation module to meet evolving statistical demands and market dynamics. The literature review uncovered the limitations of existing mobile data-gathering frameworks, prompting the proposal of a custom mobile data-gathering framework designed to address issues related to privacy, security, energy efficiency, and sensing capabilities. A comprehensive evaluation approach included a literature review, critical assessment, comparative analysis, and user feedback. Practical validation within the Prices and Wages Division confirmed the system's efficiency and utility, earning positive feedback from department officers. In conclusion, this research presents a robust and secure remote data collection system that significantly enhances the CCPI calculation process. The system's adaptability, data security, and efficiency make it a valuable asset for economic metric tracking. Future research may further refine and expand similar projects, emphasizing the importance of technological innovation in streamlining data collection processes for economic analysis and policy-making.

Keywords— Remote Data Collection, Colombo Consumer Price Index, Data Security, Mobile Application Development, Database Design, Data Encryption, Statistical Functions, System Architecture

I. INTRODUCTION

The Department of Census and Statistics, a pivotal government agency, in Sri Lanka which is responsible for calculating the Colombo Consumer Price Index (CCPI) which is a measure of inflation and is used to track changes in the prices of a basket of goods and services purchased by consumers in the Colombo area. The CCPI serves as an essential economic indicator to monitor and assess the cost of

living and inflation trends in Sri Lanka. The CCPI is based on a specific base year (usually 2021=100) and is updated regularly to reflect current price levels [1]. The index helps policymakers, businesses, and the general public understand the impact of price changes on their purchasing power and overall economic well-being. The main objective of this project is to design a custom remote data collection framework and develop a complete system based on that framework to introduce an effective, efficient, and more secure remote data collection system architecture for the industry. The current process of CCPI estimation is a crucial economic metric and currently involves labor-intensive, manual data collection processes from 14 centers in Colombo. Hence this research is poised to transform the conventional workflow within the Prices and Wages Division into a semi-automated, digital system.

The system architecture adopted a three-tier web application design, enabling data collection from remote locations, centralized data storage, and accessibility from internal and external sources. User-friendly interfaces were implemented in both mobile and desktop applications, with strict adherence to security standards. Security played a crucial role, and the study recommended a hybrid encryption approach, combining RSA and AES-256-CBC, to ensure robust data protection. Server and desktop applications complemented the mobile framework, each serving specific functions within the data collection process. Database design focused on scalability and efficiency, with mathematical functions embedded within the database management system to optimize data processing. The CCPI calculation, based on the Modified Laspeyres formula, was integrated into the system.

II. OBJECTIVES

Specific objectives of this research are to scrutinize the current workflow to construct an efficient conceptual framework, develop an information system, optimize CCPI calculations for heightened overall efficiency while prioritizing data security, and develop a customizable CCPI

calculation module, enabling adaptability to changing statistical demands and market dynamics.

III. REVIEW OF LITERATURE

The focus of the literature review was to identify the key features of remote data collection systems and how those systems were implemented. Security measurements were analyzed for remote data transfer applications in the second phase. This analysis identified the key factors for establishing a secure connection using a public network, between the data collection application and the data collecting server. Data confidentiality was the primary focus of this analysis. Several kinds of research were studied regarding data encryption techniques to identify the security and efficiency of the various encryption techniques.

A. Remote data collection frameworks

Certain requirements, such as task specification, task management, sensing, and data management, have been identified in the literature with regard to mobile data-gathering frameworks.[2] Nevertheless, it has been discovered that current mobile data collection frameworks, including SeeMon, DEAMON, PRISM, Medusa, USense, MECA, MOSDEN, C-MOSDEN, and Gps, do not fully satisfy these requirements. They particularly show shortcomings with regard to energy efficiency, privacy, security, and sensing. These flaws are demonstrated by the utilization of obsolete data transfer formats, less secure data exchange technologies, a lack of ability to use modern sensors, and a limited degree of device adaptability.

The literature emphasizes the need for creating a unique mobile data collection framework that complies with the requirements in order to address these problems. A thorough evaluation of this kind of framework should be conducted by comparing these specifications with the outcomes of earlier studies. In order to accelerate its development, a review of knowledge areas related to frameworks for developing mobile applications, modern data transfer formats, data encoding strategies, data encryption techniques, and modern desktop application development methodologies is necessary. This all-encompassing strategy seeks to address the shortcomings found in current frameworks and guarantee the development of a reliable and flexible system.

B. Database design techniques

The suggested system has to be compatible with contemporary technology and meet the department's requirements for data collection. It must be able to continue operating for at least five years without major changes, which means that persistent technologies and procedures must be chosen. A thorough mobile application framework for remote data gathering can be created by utilizing the many mobile data collection frameworks that have been studied in the literature [2]. This study identifies essential elements for creating a flexible frontend and backend data collection application, as shown in figure 1.

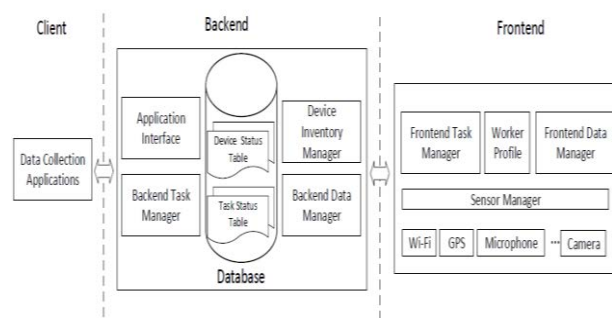


Fig. 18. Schematic Architecture of General-Purpose Mobile Data Collection Framework [2]

The suggested framework is not specific to any particular set of data collection requirements; rather, it is meant to be flexible. Users should be able to start different data collection tasks according to their needs, including the client. They should also be able to run multiple tasks at once and add or remove tasks as needed. These requirements are successfully met by this flexible structure. Four main criteria have been identified by researchers: requirements for data management, sensing, task management, and task specification. This framework's backend is made up of five main parts:

- a) *Application interface*: Responsible for user interactions and data collection needs, serving as the interface between clients and data collection applications.
- b) *Device inventory manager*: Manages data-collecting mobile devices, storing device details for task assignment.
- c) *Backend task manager*: Assigns tasks to mobile devices based on task and device specifications, while monitoring task performance.
- d) *Backend data manager*: Collects and aggregates data from mobile devices, distributing it among various components, and performing data preprocessing when necessary.
- e) *Database*: Stores all data collected from various data collection tasks.
- f) *Front-end components interact with the backend as a separate unit*:
- g) *Worker profile*: Stores mobile user preferences for data collection.
- h) *Front-end task manager*: Receives tasks from the backend and tracks running data collection tasks.
- i) *Sensor manager*: Interfaces between applications and sensors, collecting sensor data for data collection or task management.
- j) *Front-end data manager*: Receives data from sensors and sources, sends it to the backend, and conducts data preprocessing to ensure efficient transmission and device performance.

As per the literature [3] key characteristics of their mobile data collection application were identified during initial discussions. Firstly, the application prioritized simplicity to accommodate users with limited time, emphasizing ease of

use. Secondly, it aimed for bi-directional communication, facilitating seamless server-to-application and application-to-server interactions to prevent data discrepancies in unpredictable conditions. Thirdly, offline functionality was crucial to ensure continuous operation without an internet connection, safeguarding against data loss. Additionally, robust security and user authentication measures were emphasized to protect sensitive data. The application's adaptability to congested, remote areas necessitated these fundamental features and a backup data storage strategy in case of connectivity issues, upholding data confidentiality in adherence to contemporary security standards.

C. Security Measurements

The literature [25], which explores security measures used by Java ME-based mobile data collection systems, found that while basic protection measures were incorporated, minimal effort was made to enhance security. This includes a mobile data-gathering application and a database server. Most programs only provide basic security and store data in various formats.

The researchers suggested a safe data-storage technique for mobile data-gathering apps in order to address these problems. Confidentiality, authorization, offline authentication, password and data recovery, and preserving security even in the event that an attacker accesses stored data are among the primary security issues they identified. They suggested user-specified hashing algorithms to improve security in the case that hash keys are compromised, and they promoted the use of cryptographic technology for data encryption during transmission and storage.

The aim of L. H. Iwaya's work, "A security framework for mobile health data collection" [26], is to improve security for a medical application that handles private information. In order to enable authentication and key exchange (AKE), a key management mechanism (KMM) has been introduced. Additionally, symmetric encryption algorithms and Key Derivation Functions (KDFs) have been prioritized. Given the different benefits and drawbacks of these approaches, it is clear that the system architecture must incorporate a more reliable and secure remote data collection technique.

D. Mobile application development challenges

The creation of a mobile application, which is essential to these system design methodologies but challenging considering the variety of mobile devices available in terms of hardware, operating systems, and screen sizes, is one of the main challenges. Creating an application that works with all devices is a difficult task. Even applications designed for a specific device require knowledge of the specific mobile platform. Changes in the way that people eat, particularly the way that university students incorporate fast food into their daily lives, have become noticeable in Sri Lanka [8]. Examining the growing incidence of fast food consumption among students is crucial due to its possible influence on public health, particularly in view of rising obesity rates and associated health problems like diabetes and cardiovascular disorders [10] [11]. Even seasoned developers face

considerable challenges in creating a functional mobile application, as demonstrated in a previous study [1].

E. Handling large data collections

A crucial requirement for stakeholders is the ability to run statistical analyses on collected data. Specific statistical operations must be carried out by the system on the given items or object series. Creating dynamic mathematical functions that can choose and evaluate data inside the program is the difficult part of achieving this. The client-server architecture is the only realistic choice given the features of the system. Therefore, the implementation of dynamic mathematical functions in client-server systems was the main focus of the literature review.

C. Fleming and S. Goings' "Statistical Analysis Enhancement Report" [24], which emphasized the significance of integrating statistical functions into the database, particularly for handling large datasets within a single database, served as an inspiration for the project team. The creation of the web-based data processing system known as ESP (Elevated Service Performance) allowed for the successful testing and development of a logical framework. With the help of this framework, statistical functions including correlation, coefficient, linear regression, and confidence intervals could be incorporated into the central database. The logical diagram of the ESP system shows how data handling and analysis tasks are integrated within the database, utilizing unique statistical techniques in MySQL to achieve high performance. The project's goal of improving data processing system portability and performance for large datasets was highlighted by test results that demonstrated efficient processing even with complicated procedures involving joins, table creations, and GROUP BY statements. [24].

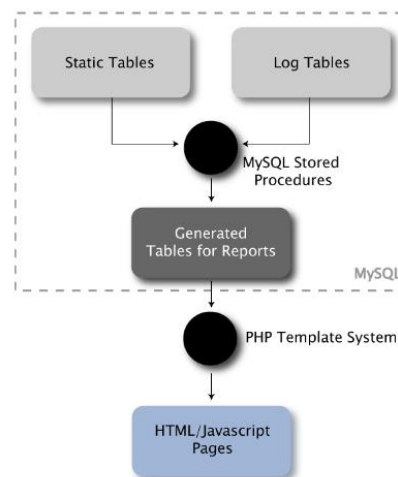


Fig. 19. The ESP System Logical Diagram [24]

IV.METHODOLOGY

To carry out the project, the entire operation is divided into the following major steps.

- a) Analyze requirements
- b) Conduct a literature review

- c) Develop a logical framework
- d) Select tools and frameworks for system development
- e) Design and develop the system
- f) Evaluate the system

The requirements were analyzed and finalized in the first stage to get a clear idea of what should be developed. Once the requirements were finalized, a comprehensive literature review was conducted to understand previous works that had been completed to meet the same requirements. The advantages and disadvantages of existing systems and frameworks were identified based on the literature review.

Based on the findings of the literature review, a complete logical framework was designed as a generic framework that can be applied in almost every remote data collection purpose by taking advantage of existing systems and covering their disadvantages.

After completing the complete logical framework, a specific system was designed and developed for the Department of Census and Statistics to collect data and produce CCPI using that framework. The developed system was then evaluated in various scenarios.

V. SYSTEM DESIGN AND ARCHITECTURE

A. System Architecture

A web-based remote data gathering system was designed and constructed to meet departmental requirements, incorporating features such as data collection from remote areas, maintenance of a centralized database, and accessibility of collected data by predetermined internal and external locations. The system adopts a "N-Tier" architecture, utilizing the Three-Tier design to divide the entire system into three distinct tiers (figure 3)

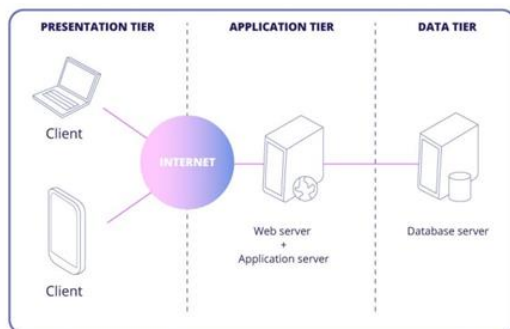


Fig. 20. Three-Tier Web Application Architecture [22]

To fulfill the essential activities, two key system components were designed based on user requirements: a mobile application for remote data gathering and a desktop application for central data storage and job management. A centralized database was deemed crucial, necessitating a database server and a web server for internet data communication. The system components were developed in phases and integrated to create an Internet-based system using HTTP to connect devices, as illustrated in Figure 4.

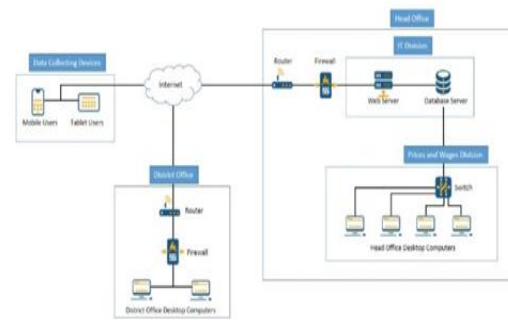


Fig. 21. Proposed CCPI Process Supporting System Diagram

B. Logical framework

The system was composed of three main components: mobile, server, and desktop, each with specific functions tailored to user requirements. Object-Oriented Programming facilitated the design of well-defined interconnected modules for these components. The system components were structured as logical modules, offering reusability and customized operations for specific scenarios. To ensure adaptability for various data collection needs, the system was further divided into logical components, allowing reimplementing or modification as required. This design approach made the system highly configurable and adaptable to remote data collection scenarios.

The system consisted of three major components:

- a) *Mobile Application*: Responsible for collecting remote data, storing it locally, and transmitting it over the Internet.
- b) *Server Application*: Managed internal server tasks such as central data management, access control, and database administration.
- c) *Desktop Application*: Handled acquired data, generated reports, visualized data, and managed agents and devices.

The mobile application encompassed two key component categories: user interfaces for interaction and internal components for underlying tasks. These internal modules were fundamental components of the logical framework and utilized the Android API for hardware access. The internal modules included the JSON Handler for data encoding/decoding, the HTTP Handler for Internet data transfer, the Data Encryptor/Decryptor for AES and RSA encryption/decryption, the Graphic Handler for graphical components, and the Device Manager for accessing device hardware through the Android API.

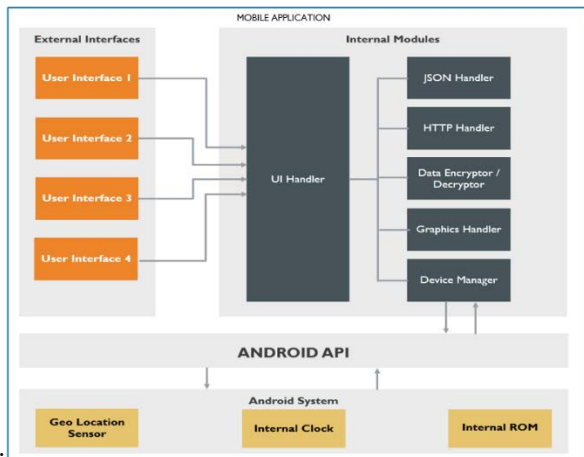


Fig. 22. Mobile Application Logical Framework

The server program was structured into three tiers, each containing numerous modules. The first layer, exposed to the external network, managed incoming HTTP requests, redirecting legitimate traffic to the necessary operational modules. These internal modules served as the logical framework's third layer by using pre-existing code libraries.

The server application provided access to only four custom-built modules:

- d) *Route Handler*: Accepted HTTP requests, filtered and redirected traffic.
 - e) *Access Manager*: Authorized users for data collection.
 - f) *Data Collector*: Gathered data from the mobile app and stored it in the database.
 - g) *App Updater*: Initialized and updated the mobile app for specific data collection tasks.
- Supporting modules included:
- h) *Data Encryptor/Decryptor*: Offered AES and RSA encryption/decryption functions.
 - i) *SQL Database Manager*: Managed MySQL database operations.
 - j) *JSON Data Handler*: Encoded and decoded data in JSON format.

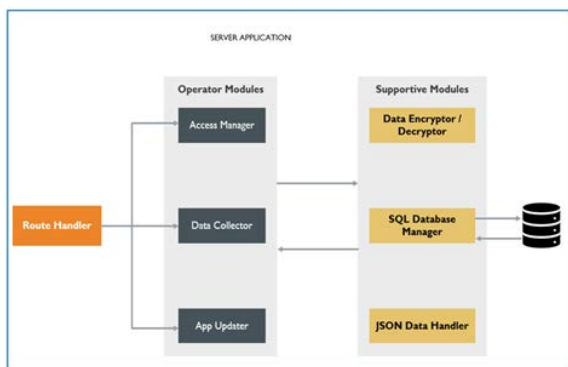


Fig. 23. Server Application Logical Framework

Many layers make up the desktop application. The user interface layer, which interacts with the user, is encompassed by the outermost layer. All the required operations behind the interfaces are executed by the internal module layer. On top of the Windows operating system, the .Net Framework is operated upon by all these modules. In the logical structure, the following essential internal modules were implemented:

- k) *SQL Database Manager*: The interactions between the central MySQL database and the desktop application are maintained.
- l) *Report Generator*: The reports required by the user are generated.
- m) *Data Visualizer*: Visual components for the user interfaces for visualizing data are generated.
- n) *Data Encryptor/Decryptor*: Data encryption and decryption operations are provided using both AES and RSA encryption algorithms.
- o) *Device Manager*: Data is collected from internal hardware by interacting with the underlying operating system.
- p) *Network Manager*: HTTP data is handled, and network tunneling is supported.

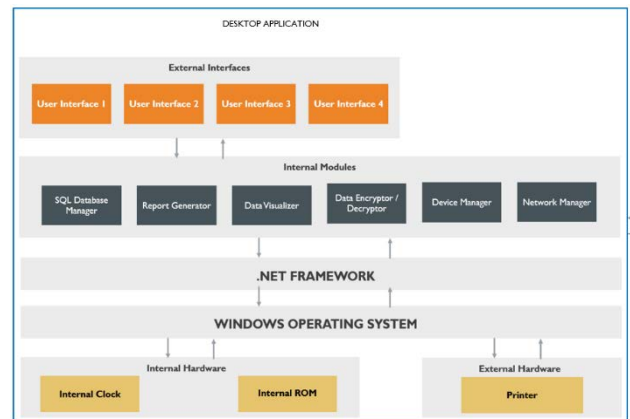


Fig. 24. Desktop Application Logical Framework

To link various system components, the complete system makes use of the World Wide Web service via the Internet. As a result, each system component has a common module for connecting to the World Wide Web through the HTTP protocol. All the other logical components are committed to carrying out internal activities in accordance with the requirements.

C. Database Design

Due to the weekly collection of thousands of data points, the implementation of a database was necessitated to finalize the system. The database was required to possess the following characteristics in alignment with project-specific requirements:

- The collected field data was to be held.
- Log details of system operations were to be stored.
- Statistical operations were to be performed, and data for application reports was to be provided.

To meet these criteria, specific types of database objects, such as database tables and stored procedures, were designed to serve the data store and execute computations, respectively.

Based on the findings of the literature research, it was determined that the ideal approach for designing a system to perform mathematical functions on extensive datasets was to implement these functions as procedures or functions within the database management system (DBMS). The DBMS inherently possessed a set of methods for handling vast data volumes. Consequently, embedding mathematical operations within the database proved significantly more efficient than transferring data to local applications and conducting statistical calculations there. In accordance with the client's specifications, the system was developed to compute statistical functions for the following operations:

- a) Minimum
- b) Maximum
- c) Mean
- d) Geomean
- e) Median
- f) Average

g) Colombo Consumer Price Index (using the Modified Laspeyres formula)

Most of these formulas were standard for dataset calculations. Additionally, the DCS employed the Laspeyres formula for calculating the CCPI, albeit with modifications. This adjusted formula was utilized by the department to determine the CCPI value, as outlined in official publications by the DCS.

$$I_0^t = \sum_{i=1}^n w_i^0 \frac{P_i^t}{P_i^0} \quad \text{Where } t = \text{time, } i = i^{\text{th}} \text{ item}$$

$$I_0^t = \sum_{i=1}^n \left[w_i^0 \frac{P_i^{t-1}}{P_i^0} \right] \frac{P_i^t}{P_i^{t-1}} \quad \text{Where } \left[w_i^0 \frac{P_i^{t-1}}{P_i^0} \right] = w_i^{t-1} = I_i^{t-1}$$

$$I_0^t = \sum_{i=1}^n w_i^{t-1} \frac{P_i^t}{P_i^{t-1}} \quad \text{Where } \begin{aligned} P_i^t &= \text{Price of the } i^{\text{th}} \text{ item in the current period } t \\ P_i^{t-1} &= \text{Price of the } i^{\text{th}} \text{ item in the previous period} \\ w_i^0 &= \text{Base period weight} \\ w_i^{t-1} &= \text{Weight of the } i^{\text{th}} \text{ item in the previous period} \end{aligned}$$

Fig. 25. CCPI Calculation Formula [23]

A comprehensive logical design was created to incorporate this function into the computational stored procedure in the database management system, as shown in the flow chart below.

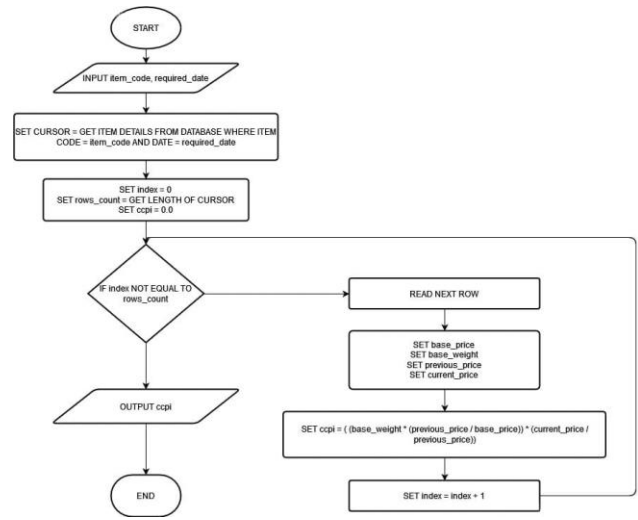


Fig. 26. CCPI Calculating Procedure Flow Chart

Based on the user's request, the data-receiving programs referred to all of these distinct database items. The graphic below represents the logical framework for interaction between the data-receiving application and the database.

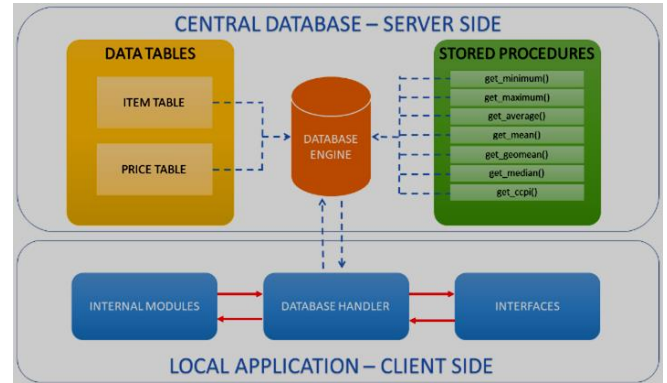


Fig. 27. Customized Statistical Operations Implementation

VI.ADOPTED PROGRAMMING LANGUAGES, FRAMEWORKS, AND TECHNOLOGIES

A. Mobile application development

Mobile application development frameworks were utilized in the process of developing mobile applications in order to make the process of creating generic applications that work with a variety of devices easier. According to Abdullah et al. [4], cross-platform mobile development approaches allowed for single-coding and multi-platform execution, which reduced complexity and saved time. The project team selected Flutter, a user interface toolkit, from among the available cross-platform frameworks because it allows developers to create mobile apps with a single code base that works on both iOS and Android platforms. Flutter is a great option for cross-platform development because of its higher-quality application execution speed and CPU utilization, as demonstrated by studies conducted by Wasilewski and

Zabierowski [5] and Dagne [6]. Its appeal for developing effective, high-performance applications was further increased by its open-source nature and a large number of third-party packages.

B. Server application development

When selecting a programming language for developing server-side scripts, various factors were considered. As outlined in the literature on "Analysis of PHP and Java Languages for Enterprise Applications" [13], server-side applications are expected to exhibit qualities like timeliness, productivity, security, and predictability. Notably, both the client's and developer's environments featured Windows operating system devices. Multiple Windows-based internal servers and web servers were run by the DCS. Therefore, the ease of script development and deployment in the Windows platform was essential. PHP's ease of use and learning, flexibility, ease of integration, affordability, strong open-source community support, and beginner-friendly nature in web development demonstrated the advantages of the LIBXML2 XML parser over Java's Woodstox. In [13][14], PHP was therefore the perfect option for developing server applications.

C. Desktop application development

When developing a desktop application, C#.Net was chosen due to its strong code base, seamless integration with Windows, and efficiency in handling complex functionalities. Microsoft's website highlights C#.Net as the most popular language for .Net development, promoting code reuse and offering extensive libraries. The Visual Studio IDE, a powerful tool, is freely available for independent developers. Other benefits of C#.Net include garbage collection, efficient event handling, interoperability, reflection mechanisms, and easy access to a large number of free "NuGet" packages. Because of its ability to work with remote relational databases, it can be quickly employed in the development of enterprise information systems [15–17].

D. System programming model

Leveraging its inherent benefits, the system was built using the Object-Oriented Programming (OOP) architecture. OOP was used to increase productivity by using reusable code libraries, according to the online article "What is Object-Oriented Programming (OOP)?" on "techtargget.com" [18]. OOP also increased readability, effectiveness, and code reuse, enabling quick updates or improvements without sacrificing flexibility and dependability.

E. Data communication and Security

The first step in establishing a communication infrastructure involved selecting a standard data transport format. The commonly used formats, XML (Extensible Markup Language) and JSON (JavaScript Object Notation), were considered. An article on "techtargget.com" [19] explicitly stated that JSON is superior to XML, citing JSON's simplicity, conversion into JavaScript objects, shorter length, faster reading and writing, and its ability to accommodate data structures such as arrays. Data security was critical for an application collecting and managing sensitive data. The main

solution was encryption. Among the different encryption techniques, researchers at Sri Guru Granth Sahib World University [7] discovered that AES encryption is the most effective and safest. Nevertheless, the symmetric nature of AES encryption created difficulties with key distribution. Asymmetric encryption was considered, but it had communication channel limitations.

To address these issues, a hybrid encryption approach was adopted, combining asymmetric (RSA) and symmetric (AES-256-CBC) encryption. Research by Komal Rege, Nikita Goenka, Pooja Bhutada, and Sunil Mane [10] showed that hybrid encryption with AES and RSA provided robust security, even in inherently insecure environments like Bluetooth.

Implementing this hybrid encryption in the mobile application (developed in Flutter) and server-side scripting (in PHP) required managing two code bases for RSA and AES-256-CBC encryption. Dart's "pointycastle" package facilitated RSA key pair generation, while PHP's "openssl" package handled AES key and IV generation, encryption, and decryption. This approach ensured secure data transmission for the project, maintaining confidentiality during transit.

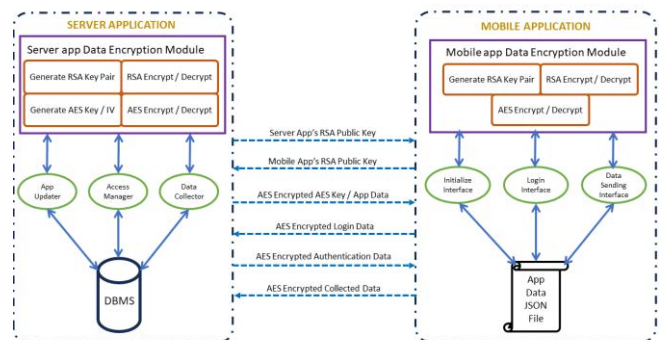


Fig. 28. Hybrid Encryption Mechanism

F. Database development

Relational Database Management Software (RDBMS) was used to create a centralized database in order to meet system requirements. RDBMS was excellent at database operations and was compatible with many different languages. There were options for both licensed and open-source RDBMSs; open-source was cost-effective. As a result, MySQL was chosen for the system. "W3Schools.blog" stated that due to its storage engine, MySQL was free, safe, efficient, and compatible with most major operating systems. The Client-Server architecture of MySQL was incorporated into the system. MySQL's benefits in commercial software, such as its high performance, user-friendliness, scalability, speed, and improved security, were emphasized in Ion-Sorin STROE's literature [21].

VII. EVALUATION AND TESTING

The testing approach was ultimately designed to align with the system's objectives, incorporating four specific goals. Consequently, the entire evaluation process was segmented into four steps, each dedicated to the analysis of a distinct

target. In the conceptual framework for remote data collection within the DCS, a literature review was conducted, encompassing the gathering of relevant literature, identification of advantages and drawbacks, and an examination of the designed conceptual framework. The SRS document served as a reference point for validating the framework's alignment with DCS requirements.

The second phase of the evaluation encompassed the testing of the designed and developed solution to verify its effectiveness within the Prices and Wages division. The testing strategy involved comparing the existing workflow and the proposed workflow with the developed system, focusing on speed, task complexity, accuracy, and security. Data was gathered through interviews and carefully documented. The third phase involved testing the developed system against user specifications.

The experimental setup comprised a well-defined test plan and a series of test cases, spanning mobile devices, web servers, and desktop computers. The developer environment served as the setting for both alpha and beta testing. User feedback is gathered during the last stage. The ideas from stakeholders are crucial in improving the system's performance and adding value.

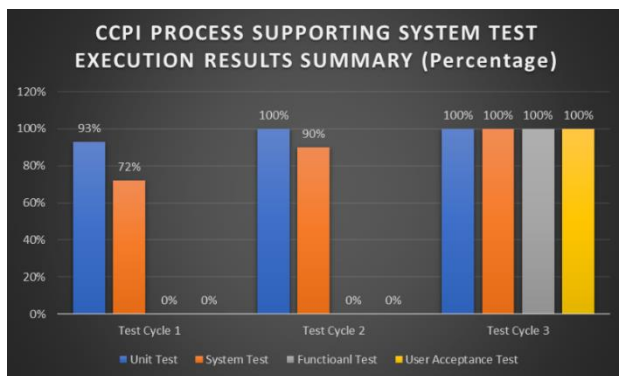


Fig. 29. Test Execution Results Summary

VIII. CONCLUSION

A generic conceptual framework was introduced as a result of this project and a complete system was developed according to that framework, for the Department of Census and Statistics, Sri Lanka. The introduced generic framework can be used in remote data collection scenarios where the data collection is supposed to be done through smartphones or tablet devices.

This framework covers the essential needs of remote data collection. Also, it covers the existing challenges of remote data collection tasks. A series of new technologies and well-planned architecture is the foundation for this framework. The following are the characteristics of the framework.

- a) *Ensure the confidentiality of data:* - Uses the hybrid encryption mechanism with both RSA and AES encryptions.
- b) *High adaptability:* - The framework can be adopted regardless of the platform it is supposed to run. The

logical components can be developed using any programming language and any cross-platform mobile application framework.

- c) *High modifiability:* - The logical components of the framework are well-structured into separate individual components which can be edited without affecting the other components.
- d) *High dynamicity:* - According to the framework, data collection questionnaires can be changed without modifying the internal code structure.
- e) *User-friendliness:* - This framework uses state-of-the-art technologies that can implement rich user interfaces. It can give the user a better experience when using the system.
- f) *High data processing efficiency:* - This framework allows complex mathematical operations using large datasets effectively using the power of the Database Management Systems.

Even though this framework addresses most of the remote data collection issues, some areas can be improved through further studies and research. Specifically cross-platform mobile application development can be challenging in some use cases. Further analysis will be needed to identify the possible solutions for expanding the capacity of this framework.

REFERENCES

- [1] Department of Census and Statistics, <http://www.statistics.gov.lk/InflationAndPrices/StaticInformation/MonthlyCCPI> (accessed Aug. 11, 2023).
- [2] International Journal of Scientific & Engineering Research, Xiaofeng Wang, and Swati V. Chande, "https://bia.unibz.it/discovery/delivery/39UBZ_INST:ResearchRepository/991005773410501241#13235327300001%2520241," bia.unibz.it, Jun. 2014, doi: 10.5815/ijmecs.2014.06.01.
- [3] P. Y. Cao, G. Li, G. Chen, and B. Chen, "Mobile Data Collection Frameworks," Proceedings of the 2015 Workshop on Mobile Big Data, Jun. 2015, doi: 10.1145/2757384.2757396.
- [4] S. Mukhi et al., "An innovative mobile data collection technology for public health in a field setting," Online Journal of Public Health Informatics, vol. 10, no. 2, Sep. 2018, doi: 10.5210/ojphi.v10i2.9114.
- [5] W. S. El-Kassas, B. A. Abdullah, A. H. Yousef, and A. M. Wahba, "Taxonomy of Cross-Platform Mobile Applications Development Approaches," Ain Shams Engineering Journal, vol. 8, no. 2, pp. 163–190, Jun. 2017, doi: 10.1016/j.asej.2015.08.004.
- [6] K. Wasilewski and W. Zabierowski, "A Comparison of Java, Flutter and Kotlin/Native Technologies for Sensor Data-Driven Applications," Sensors, vol. 21, no. 10, p. 3324, May 2021, doi: 10.3390/s21103324.
- [7] "Lukas Dagne Flutter for cross-platform App and SDK development," 2019. [Online]. Available: <https://www.theseus.fi/bitstream/handle/10024/172866/Lukas%20Dagne%20Thesis.pdf?>
- [8] J.G. Singh and S. Supriya, "A Study of Encryption Algorithms (RSA, DES, 3DES and AES) for Information Security," International Journal of Computer Applications, vol. 67, no. 19, pp. 33–38, 2013, doi: 10.5120/11507-7224.
- [9] [8]G. J. Simmons, "Symmetric and Asymmetric Encryption," ACM Computing Surveys, vol. 11, no. 4, pp. 305–330, Dec. 1979, doi: 10.1145/356789.356793.
- [10] Ali E. Taki El Deen, "Design and Implementation of Hybrid Encryption Algorithm," researchgate.net, vol. 4, no. 12, Dec. 2013,

- Accessed: Jul. 22, 2022. [Online]. Available: https://www.researchgate.net/profile/Ali-Takieddeen/publication/307545537_Design_and_Implementation_of_Hybrid_Encryption_Algorithm/links/57c7e53a08aec24de042bf4d/Design-and-Implementation-of-Hybrid-Encryption-Algorithm.pdf
- [11] Komal Rege, Nikita Goenka, Pooja Bhutada, and Sunil Mane, "Bluetooth Communication using Hybrid Encryption Algorithm based on AES and RSA," *citeseerx.ist.psu.edu*, vol. 71, no. 22, Jun. 2013, Accessed: Jul. 22, 2022. [Online]. Available: <https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.402.8867&rep=rep1&type=pdf>
 - [12] Tim Anderson, "Microsoft's OS joins macOS and Linux at the Flutter party, but guess which one performs best? Hint: It's not Windows," *www.theregister.com*. https://www.theregister.com/2020/09/23/flutter_targets_the_windows_desktop/ (accessed Jul. 22, 2022).
 - [13] S. Mukhi et al., "An innovative mobile data collection technology for public health in a field setting," *Online Journal of Public Health Informatics*, vol. 10, no. 2, Sep. 2018, doi: 10.5210/ojphi.v10i2.9114.
 - [14] M. Bello and S. Kissinger, "Analysis of PHP and Java Languages for Enterprise Applications," Sep. 2017. Accessed: Oct. 07, 2022. [Online]. Available: https://www.researchgate.net/profile/Aliyu-Muhammad-publication/320020931_Analysis_of_PHP_and_Java_Languages_for_Enterprise_Applications/links/59c90ac9a6fdcc71929d06f/Analysis-of-PHP-and-Java-Languages-for-Enterprise-Applications.pdf
 - [15] "Top 6 Advantages Of Php Over Other Programming Languages," *GoodWorkLabs: Big Data | AI | Outsourced Product Development Company*, May 23, 2015. <https://www.goodworklabs.com/top-6-advantages-of-php-over-other-programming-languages/>
 - [16] "C# | Modern, open-source programming language for .NET," *Microsoft*. <https://dotnet.microsoft.com/en-us/languages/csharp> (accessed Oct. 07, 2022).
 - [17] "What are the advantages of C#?," *www.dotnet-guide.com*. <https://www.dotnet-guide.com/what-are-the-advantages-of-c-sharp.html> (accessed Oct. 07, 2022).
 - [18] K. Hule and Z. Shaikh, "Object Relational Mapping Tool for C#.NET Framework," *International Journal of Innovative Research in Science, Engineering and Technology*, vol. 03, no. 08, pp. 15185–15191, Aug. 2014, doi: 10.15680/ijirset.2014.0308017.
 - [19] A. Gillis, "What is Object-Oriented Programming (OOP)?," *SearchAppArchitecture*, Jul. 2021. <https://www.techtarget.com/searchapparchitecture/definition/object-oriented-programming-OOP>
 - [20] W3Schools, "JSON vs XML," *W3schools.com*, 2019. https://www.w3schools.com/js/js_json_xml.asp
 - [21] by, "MySQL advantages and disadvantages - W3schools." <https://www.w3schools.blog/mysql-advantages-disadvantages>
 - [22] Ion-Sorin STROE, "MySQL databases as part of the Online Business, using a platform based on Linux." [Online]. Available: <http://www.dbjournal.ro/archive/5/5.pdf#page=4>
 - [23] Y. Luchaninov, "Web Application Architecture: Choosing the Right Type in 2021," *MobiDev*. <https://mobidev.biz/blog/web-application-architecture-types>
 - [24] "BULLETIN OF SELECTED RETAIL AND PRODUCER PRICES," *Statistics.gov.lk*, 2022. http://www.statistics.gov.lk/InflationAndPrices/StaticInformation/Bulletins/BULLETIN_OF_SELECTED_RETAIL_AND_PRODUCER_PRICES2017-2020 (accessed Oct. 26, 2022).
 - [25] C. Fleming and S. Goings, "Statistical Analysis Enhancement Report Colorado School of Mines Computer Science Field Session 2008 Data Verity #1," 2008. Accessed: Oct. 27, 2022. [Online]. Available: <https://cs-courses.mines.edu/csci370/FS2008/DV1Final.pdf>
 - [26] S. Gejibo, F. Mancini, K. A. Mughal, R. A. B. Valvik, and J. Klungsoyr, "Secure data storage for mobile data collection systems," *Proceedings of the International Conference on Management of Emergent Digital EcoSystems - MEDES '12*, 2012, doi: 10.1145/2457276.2457300.
 - [26] L. H. Iwaya, "A security framework for mobile health data collection.," *www.teses.usp.br*, Feb. 11, 2014. <https://www.teses.usp.br/teses/disponiveis/3/3141/tde-23122014-143956/pt-br.php> (accessed Oct. 27, 2022).

Rich Computer Network Infrastructure for the University of Vocational Technology (UoVT)

H K S H Premadasa
Innodata Lanka Pvt Ltd
No:5, Mihindu Mawatha
Colombo 12, Sri Lanka.
spremadasa@innodata.com

V B Godagama,
Orel Corporation Pvt Ltd
Orel Park,
Megoda, Sri Lanka.
vishwa@orel.com

H P A I Pathirana,
Department of Software Technology
University of Vocational Technology
Rathmalana, Sri Lanka.
pathirana@uovt.ac.lk

Abstract — A robust and efficient university network infrastructure plays a pivotal role in fostering seamless academic pursuits for both students and academic staff. Within the precincts of the university's computer laboratories, the provision of wired network accessibility is imperative to enable students to engage with digital resources and connect with the shared storage drive, thereby facilitating the secure preservation of their academic and personal endeavors. Furthermore, the ubiquitous availability of the Wi-Fi network across the university premises assumes paramount significance, ensuring that students can engage in university-related activities without encountering disruptive interruptions. Concurrently, the academic faculty necessitates unimpeded access to the wired network to fulfill their professional obligations. Simultaneously, their access to the Wi-Fi network should remain unhindered, affording them the flexibility to seamlessly integrate digital tools and resources into their instructional practices. The University of Vocational Technology (UoVT) has a network infrastructure that encompasses these fundamental requisites, thereby catering to the essential needs of both students and faculty members. This study embarks on a comprehensive exploration and assessment of the existing network tools and technologies at UoVT. The primary objective is to identify and surmount the challenges posed by the current network framework. By delving into this endeavor, the research aims to propose an innovative network design that leverages cost-effective and pertinent technologies. These design recommendations are poised to enhance the efficiency, reliability, and scalability of the university's network infrastructure, optimizing its capacity to support the diverse and evolving demands of academic endeavors. Through the discerning analysis of prevailing network paradigms and the strategic integration of advanced solutions, this research contributes to the ongoing enhancement of the academic landscape at UoVT.

Keywords—wired/wireless network, roaming, ubiquitous access

I. INTRODUCTION

University networks constitute vital conduits for seamless academic operations, facilitating wired connectivity within computer labs for resource access and secure data storage.

Ubiquitous wireless network availability empowers uninterrupted university activities. Faculty benefits from both wired access for professional duties and unencumbered Wi-Fi use. The University of Vocational Technology's network embodies these core facets, fostering an environment conducive to learning and research. This investigation scrutinizes existing network tools and technologies, seeking to optimize infrastructure efficiency and propose a cost-effective, innovative network design. The ensuing blueprint aims to elevate network performance, accommodating evolving academic demands and enriching the educational experience. In this research, that blueprint is introduced addressing the research problem, and the following objectives are achieved in this research as solutions to identified problem statements.

- I. To identify the performance gap of the existing UoVT network infrastructure
- II. To increase the use of the UoVT network among students effectively for better academic experience.
- III. To utilize the existing UoVT network infrastructure for a better service delivery.
- IV. To introduce evolving affordable concepts to adapt to existing network infrastructure.
- V. To introduce a wireless network access for guest user without introducing any threat/vulnerability.

Subsequently, the introduction of concepts is aimed at facilitating the implementation of a high-quality standard network infrastructure at a cost-effective rate for the university, ultimately leading to the enhancement of the quality of education provided.

II. LITERATURE REVIEW

The context of this issue revolves around assessing the rationale behind enhancing the university's network infrastructure, drawing upon scholarly publications as primary

information sources. Furthermore, the discussion delves into contemporary technologies in the ever-evolving global landscape to provide a comprehensive comprehension of their practical integration.

A. Background study

In today's academic landscape, robust computer network infrastructure in universities plays a crucial role, serving as the foundation for various educational, administrative, and research functions [1]. This review explores the fundamental aspects and advantages of advanced computer network implementation in higher education. It analyzes the evolving technological environment in universities and its profound impact on pedagogy, research, scholarship, and institutional administration. Universities have shifted from primarily supporting administrative tasks to encompassing vital academic and research functions due to the increasing reliance on digital assets, online education, and collaborative research in general.

However, administrative efficiency remains essential for universities' smooth operation [2], [3]. Advanced network infrastructure facilitates centralized data management, student information systems, and enterprise resource planning (ERP) systems, improving tasks like admissions, registration, financial management, and human resources. Despite its benefits, universities face challenges such as cyber security threats, scalability issues, and budget constraints. Striking a balance between expanding network capabilities and ensuring data security remains a constant concern for administrators.

In the digital age, rich computer network infrastructure is indispensable, reshaping pedagogy, research, scholarship, and administrative efficiency [2]. As universities adapt to evolving technology, managing advanced network infrastructure wisely is crucial for long-term success. Further exploration is needed to find optimal strategies for maximizing benefits while addressing the challenges inherent in maintaining this critical infrastructure.

B. Technologies in the Contemporary World

1) *Wired network*: The university's wired network constitutes a foundational cornerstone of academic endeavors, affording students situated within designated computer laboratories unhindered access to a plethora of digital scholarly resources, coupled with the secure archival of their academic outputs[4]. This comprehensively designed wired infrastructure guarantees a reliable and high-capacity connection, paramount for the execution of data-intensive scholarly tasks. Additionally, the academic faculty heavily relies upon this intricate network architecture to discharge their professional obligations, thereby facilitating streamlined communication channels and the judicious utilization of pertinent educational materials. Thus, the robustness of the university's wired network underpins an education-supportive environment, adeptly accommodating the evolving pedagogical landscape.

2) *Wireless network*: The term "wireless" refers to a mode of telecommunications in which electromagnetic waves are employed to transmit signals across a portion or the entirety of the transmission path, reducing the necessity for physical cables. Wireless transmission offers numerous advantages when compared to wired communication. These advantages encompass the ease of network installation, operation, and maintenance, as there are no associated cabling expenses [5]. The chosen wireless technology for the network design is 802.11, which is an advanced set of specifications for Wireless Local Area Networks (WLANs) developed by a consortium within the Institute of Electrical and Electronics Engineers (IEEE). Utilizing Wi-Fi, mobility is less constrained, and it can provide extensive coverage over significant distances.

III. The university's wireless network constitutes an indispensable element of the academic ecosystem, providing students and faculty with pervasive connectivity across campus [6]. This wireless infrastructure empowers students to engage seamlessly in learning activities, enabling ubiquitous access to digital resources and facilitating collaborative endeavors. Faculty members benefit from the flexibility of this network, enhancing their instructional methodologies through real-time data dissemination and interactive pedagogies. The robustness of the university's wireless network is integral to modern education, accommodating the diverse demands of a technologically driven pedagogy while fostering an enriched scholarly environment conducive to dynamic knowledge exchange.

1) *Wireless Local Area Network Controller (WLC)*: The implementation of a wireless LAN controller within a university setting constitutes a strategic imperative for seamless network management and optimized connectivity [7]. This technological apparatus serves as a centralized command center, orchestrating the intricate operations of the wireless network. By efficiently managing access points, bandwidth allocation, and security protocols, the controller ensures uniform coverage across campus, fostering uninterrupted access to digital resources. Furthermore, it facilitates the enforcement of stringent authentication measures, safeguarding sensitive academic data. The integration of a wireless LAN controller embodies a forward-looking approach, enabling the academic institution to effectively adapt to evolving network demands while providing an enriched digital environment conducive to scholarly pursuits.

2) *Dynamic Host Configuration Protocol (DHCP)*: In a university network, DHCP plays a pivotal role in simplifying and optimizing network management [8]. By dynamically assigning IP addresses to devices, DHCP eliminates the need for manual configuration, enabling seamless connectivity for students, faculty, and staff. This automated allocation conserves IT resources and reduces the likelihood of IP conflicts. Moreover, DHCP enables efficient

utilization of the IP address pool by releasing addresses from inactive devices. This centralized control enhances security through easier tracking of connected devices. In essence, DHCP streamlines network administration, fosters smoother communication, and supports the dynamic and ever-evolving nature of a bustling university environment

3) *Virtual Local Area Networks (VLANs)*: Within the university context, VLANs hold significant import as strategic network constructs [9]. By partitioning the physical infrastructure into discrete logical segments, VLANs enable refined control over data traffic, providing efficient resource allocation and heightened security protocols. By grouping devices based on shared attributes, such as academic departments or research clusters, VLANs facilitate streamlined data administration and elevated intercommunication. This judicious deployment optimizes network performance, curtails congestion, and fortifies the preservation of sensitive academic and research data. Overall, VLANs serve as a linchpin in fostering a scholarly environment characterized by secure, efficient, and interconnected digital discourse.

4) *Remote Authentication Dial-In User Service (RADIUS)*: Within the academic realm of a university, the RADIUS server holds paramount significance within the Wireless Local Area Network (WLAN) infrastructure [10]. Operating as a central authentication and authorization framework, the Radius server plays a critical role in ensuring secure and controlled network access. It meticulously validates user credentials before granting entry, thereby safeguarding confidential academic information from unauthorized breaches. Through seamless integration with existing identity management systems, the Radius server establishes a unified and coherent authentication process, harmonizing user access across diverse campus resources. This strategic deployment not only fortifies the WLAN's security posture but also streamlines user management, enhancing administrative efficiency. By facilitating personalized access based on user roles and affiliations, the Radius server optimizes network utilization and contributes to an environment that fosters collaborative learning and research, underpinned by robust data integrity and uncompromised privacy.

5) *Active Directory*: Active Directory (AD) assumes a pivotal role within the domain controller infrastructure [4]. Functioning as a centralized directory service, the AD facilitates user management, resource allocation, and security policies. It encompasses a structured hierarchy of objects that encompass users, devices, and resources, fostering a cohesive and organized digital ecosystem. Within this framework, the domain controller governs authentication, authorization, and access control, ensuring that only authorized users gain entry to network resources. Through integration with various services, such as Single Sign-On (SSO), the AD streamlines user access across a plethora of university systems, enhancing

operational efficiency. This strategic implementation optimizes resource utilization, enforces uniform security policies, and simplifies administrative tasks, ultimately contributing to a secure, interconnected, and streamlined academic environment conducive to collaborative learning and scholarly exploration.

6) *Secure Network Implementation*: this is of paramount importance in the university network environment by considering multiple different stakeholders using the network [11]. Universities handle vast volumes of sensitive data, including student records, research findings, and financial information. A secure network safeguards this information from malicious actors, preventing data breaches and unauthorized access to preserve the credibility of the university name. Moreover, in an era of online learning and collaboration, network security ensures uninterrupted access to educational resources and virtual classrooms, maintaining the integrity of academic activities. Beyond data protection, it also promotes a safe and productive digital ecosystem for students and staff. With cyber threats continually evolving, robust network security measures are indispensable in preserving the trust, reputation, and operational efficiency of universities. Nevertheless, it is better to prepare for such a situation by maintaining the backups on sensitive information

7) Use of the Computer Network at Universities

8) Computer networks play a crucial role in universities, providing essential services to students, faculty, and staff. Here are some common uses of computer networks at universities:

9) *Single Sign-On (SSO)*: Many universities implement Single Sign-On systems, allowing users to log in once and access multiple services without having to log in again [12]. This simplifies the user experience and enhances security. Once authenticated, users can access various resources such as email, learning management systems (LMS), library databases, and more.

10) *Learning Management Systems (LMS)*: Platforms like Moodle, Canvas, Blackboard, or Sakai are widely used to manage and deliver course content [13]. These systems facilitate online learning, enabling instructors to share resources, assignments, quizzes, and grades. Students can access these materials, submit assignments, and communicate with professors and peers through the LMS.

11) *Email and Communication*: University-wide email systems are essential for communication among students, faculty, and staff [13]. These systems often include features such as calendars, contact lists, and collaboration tools. University email addresses are also used for official communications and announcements.

12) *Research and Collaboration*: Computer networks enable collaboration among researchers, both within the university and with external partners [14]. Researchers can share data, collaborate on projects, and access online resources and databases. High-performance computing clusters and storage systems are often connected to the university network to support complex research computations.

13) **Library Resources:** Universities provide online access to vast digital libraries, journals, and databases [15]. Students and faculty can access these resources remotely, allowing them to conduct research and access academic materials from anywhere with an internet connection.

14) **Virtual Private Network (VPN):** Universities often provide VPN services to secure network connections, especially for accessing sensitive information or resources from off-campus locations [16]. This is crucial for remote learning, research, and collaboration.

15) **Wi-Fi Networks:** Wi-Fi is prevalent across university campuses, providing students and staff with internet access on laptops, tablets, and smartphones [5]. This enables flexibility in studying and working from various locations on campus.

16) **Administrative Systems:** Computer networks support various administrative functions, including student information systems, human resources systems, financial systems, and other enterprise applications that help manage university operations [2].

17) **Online Registration and Student Portals:** Universities use computer networks to facilitate online registration, course selection, and provide students with access to their academic records, schedules, and other important information through web-based portals [1].

IV. RESEARCH METHODOLOGY

In this section, we explain how we set up our experiment and the methods we employed for measurement. We also discuss the metrics we monitored during our experiment and acknowledge the assumptions and constraints we faced while working in a real-world setting where certain variables were challenging to control.

A. Methodology

After an extensive literature review, this study aimed at gaining insights into current trends in computer network infrastructure development in the university environments. Additionally, an examination of the university's existing network infrastructure is conducted through interviews with network administrators, faculty, and non-academic staff, along with the distribution of questionnaires to students. Subsequently, the gathered data is subjected to multifaceted analysis to identify strategies for enhancing the university's network implementation. Consequently, several recommendations emerge for optimizing the university's network infrastructure.

Additionally, a questionnaire was administered to university undergraduates to gain insights into their utilization of both wired and wireless networks. Moreover, the same questionnaire was employed to gauge the expectations of undergraduates regarding their interactions with the computer

network. By referring to all the aspects of the use of the network, a set of recommendations is made for better user experience in a well secure manner.

B. Research Design

Figure 1 provides a visual depiction of the experimental design, delineating the sequential execution of experimental procedures as outlined in the methodology. Each step is explicitly illustrated to elucidate its specific role and contribution throughout the course of the experiment.

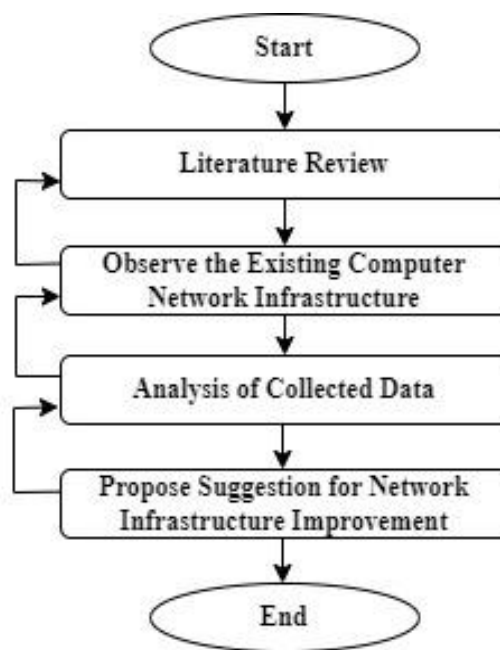


Figure 1: Research Design

V. OBSERVATION OF EXISTING NETWORK INFRASTRUCTURE

The wired network connectivity is available for the place where the physical wall port accessibility is available, because the IP address assignment happens automatically via DHCP. As a result, the university wired network accessibility is limited for the number of existing wall ports available at maximum. However, at present, the wall ports are placed in the computer labs, library, staff offices and classrooms only, and it is not flexible to scale up the wired network addressing the present demand to access the network in open areas. Further, students have a grievance to have the Internet access, as they have accessibility via labs, library only. Eventually, there is a demand for using the wireless network.

Wireless network is in demand among all the stakeholders, but it has been limited by assigning a password for each access point not allowing everyone to access. Academic staff has access to the identified wireless network via its Service Set Identifier (SSID) with a given password, and they do not have access to any other wireless access point without a password. Furthermore, there is no wireless network access for the student at all, and there is an increasing demand to access

wireless networks. As a result, the standards are compromised in the university environment.

Moreover, it is better to have domain controllers at least at the computers in the laboratory for access control, and the shared space is also very useful for everyone to maintain academic material safely at one place. However, the present network infrastructure has not facilitated either of the above two services in practice. As a result, everyone uses the common administrator login to access the computers in the laboratory, and they must keep a copy of their work in their own secondary storage to be on the safe side as there is no secure shared storage space over the storage servers.

Nevertheless, the existing firewall is a software based firewall due to constraints with allocating budget, but it serves the purpose minimally. In due course, the university web, university admission portal, Moodle based online learning management system etc. are not deployed in house due to the potential exploitation of local network via public access. Further, the Examination Information Management (EMIS) and leave/attendance management system are deployed in the in house server, and it is accessible only via university network. Those systems are user friendly, if there is public access to those systems, but those are not arranged due to security concerns. A single instance of a server facilitates the above services; EMIS, and leave/attendance management system, and this introduces a Single Point of Failure (SPOF) by disrupting the smooth functionalities. When a SPOF fails, it can trigger cascading issues, resulting in network downtime, data loss, or service interruptions.

Utilizing virus guards in a university environment is of paramount importance in safeguarding both data and the academic community, but the UoVT is not using a standard virus guard for the university computers which are shared by multiple students and staff. Instead, different individuals utilize different virus guards to reduce the risk.

The existing VLAN is useful for sharing the Internet bandwidth among different physical locations assuming users are equally distributed, so everyone can have fair access to the Internet. Although the existing VLANs implementation serves the above purpose, there is no effective implementation of the VLANs with meaningful segmentation of users and secure concepts. It is better to evaluate the existing VLANs in detail to propose recommendations.

VI. RESULTS

A. Outcome of the interview with stakeholders

The first interview was conducted with the network administrator of the university to obtain detailed understanding of the existing network. Then, the academics of the university were interviewed for their experience of the use of the existing university network.

As per the network administrator, at present, there are a few servers maintained at the server room for in-house use; Active directory domain controllers, Examination Management Information System (EMIS), Attendance management Server, Backup Server, Network Attached Server (NAS), Windows Server Update Service (WSUS). As a result, in-house services are not introducing much traffic to the network, and the existing network is utilized more on accessing the Internet. Moreover, the security of the internal network is preserved by implementing a software firewall. The present network design is mainly based on VLANs and there are two core switches, multiple distribution switches and many access switches within the network. The two core switches are placed on two main buildings which facilitate dynamic IP address assignment via Dynamic Host Configuration Protocol (DHCP). Distribution switches are coordinating in-between the core switch and Access switches to facilitate end users.

Structured interviews were undertaken, engaging five academicians and two non-academic individuals, in order to discover their experiences pertaining to the utilization of the present network infrastructure. Academic personnel exhibit their preference for accessing the university network via a variety of computing devices, including laptops, desktops, and mobile devices. The current wired network infrastructure adequately caters to their needs with regard to desktop and laptop usage, boasting stable connectivity and satisfactory network speeds. Conversely, non-academic staff exclusively relies upon their official desktop workstations for utilizing wired networks for connectivity. In the context of wireless networks, academicians predominantly employ them for their laptops. The prevailing Dynamic Host Configuration Protocol (DHCP) implementation facilitates convenient wireless network use. Nonetheless, the existing wireless network architecture suffers from segmentation of users based on their physical location through VLAN technology, and multiple Service Set Identifiers (SSID) have been assigned just to identify the physical area, each necessitating authentication via password, restricting users to specified access points dedicated to specific SSIDs. This limitation inhibits the seamless use of wireless networks beyond designated access points, which is a concern shared by academicians. In summary, both wired and wireless network usage experiences have been generally positive, although the desire for a seamless roaming capability across the university campus is a notable concern among the interviewed stakeholders due to the poor flexibility.

B. Outcome of the questionnaire with students.

The questionnaire was shared with the students via the group emails at the Faculty of Information Technology, the UoVT via a Google form. This sample is selected based on convenience sampling among the students of the university. Then, there were 184 responses for the questionnaire and this study is based on that.

At present, the wired network is available in the university, and 69.5% of the responses are not frequently using the wired network as per Figure 2. Further, in Figure 3, 70.7% of them use the computer network at the computer laboratory. It describes the use of the network had been limited when students has the lectures/practical at the computer labs.

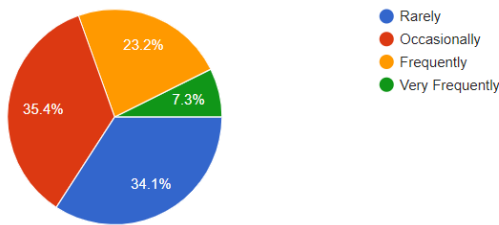


Figure 2: The Use of Wired Network

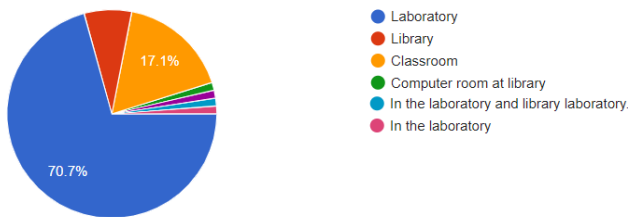


Figure 3: The Regular Venue of Using Wired Network

As per Figure 4 illustrates, 74.4% of the students are satisfied with the stability of wired networks at different venues; computer laboratories, library, classroom.

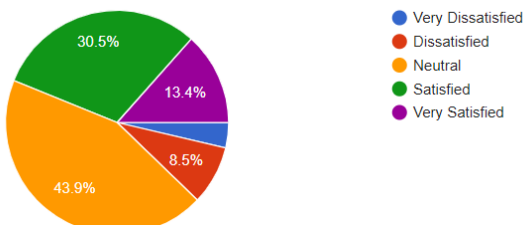


Figure 4: The Reliability and Stability of the Wired Network

As the present university network fulfills the essential requirement of the university, 90.2% of the students are either satisfied or natural in the use of the wired network by referring to Figure 5. It is convinced that the university provides a rich wired network.

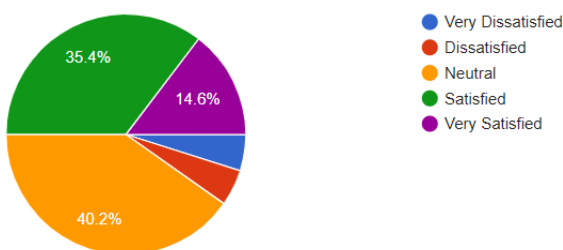


Figure 5: The Satisfaction of Use of Wired Network

However, students are preferred to use the wireless network at the university as per the findings illustrated in Figure 6, although the existing wireless network is not accessible for the students. Students have access to the wired network only.

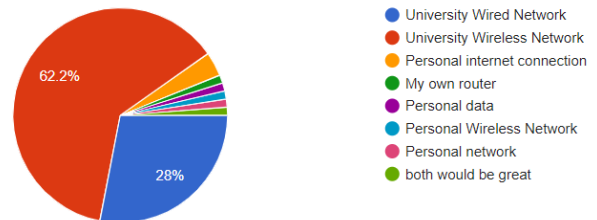


Figure 6: The Preference of Use of Network

As per the information collected via the questionnaire, the above discussion is further extended towards the discussion section also together with the data collected via the interviews.

VII. DISCUSSION

A. Interpretation of the Result

The existing network serves the purpose of the university as per the information collected, and the users are satisfied in the use of wired network. However, there is enough room for the improvement of the network by utilizing the existing infrastructure. The existing wired network is available at the computer laboratories, the library, the classrooms and workbench of the staff. However, the existing number of ports is not adequate to cater the present demand. Further, it is important to have wall ports in the open environment for anyone to access. Those ports can be assigned to separate guest VLAN which has only the Internet access.

In the physical network, although the entire network is logically apart by using VLAN technology, there is no consideration of the different administrative divisions for assigning users into the VLANs. Instead, VLANs are used to share the bandwidth fairly. To overcome the issues related to VLAN, it is essential redesign the existing wired network design by referring the different group of staff into different VLANs and different divisions such as library, computer labs, classrooms, guests etc into different VLANs. Then, the privileges are configured for the VLANs accordingly via Access Control List (ACL). Eventually, the level of security is enhanced while providing the flexibility to access network even for guests.

In the university network, the DHCP has been configured through the layer 3 switch, and it serves the purpose. However, the implementation of DHCP server separately improve the quality of service via mac-address filtering, improved way of IP-reservation etc. The proposed solutions encompass a dual-component approach, comprising servers tailored for demand management and services designed to cater to the specific requisites of the university. In scenarios characterized by

heightened demand, the imperative of redundancy becomes evident, aimed at ensuring optimal network uptime while minimizing instances of network downtime. This necessitates the implementation of dual domain servers, each operating independently, thus mitigating the risk of service disruption. Concurrently, the essentiality of network continuity is further underscored through the employment of two dedicated servers dedicated to the DHCP service. This protocol facilitates the allocation of IP addresses while enabling reservations based on MAC addresses. To effectively accommodate the Increasing volume of educational resources, including learning materials and assignments, the integration of a Network Attached Storage (NAS) system assumes significance. This repository not only ensures sufficient storage capacity but also serves as a platform for the seamless submission and retrieval of assignments, constituting a cornerstone of academic engagement.

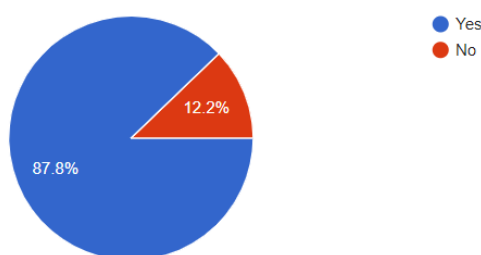


Figure 7: Preference of Use of Wireless Network

The wireless network is in demand. Academic staff emphasizes the importance of implementing wireless accessibility across the university. Nevertheless, as illustrated in Figure 7, a substantial majority of students, specifically 87.8%, exhibit a preference for wireless networks. Given the pronounced preference for wireless networks among the students, it is strongly advocated for a significant overhaul and enhancement of the university's wireless network infrastructure.

To establish rich wireless network, within the firewall, profiles are established, each endowed with specific access levels. The Active Directory (AD) system encompasses both users and Organizational Units (OUs), assigning approved access levels accordingly. It is useful for introducing SSO infrastructure combining the entire services offer.

By utilizing the existing physical resources, the RADIUS server assumes the role of an intermediary, facilitating the connection between Wireless LAN Controller (WLC) requests and the Active Directory. The WLC itself is meticulously configured with essential parameters such as VLAN settings, Service Set Identifier (SSID) specifications, Access Point details, and the enumeration of MAC Addresses pertaining to authorized devices.

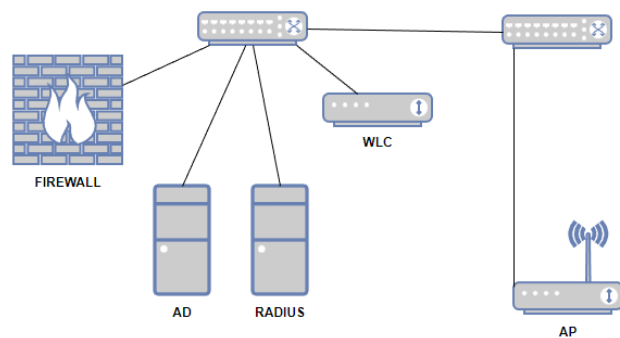


Figure 8: The proposed wireless network infrastructure

After the implementation of Wi-Fi connectivity, users are provided with the capability to select the associated Service Set Identifier (SSID) and subsequently log in by utilizing the provided credentials. The initial step involves the validation of these credentials through authentication with the Domain Controller (DC), followed by passage through the RADIUS server and Firewall. This validation process serves to verify whether the selected VLAN is permissible for the user and, if so, grants the user predetermined access privileges.

Throughout this sequence, the Wireless LAN Controller (WLC) fulfills the essential role of determining the appropriate VLAN selection and assigning the relevant Dynamic Host Configuration Protocol (DHCP) IP address to the user's device, facilitating the establishment of a network connection. Once the IP address is assigned, the user's device becomes associated with the designated SSID, thus enabling access to the authorized network resources and services.

For the information security, at present, the existing software firewall serves the purpose at minimum level, but it is highly recommended to implement hardware firewalls. This comprehensive approach underscores an unwavering commitment to network resilience, data integrity, and cyber security within the university domain. Such secure environment permits deploying university web site, admission portal inside the university, and it is possible to grant public access for the leave/attendance system, EMIS. Moreover, standard virus guard is not available at the moment, instead low-level virus guard is utilized for free. Eventually, the entire computer network is at risk of being infected by the viruses. By regularly updating and maintaining these safeguards, universities not only protect their digital assets but also foster an environment of trust and security. Furthermore, virus guards promote responsible online behavior among students and staff, reinforcing the institution's commitment to a safe and resilient academic ecosystem.

As per the discussion here, there is enough room for the improvement of the present network by utilizing the existing infrastructure and by adding new features to it.

B. Proposed solution

After having complete understand about the existing network and the idea about possible solution to introduce rich network, the prioritized recommendations are made for consideration to implement as follows;

- Implement domain controller (AD service) with essential policies for users and computers, then enroll all the staff/students at the university as the users with credentials.
- Reconfigure the VLANs in a meaningful manner while incorporating ACL for different user groups including guests.
- Reconfigure the existing wireless network through different STUDENT-VLAN allowing students to access via common password without taking much time.
- Improve the wireless network with WLC, AD, RADIUS and AP and provide multiple SSID as the wireless network solutions.
- Implement DHCP server on existing infrastructure to centrally manage the IPs.
- Implement hardware firewall for truly secure networking environment in the university.
- Maintain the redundant server for critical servers as required by considering the affordability; AD, DHCP, NAS etc.

Once the above list of recommendations is considered, the top priorities are at the top by utilizing the existing network, then the bottom ones are considered after implementing top once due to budget constraints.

VIII. CONCLUSION

In this research, the present university network is analyzed to understand the need of the rich computer network infrastructure, and the proposed recommendations are listed based on the identified priorities. Those recommendations are focused on cost-effective implementation of rich network by utilizing the existing network infrastructure. As a result, top ones can implement with immediate effect on existing network infrastructure, and there should be extra budget to implement lowest ones. This would be stepwise process, and it is possible to have complete rich computer network for the university, once all the recommendations are implemented.

REFERENCES

- [1] N. Selwyn, "The use of computer technology in university teaching and learning": a critical perspective. *Journal of computer assisted learning*, vol 23, no .2, 2007, pp. 83-94.
- [2] M.A. Adeoye, "Management information system: Tools for achieving administrative effectiveness in private universities." *Indonesian Journal of Multidisciplinary Research* 3.1, 2023, pp. 65-72.
- [3] B. Gao, "Efficiency of Computer Application on Administrative Affairs of Universities." In 3rd International Symposium on Social Science (ISSS 2017), 2017 pp. 655-658. Atlantis Press.
- [4] N.C. Iyer, A.M. Kabbur, and H.G. Wali, "Implementation of Active Directory for efficient management of networks". *Procedia Computer Science*, 172, 2020, pp.112-114.
- [5] N.L. Shane Byrer, and R.M. Jackson, November. "Wired for wireless: extending your network and expanding your reach". In *Proceedings of the 30th annual ACM SIGUCCS conference on User services*, 2002, pp. 286-287.
- [6] G. Durgesham, M. Naseer, S. Srinivas, N. Fatima, and S.N.Abdul, "A qualitative study on challenges of higher education in India." *Journal homepage: www.ijrpr.com* ISSN, 2582, 2022, pp.7421.
- [7] T. Henderson, D. Kotz and I. Abyzov, September. "The changing usage of a mature campus-wide wireless network". In *Proceedings of the 10th annual international conference on Mobile computing and networking*, 2004, pp. 187-201.
- [8] T.N. Turna, and K. Fatima, "To Design and Configure University Area Network using EIGRP and DHCP". *International Journal of Computer Applications*, 2021, pp.888-927.
- [9] S. Vakharkar, and N. Sakhare, "Critical analysis of virtual LAN and its advantages for the campus networks". In *Mobile Computing and Sustainable Informatics: Proceedings of ICMCSI 2021*, pp. 733-748. Springer Singapore.
- [10] A. Enaceanu, and G. Garais, 2010. "Cost Effective RADIUS Authentication for Wireless Clients. *Database Systems*", pp. 27.
- [11] M.N.B. Ali, M.E. Hossain, and M.M.Parvez, "Design and implementation of a secure campus network". *International Journal of Emerging Technology and Advanced Engineering*", vol. 5, no. 7, 2015, pp.370-374.
- [12] S. Suriadi, E. Foo, and Jøsang, A. "A user-centric federated single sign-on system". *Journal of Network and Computer Applications*, vol. 32 no. 2, 2009, pp.388-401.
- [13] A. Ghosh, A. Nafalski, Z. Nedic, and A. P. Wibawa, "Learning management systems with emphasis on the Moodle at UniSA". *Bulletin of Social Informatics Theory and Application*, vol. 3 no.1, 2019, pp. 13-21.
- [14] E. Johnston, C. Burleigh, and A. Wilson. "Interdisciplinary Collaborative Research for Professional Academic Development in Higher Education". *Higher Learning Research Communications*, vol. 10 no. 1, 2020, pp. 62-77.
- [15] R. Ilahi, I. Widiaty, D. Wahyudin, and A.G. Abdullah. "Digital library as learning resources". In *Journal of Physics: Conference Series*, vol. 1402, no. 7, 2019, pp. 77-144.
- [16] D. Deshmukh, and B. Iyer. "Design of IPSec virtual private network for remote access". *International Conference on Computing, Communication and Automation (ICCCA)*, IEEE, 2017, pp. 716-719.

Conceptualizing the "Quality Teledrama" as the future of Sri Lankan Teledrama Art and Cultural Industry for 2023-2032, fifth decade

Senesh Dissanaikē Bandara
Department of Sinhala and Mass Communication
University of Sri Jayewardenepura
Nugegoda, Sri Lanka
Email: seneshdissanaikēbandara@sjp.ac.lk
ORCID: 0009-0003-4044-4917

Abstract— Sri Lankan 'Teledrama', a cultural industry with a four-decade evolution, has experienced a decline in artistic quality in the last decades due to consumerism and mis-commercialization. The genre's original progressive artistic qualities have been replaced by consumerism, leading to a disconnect between elite viewers and the new generation. This research study focuses on the evolutionary peculiarities of Sri Lankan 'Teledrama' influenced by Sri Lankan media policies. The study used a mixed research methodology, combining analytical and empirical approaches, and used sources such as books, research papers, commission reports, acts, research theses, and periodicals for data collection. The research identified four paradigm shifts: the establishment of "True" Sri Lankan Teledrama in the 1983-1992 decade, the stability of "True" Sri Lankan Teledrama in the 1993-2002 decade, and the challenge of "Fake" Mega Dailies in the 2003-2012 decade. The fourth paradigm shift, the 2013-2022 decade, was identified as the catastrophic decade of "Fake" Mega Dailies diminishing the quantity of "True" Sri Lankan Teledrama. The main reason for this situation is the uncertain media policies implemented by every regime, which are directly responsible for the decline. To ensure the sustainability of Sri Lankan 'Teledrama' as a cultural industry and national art expression, the study proposes a consistent media policy titled 'Quality Teledrama Decade-2023-2032' for the next decade.

Keywords— Mass Media Policies, Teledrama, Genres, Paradigm Shift, Quality Television, Unique Identity

1. INTRODUCTION

The study aims to compare the unique characteristics of Sri Lankan 'Teledrama' with previous television media program genres, focusing on the reasons that influenced its evolution. It also analyzes contemporary Sri Lanka's electronic mass media policies related to television and the impact of mass media policies on the evolution of the genre. The scope of the study covers four decades, starting in 1983 and concluding in 2022.

The research study provides an introduction, outlines the research problem, objectives, research gap, origins, subject areas, methodology, limitations, and chaptering in the research aims to understand the evolution of the genre [1] and its impact on mass media policies in Sri Lanka.

The research gap is that there has been no systematic academic study of the "True" [2] Sri Lankan 'Teledrama' genre's distinctiveness, and the emergence of a "Fake" [3] Mega Dailies movement has not been discussed in formal studies.

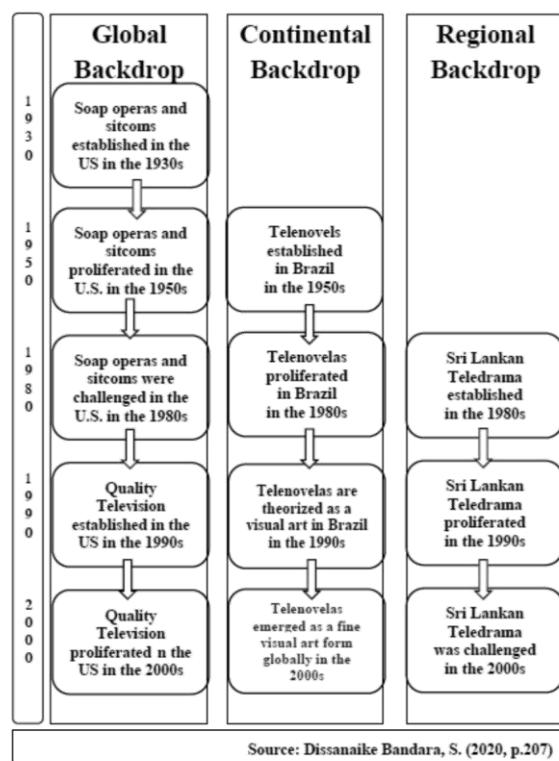
Further, it examines the socio-political-economic background of Sri Lankan 'Teledrama', its novel concept, its unique artistic characteristics, and its establishment as a visual art genre. It also examines the parallel international backdrop and its socio-political-economic context of the conceptualization in its first decade from 1983 to 1992.

This study analyzes the establishment of Sri Lankan 'Teledrama' as a traditional visual art genre in its first decade of prominence. It explores the possibility of theorizing a stream of "True" Sri Lankan 'Teledrama' based on its unique characteristics and the methodological factors that influenced its theorization. The second decade from 1993 to 2002 was observed as the decade of "True"-Teledrama stability.

The investigation on the negative impact of government mass media policies on Sri Lankan Teledrama, focusing on mass media policy and law in the country. The study examines electronic mass media policies and their inconsistencies. The Sri Lankan 'Teledrama' stream, which had unique characteristics due to the commercialist movement, was undermining the genre. The third decade from 2003 to 2012, noticed the "True"-Teledrama challenged in its evolutionary features.

Then it explores the emergence of a "Fake" Mega Dailies movement in Sri Lanka, focusing on its negative effects on the characteristics of "True" Sri Lankan Teledrama. So, the study

identifies inherent vices in the creation and maintenance of “Fake” Mega Dailies by inquiring the twelve (12) constitutive qualities of Robert J. Thompson’s concept of ‘Quality



Teledrama’ [4]. The surveying the evolutionary backsliding from “True” Sri Lankan Teledrama to “Fake” Mega Dailies, in the fourth decade from 2013 to 2022, the disastrous decade of “Fake” Mega Dailies, the decade of ‘real-Teledrama’ descended.

II. LITERATURE REVIEW

The literature review serves as the basis for the study, which includes an analytical investigation of meaningful academic definitions, a comparative analysis with previous corresponding television program genres, and an analytical inquiry based on thematic theories of television studies. The study aims to determine if there are any unique inherent characteristics of the Sri Lankan ‘Teledrama’ genre, which are evident from its evolutionary characteristics, determining it as a modern and sophisticated visual art genre.

The literature review includes an exploration of world, continental, and regional backgrounds, as well as an exploration of the concept of television programming, drama programming for television, television program product classification, and television program genres.

Fig. 1. Analysis of Sri Lankan Teledrama’s Establishment, Proliferation, and Challenges Along with an International Context

Sri Lankan Teledrama never copied, the characteristics of soap opera [5], sitcom [6], or telenovela [7], and incepted with unique characteristics.

The study also includes a descriptive investigation of the evolutionary characteristics of the Sri Lankan ‘Teledrama’ genre based on thematic conceptual analysis of television studies, as well as a characteristic investigation based on the concepts of ‘television art entertainment’, [8][9] ‘teleliteracy’, [10] ‘televsuality’, [11] and ‘Quality Teledrama’ [12]. Thus, this research study provides the theoretical basis for the study as follows.

A. ‘Television Art Entertainment’

The general statement that everyone has made that our world has changed because of the medium of television should be reconsidered. But it is better to understand the reasons for holding this kind of opinion with some examples. Since the medium of television comes into existence mainly as a result of scientific as well as technical research, it itself influences the cultural form of the medium of television (Williams 1975, 1-12).

The medium of television is merely a tool to maintain a dominant ideological discourse, performing only simple encoding and decoding, repeating the same codes familiar to the audience on a daily basis (Hall 1980, 128).

B. ‘Teleliteracy’

Teleliteracy should be understood as a media studies matter. Teleliteracy is the audience’s fluent engagement with what is represented by the language and content of the television medium. Dealing with them with clear reasons. There is no reason to clash with it or to be afraid of clashing with it. How should television audiences deal with it? In fact, teleliteracy is something to be embraced, not condemned (Bianculli 1992, 282).

C. ‘Televsuality’

The ongoing digitization transformation, the development of television media production technology, as well as the inevitable new situation in the expansion of television media distribution systems, has resulted in a change in ‘televsuality’, i.e. the emergence of stronger and more innovative interpretations of television program content than existed in television media until then. Style, crisis, and authority are also changing (Caldwell 1995, 10).

D. ‘Quality Teledrama’

Because the programs produced for ‘Quality Teledrama’ need to be unique, a high creative contribution from the imagination that passes through their production is essential. Because the expectation of profit is not the only expectation, ‘Quality Teledrama’ is a struggle in the existing industry. Because of the uniqueness of the programs, the audience who associates with ‘Quality Teledrama’ explores the content of the program itself. Realistic characters and believable events are always expected. By that, ‘Quality Teledrama’ awakens the thoughts of the audience and makes the audience intelligent. ‘Quality Teledrama’ challenges the audience to the existing novelty of the formats presented or innovative

versions of them and the audience is confronted with them as they become enlightened. Literary-based and writer-centered 'Quality Teledrama' should be sensitized with its own consciousness and take a realistic approach by discussing current events. Thus, if 'Quality Teledrama' is completed, it will receive high critical responses and even deserve an award (Thompson 1997, 13).

III. METHOD

A mixed method made by the synthesis of analytical and empirical research methods is used here. Research methods were Collection of historical data and Contemporary subject area content, Interviews with key creatives, Criticism and investigation of solid designs, Library use, Audio-visual programs, and Interviews.

The research study's conclusions were arrived at by analyzing primary and secondary data and factual information collected through the aforementioned methods, thematically, chronologically, numerically, and descriptively.

A. Data collection in research studies:

Data collection in research studies involves gathering information from various sources, including academic theses, research studies, printed books, newspapers, magazines, periodicals, government publications, documents, pamphlets, electronic media, and online material. This includes audio-visual tapes, discs, screenplays, advertisements, and promotional materials from periodical and contemporary teledrama productions.

Field studies involve interviews with Teledrama creators, professionals, artisan associations, and mass media policy makers, as well as the panel of judges, organizing committees, and survey panels of television channels. Participatory and alternative studies involve filing facts based on experiences gained from my personal teledrama productions, professional association activities, feedback from judging panels, and survey panels of television channels.

Academic articles, review articles, columns, and books published by my authorship on related subject areas are also used. Experiences from study visits in the India, United States, China, South Korea, Myanmar, Germany, Switzerland, and Malaysia are also considered. Professional involvement as an advisory committee member and jury member is also considered. Sample surveys are conducted through directed questionnaires to gather data from Teledrama audiences and practitioners.

B. Data collection, Analysis and Conclusion:

The conclusions of this research study were arrived at by analyzing and analyzing the primary and secondary data and factual information collected through the aforementioned

methods, thematically, chronologically, numerically and descriptively.

C. Limitations of the research study:

The research study focused on the period 1983-2022, focusing on the absence of a formal preservation system for teledramas in Sri Lanka. This led to a lack of sources related to the subject area, as well as the absence of formal storage of data, reports, and statistics by producers, sponsors, or channels. Additionally, all teledrama makers, critics, and individuals with authentic knowledge and experience are either deceased or out of the field. The source of some data presented from tele designers, critics, and those with authentic knowledge is uncertain. Additionally, there were insufficient systematic academic research studies conducted with relevant variables within a logical conceptual framework, which could be used as a source for this study.

IV. FINDINGS AND RESULTS:

This academic study or research explores four paradigm shifts according to the evolutionary as per the decades in Sri Lankan teledrama according to its media art and the culture industry.

A. Decade I: 1983-1992:

- Experiencing the television medium as a public practice in Sri Lanka, commenced in 1979, becoming the most popular medium out of all other media and arts at its inception.
- In 1983, with telecasting of 'Dimuthu Muthu' ⁵, the Sri Lankan television audience experienced a locally made television drama serial first time in history, and it established a new popular television art genre with unique characteristics in the country.
- 'Dimuthu Muthu' was Directed by Dr. D.B. Nihalsinghe, commenced on January 19, 1983 with 26 Episodes.
- Despite all the international terms used to label the genre of television drama serials, Sri Lankans named the particular genre with unique characteristics, as 'Teledrama' at its launch.
- The Sri Lankan 'Teledrama' genre was conceptualized not with any influence of renowned soap operas and sitcoms, but the unique characteristics of its form and content were established through the Sri Lankan media art experience in film, radio, theater, and literature.
- The creators who joined to create Sri Lankan 'Teledrama' in the first decade of 1983-1992, had previous expertise in on aforementioned media arts and could establish a new media art and cultural industry which can way forward to next decade.
- Sri Lankan 'Teledrama' served as a motivating force for the public's usage of the mass media by its form, and a driving force for the public's visual media literacy through its content in society.

- The Sinhala language labelling as “ටෙලිනාට්‍යය” (“*Telinaatya*”) and also its English language translation as “Teledrama” is coined by Dhamma Jagoda [13], former head of Drama Unit of Sri Lanka Rupavahini Corporation in 1983.
- Therefore, the first decade of 1983-1992, is remarked as 'The Decade that Established the Sri Lankan Teledrama' in evolutionary history.

B. Decade II:1993-2002:

- In 1992, the regime of the country on its undefined mass media policy, decided to establish private-owned profit-oriented commercial television channels, which operated based on a broadcasting license system in a background of no regulations on the form or content of the television programs.
- In the decade of 1993-2002, those commercial television channels with purely commercial goals never considered the Sri Lankan 'Teledrama' genre as a Visual Art with unique characteristics, which it had at its inception and during the previous decade.
- The next generation of creators who joined the Sri Lankan 'Teledrama' in this second decade of 1993-2002, was formed with the previous decade's experts' trainees, critics and journalists, stage dramatists, and next-generation promising filmmakers with a finer televisuality.
- Though the commercial television channels were expanding rapidly, the state-owned, public service-oriented two (02) national television channels held a proper telecasting schedule for the Sri Lankan 'Teledrama' broadcasting, and it ensured a stable audience with teliteracy.
- Aforementioned new generation could stabilize the Sri Lankan 'Teledrama' with the unique characteristics to progress to the next decade with the great support of the two (02) national television channels which provided the space for their creative expression.
- Therefore, the second decade of 1993-2002, is remarked as 'The Decade that Stabilized the Sri Lankan Teledrama' in evolutionary history.

C. Decade III:2003-2012:

- In 1999, the regime of the country by its undefined mass media policy, decided to abolish the television license fee to use television receivers which had been a fixed income for the two (02) of the national television channels.
- Then, the two (02) national television channels had to step into a commercial rat race forgetting the facilitating of Sri Lankan 'Teledrama' with unique characteristics like the other profit-oriented commercial channels.
- The state channels as same as the commercial channels, which lost their fixed income and were automatically directed to the market competition by the government,

had to follow the commercialistic business models in relation to telecasting Sri Lankan 'Teledrama'.

- The attributes maintained by Sri Lankan 'Teledrama', such as the single sponsor, the weekly telecast, the quarterly scheduling, the no mid breaks, the standard duration for drama content and advertising content, the prior approval for the script, the approval for the audiovisual content, were disregarded in this backdrop.
- In the 2003 to 2012 decade, the mass media policy with no support downgraded the locally produced and created Sri Lankan 'Teledrama', and the government made no barriers to importing the lower standard daily serials to be dubbed in the Sinhala Language.
- The production price for an original Sri Lankan 'Teledrama' with unique characteristics for the elite audience was directly challenged by the importing price of the lower standard daily series with soap opera characteristics.
- It was obvious that the price can be cheaper when the imported content was already earned multiplied profits by previously having telecast several times in other so many languages before importing for dubbed in Sinhala.
- The decline of the elite television drama audience resulted when the "True" Sri Lankan Teledrama which is original and inherited with unique characteristics, was challenged quantitatively by an imported, lower standard, "Fake" Mega Dailies overflood.
- Therefore, the third decade of 2003-2012, is remarked as 'The Decade that the overflood of “Fake” Mega Dailies which challenged the qualities of “True”- Sri Lankan Teledrama' in evolutionary history.

D. Decade IV:2013-2022

- After the mass media policy had abolished the television receiver license fee and drove the two (02) state-owned public service-oriented television channels to be commercialized, ended the state's last patronage to maintain the unique characteristics of the Sri Lankan 'Teledrama'.
- Thus, the unique characteristics of the True Sri Lankan 'Teledrama', in the processes of creating, investing, producing, marketing, and telecasting as a cultural product were badly reinstated as a mere commercial product with lower standards as the repercussions.
- When there are no accepted guidelines, the commercialistic private channels followed day-to-day business models, which the elite television audience gradually rejected, and the remainder accustomed to mere airtime wasters who irrationally imitate the television advertisement contents.
- During the decade of 2013-2022, in the face of the overflood of “Fake” Mega Dailies the quality of Sri Lankan professional teledrama creative force and the standards of the updated equipment and techniques were extinct while the amount of "True:" Sri Lankan

'Teledrama' was possible to be counted by fingers of the hand.

- Therefore, the fourth decade of 2013-2022, is remarked as 'The Decade that diminished the quantity of “True”- Sri Lankan Tele Drama in the face of the dominance of “Fake” Mega Dailies in evolutionary history.

E. Decade V:2023-2032:

- Though the contemporaneous Sri Lankan Teledrama productions, the creators, and its industry have been indicted for the downgrading of the genre, the truth is the uncertainty of media policies in Sri Lanka has been excluded from the denouncement which ought to be responsible fundamentally.

V. DISCUSSION:

A. Decade I: 1983-1992:

Television in Sri Lanka began in 1979 and became the most popular medium at its inception. In 1983, the Sri Lankan audience experienced a locally made television drama serial, "Dimuthu Muthu," which established a new popular television art genre with unique characteristics. The Sri Lankan 'Teledrama' genre was conceptualized without influencing soap operas or sitcoms, but rather through Sri Lankan media art experience in film, radio, theater, and literature. The creators of Sri Lankan 'Teledrama' in 1983-1993 had previous expertise in these media arts, establishing a new media art and cultural industry that could move forward in the next decade with 'televisuality'. The genre served as a motivating force for mass media usage and driving visual media literacy in society.

The first decade of 1983-92 is considered the 'Decade that Established the Sri Lankan Teledrama' in evolutionary history.

B. Decade II:1993-2002:

In 1992, the Sri Lankan regime established private-owned commercial television channels based on a broadcasting license system without regulations on the content or form of the programs. The process was seen as unfair, as one recipient was also a member of the issuing committee. In the decade of 1993-2002, commercial television channels did not consider the Sri Lankan 'Teledrama' genre as a unique visual art. The next generation of creators, including experts, trainees, critics, journalists, stage dramatists, and filmmakers, joined the Sri Lankan 'Teledrama' in the second decade of 1993-2002. Despite rapid expansion, state-owned national television channels maintained a proper telecasting schedule for the Sri Lankan 'Teledrama' broadcasting, ensuring a stable audience with 'teleliteracy'. This new generation successfully stabilized the Sri Lankan 'Teledrama' with its unique characteristics, progressing to the next decade with the support of these channels.

This period is considered the 'Decade that Stabilized the Sri Lankan Teledrama' in evolutionary history.

C. Decade III:2003-2012:

In 1999, the Sri Lankan government's undefined mass media policy abolished the television license fee for national television channels, leading to a commercial rat race. This led to the disapproval of Sri Lankan 'Teledrama' attributes, such as single sponsors, weekly telecasts, quarterly scheduling, no mid breaks, standard duration, and prior approval for scripts and audiovisual content. From 2003 to 2012, the government downgraded locally produced Sri Lankan 'Teledrama' and allowed importation of lower standard daily serials to be dubbed in the Sinhala Language. The production price for original Sri Lankan 'Teledrama' was directly challenged by the importing price of lower-standard soap opera-like series. The decline of the elite television drama audience resulted from the overflow of fake "daily" Teledrama, which challenged the original and unique characteristics of Sri Lankan 'Teledrama'.

The third decade of 2003-2012 is referred to as 'The Decade of the Overflow of “Fake” Mega Dailies, challenging the “True” Sri Lankan 'Teledrama' in evolutionary history.

D. Decade IV:2013 - 2022

The mass media policy abolished the television receiver license fee and commercialized state-owned public service-oriented television channels, ending the state's last patronage to maintain the unique characteristics of Sri Lankan 'Teledrama'. This led to the reinstatement of the unique characteristics of True Sri Lankan 'Teledrama' as a commercial product with lower standards. Commercialistic private channels followed day-to-day business models, which the elite television audience rejected, and the remainder adapted to airtime wasters imitating television advertisement content. Between 2013-2022, the quality of Sri Lankan professional teledrama and updated equipment and techniques were extinct, while the quantity of “True” Sri Lankan 'Teledrama' was only a few.

The “Fake” Mega Dailies was proliferated by the profit-oriented commercialist television broadcasting business under the private ownership, and the “Fake” Mega Dailies prominently revealed eighty (80) disastrous vices [14], diverting from “True” Sri Lankan Teledrama of unique characteristics.

This period is considered the 'Decade that diminished the quantity of “True” Sri Lankan 'Teledrama' in evolutionary history.

VI. CONCLUSION AND SUGGESTIONS:

By means of presented in the literature review and the findings and results the following conclusions were reached by the research study.

- Since the “Fake” Mega Dailies commercialist movement rooted due to the unstable mass media policies of the previous regimes in 1992 and 1999 gradually excluded the “True” Sri Lankan Teledrama art and culture industry from the television broadcasting space. The two decades from 2003 to 2022 have proved that none of the developmental characteristics that should have been shown by any art and cultural industry after an evolutionary phase are present in the Sri Lankan 'Teledrama'.
- Only the entrenched commercialist movement of “Fake” Mega Dailies with many vices which are criticized and ridiculed in such an atmosphere where no developmental features are visible remains powerful.
- Also, as observed by this research study, it is clear that the current mass media policy making in Sri Lanka and its uncertainty were caused by providing an unnecessary legal basis as stated earlier.
- However, almost every regime that came to power after that, instead of amending it, it seems that the “Fake” Mega Dailies business is owned by business circle who are acquaintances to them, and it maintains the disastrous effects are being continued even today.
- Thus, the electronic frequency spectrum which is a public right of the people of Sri Lanka has been provided to such business acquaintances to abuse with legal support.
- In such a background, there is a popular accusation that only the contemporary Sri Lankan 'Teledrama' productions, the creators, and the production process based on it should be held accountable.
- It was clearly seen in this research study that the uncertainty of media policies maintained by the different regimes is excluded from being blamed for downgrading "True" Sri Lankan Teledrama.
- Because of this, the disaster of maintaining the “Fake” Mega Dailies must be ended immediately, and in order to remedy it, the “True” Sri Lankan Teledrama, which has been suppressed for a long time, is in a situation that cannot be rehabilitated.

This research study presents a proposal based on the Thompsonian concept with the potential to create a sustainable Sri Lankan ‘Quality Teledrama’ genre as an extension of the Sri Lankan Teledrama concept itself for a sophisticated art and cultural industry.

1. For the establishment of ‘Quality Teledrama’, it is effective to create things that are ‘extraordinary’ not ‘ordinary’.
2. For the establishment of ‘Quality Teledrama’, every generation of quality professionals should be gathered together.
3. For the establishment of ‘Quality Teledrama’, elite audiences should be attracted.
4. ‘Quality Teledrama’ would always have to contend with the consumerist audience driven by profit-seeking channels.

5. For ‘Quality Teledrama’, a credible cast of characters should be included.
6. Traditional memorable practices are needed for ‘Quality Teledrama’.
7. New genres should be created by mixing old codes and conventions for ‘Quality Teledrama’.
8. To create a unique literature for ‘Quality Teledrama’ the writer should be accepted as the centric base.
9. Self-consciousness should be raised for ‘Quality Teledrama’.
10. For the establishment of ‘Quality Teledrama’ should be lean towards controversial themes and subjects.
11. Realistic ‘Truth’ should be expected for ‘Quality Teledrama’. and
12. Productions that exhibit the above-listed eleven characteristics desired for ‘Quality Teledrama’ are to be usually award-winning and critically acclaimed. (Thompson 1997, 16)

At the conclusion of this research study, based on all the analysis considered above, the following elementary strategic suggestions, proposals and recommendations should be declared for the accomplishment of its fifth decade of "Quality Teledrama", from 2023 to 2032.

- 01: Establishing the Decade of ‘Quality Teledrama’ from 2023 to 2032 as a timeframe to recognize local teledrama as an art and culture industry and lead to national policymaking.
- 02: Establishing the concept of ‘Quality Teledrama’ as the Sri Lankan Teledrama standard.
- 03: Establishing the application of internationally accepted standard television program production process in ‘Quality Teledrama’.
- 04: Establishing the ‘Quality Teledrama’ as one-episode-per-week mode of telecasting.
- 05: Establishing the application of standards in the Development Stage correlation process in ‘Quality Teledrama’.
- 06: Establishing of “Television Screenwriter Contribution Scheme of three (03) levels” in ‘Quality Teledrama’ teleplay writing.
- 07: Establishing producer-led television production techniques in ‘Quality Teledrama’.
- 08: Establishing the Co-Production and Sponsorship Mechanisms for ‘Quality Teledrama’ investment.
- 09: Establishing the systems of ‘Teleplay Evaluation’ and ‘Production Value Evaluation’ prior to ‘Quality Teledrama’ telecasting.
- 10: Establishing the application of ‘Quarterly method’ as telecast schedule method in ‘Quality Teledrama’.
- 11: Establishing the practice of 'Quality Television Production Model' by Robert J. Thompson (1997), in ‘Quality Teledrama’.

- 12: Establishing and maintaining audited financial control in ‘Quality Teledrama’ investments.
- 13: Establishing of “Quality Television Regulatory Commission” for ‘Quality Teledrama’ protection.
- 14: Establishing sustainability of the industry by adopting the ‘Quality Teledrama Co-Investment Production Model’.
- 15: Establishing sustainability of the industry by expanding foreign investment opportunities by leading ‘Quality Teledrama’ for overseas markets.
- 16: Establishing sustainability of the industry by expanding audience reach by shifting ‘Quality Teledrama’ streaming to other language markets.
- 17: Establishing sustainability in the industry by employing a competency-based assessment system to enable the contribution of professional quality creatives to ‘Quality Teledrama’ productions.
- 18: ‘Establish sustainability of the industry by including curricula to underpin the development of knowledge, skills and attitudes in higher education and vocational education to ensure the contribution of professional-quality creatives to ‘Quality Teledrama’ productions.
- 19: Establishing sustainability of the industry by including the subject in school curricula so as to ensure an enlightened audience that expects high entertainment towards ‘Quality Teledrama’ streaming.
- 20: Establishing the sustainability of the industry by carrying out publicity and promotional programs for ‘Decade of Quality Teledrama’ as a national project from 2023 to 2032.

ACKNOWLEDGEMENTS

It was my mentor Dr. Dharmasena Pathiraja who referred me to such a comprehensive research study. Correspondingly, I would like to express my gratitude to Professor Hiniduma Sunil Senevi of Sabaragamuwa University and Dr. Manoj Alavathukotuwa of Peradeniya University. Also, I am thankful to the State Advisory Council on Television Arts of the Department of Cultural Affairs

under the Arts Council of Sri Lanka, and the Telemakers Guild of Sri Lanka who contributed greatly to make this study a success.

REFERENCES

- [22] පතිරාජ, ධර්මසේන. (2017) *සිංහල නාට්‍යයේ ආකෘතිය හා අන්තර්ගතය අතර අරගලය*. කොළඹ: සකසා ප්‍රකාශන, පි.9.
- [23] Tolstoy, Leo. (1904) What is Art?, Maude, Aylmer. (Trans.) United States : Funk & Wagnalls Company. pp.68-114.
- [24] Tolstoy, Leo. (1904) What is Art?, Maude, Aylmer. (Trans.) United States : Funk & Wagnalls Company. pp.174.
- [25] Thompson, Robert J. (1997) *Television's Second Golden Age: From Hill Street Blues to ER and Other Quality Dramas*. New York: Syracuse University Press, pp.13-16.
- [26] Geraghty, Christine. (2005) ‘The study of the Soap Opera’. in Wasko, Janet (Ed.) *Companion to Television*. New Jersey : Blackwell Publishing, pp.4.
- [27] Taftlinger, Richard F. (1996) *Sitcom: What It Is, How It Works*. Washington : Washington State University. pp.3.
- [28] Carter, E. L. (2018) *Reimagining Brazilian Television: Luiz Fernando Carvalho's Contemporary Vision*. University of Pittsburgh Press, pp.3.
- [29] Williams, Raymond. (1975) *Television: Technology and Cultural Form*. New York: Schocken Books, pp.1-12.
- [30] Hall, Stewart. (1980) *Encoding/Decoding. Culture, Media, Language*. London: Hutchinson Books, p.128.
- [31] Bianculli, David. (1992) *Teleliteracy: Taking Television Seriously. Social Science*. New York: Syracuse University Press, p.282.
- [32] Caldwell, John Thornton. (1995) *Televisuality: Style, crisis, and authority in American Television*. New Jersey: Rutgers University Press, pp.10.
- [33] Thompson, Robert J. (1997) *Television's Second Golden Age: From Hill Street Blues to ER and Other Quality Dramas*. New York: Syracuse University Press, pp.13-16.
- [34] සේනානායක, සෝමචිරි. (1990), *ධම්ම ජාගොඩ-දැනුම් සම්භාරයක ලේඛන සටහන (පෙරවිද්‍යා), ගුණරත්න, සුසිල්. (කර්තෘ), ධම්ම ජාගොඩ රූපවාහිනී සංකල්ප. නුගේගොඩ : සීමාසහිත සරසවි ප්‍රකාශකයෝ, පි.7.*
- [35] Dissanaikie Bandara, Senesh. (2020) *Quality TeleDrama Paradigm of Establishing State Electronic Media Policy for the Sustainable Future for Sri Lankan and Tele-Drama Art and Culture Industry*. (Chapter: 7). PhD Thesis. University of Peradeniya. p.611-612.

Customer Relationship Management Methods For Freelance Audio-Video Content Creators in Sri Lanka

Chathuranga Rathnaweera
Department of Film and Television Production Technology
University of Vocational Technology
Rathmalana, Sri Lanka
ftpt19b206@uovt.ac.lk

R.R.M.D.P.Rathnayake
Department of Film and Television Production Technology
University of Vocational Technology
Rathmalana, Sri Lanka
dilantha@uovt.ac.lk

Abstract— This research aims to identify effective customer relationship management (CRM) methods for freelance audio-video content creators in Sri Lanka. The study utilized a combination of in-depth interviews and literature survey to gather insights from 09 freelancers, 02 top managerial officials and 09 customers. The interviews focused on the current workflow and CRM practices used by freelancers while the literature survey identified effective CRM techniques that could be implemented by freelancers in Sri Lanka. In accordance with the findings, successful CRM strategies can increase sales and improve customer satisfaction while leading to business success. The study revealed the importance of effective communication, responsiveness to client needs and personalized attention in building long lasting client relationship in the audio-video content creation industry in Sri Lanka.

Keywords— Customer Relationship Management, Customer Retention, Customer Satisfaction, Customer Experience

I INTRODUCTION

In Sri Lanka's audio-video content creation industry, freelancers have embraced the digital age and used technology and the internet to build successful professions. This burgeoning trend has transformed audio-video content creation into a viable and competitive market. However, this very competitiveness underscores the most importance of effective Customer Relationship Management (CRM) for the sustainability and success of freelance audio-video content creators in Sri Lanka.

The rise of freelance audio-video content creators in Sri Lanka has brought to the forefront the critical need for adept CRM strategies. These strategies not only facilitate the nurturing of client relationships but also play a pivotal role in boosting customer satisfaction, loyalty, and by extension, augmenting revenue generation and business growth. As a result, this research endeavors to delve into the intricacies of CRM methods and techniques that can be specifically tailored to the unique context of freelance audio-video content creators in Sri Lanka. By unraveling these strategies, we aim to empower these creators to forge stronger client interactions, thus setting the stage for their businesses' flourishing.

II PROBLEM AND GAP

The research problem of this study is what is the extent of knowledge and understanding regarding effective customer relationship management methods among freelance audio-video content creators in Sri Lanka? Despite the importance of maintaining strong customer relationships for business growth and success, there is a dearth of information on the most efficient strategies for this specific group of freelancers. This gap in knowledge creates a challenge for Sri Lankan audio-video freelancers to effectively manage their customer relationships and increase customer satisfaction and retention. The research aims to address this gap by identifying and evaluating successful CRM methods that can be implemented by freelance audio-video content creators in Sri Lanka to enhance their business performance.

III OBJECTIVES

The research aims to identify effective customer relationship management methods for freelance audio-video content creators in Sri Lanka to improve customer satisfaction, retention, and business growth.

IV LITERATURE REVIEW

In today's marketing field, Customer Relationship Management (CRM) is a highly important concept. It is utilized extensively to establish a strong connection with customers, which in turn allows organizational management to deliver exceptional services (Adnan M. et al, 2021). In today's competitive business world, successful management of Customer Relationship Management (CRM) is increasingly important for any business. As customer expectations continue to rise, businesses must adapt their services to meet these expectations. CRM is a technique that businesses can use to connect with their customers and provide better service. Businesses that implement successful CRM strategies will increase sales, improved customer satisfaction, and ultimately, business success. Effective use of CRM technology is essential to keeping costs low, and proper CRM practices can lead to significant growth (Jayashree S. 2010). According to the study of Hamid, a CRM strategy revolves around three core elements, namely people, technology, and processes. All the three elements play a

major role in CRM implementation (Hamid A. A. et al, 2022). CRM has a significant impact on customer satisfaction, and that there is a positive relationship between the two variables. When a company has a strong and reliable CRM system, customers are more likely to be satisfied and to remain loyal to the company. The findings of the analysis demonstrate that CRM plays a role in increasing customer satisfaction levels and in increasing profitability by reducing the cost of reaching out to customers, increasing the size of the customer base, and ultimately leading to increased profits. In addition, an effective CRM system can help a company achieve a competitive advantage by reaching the right customers with the right message, at the right time, and through the right channel. According to the study, approximately 70% of customers are satisfied with the delivery and quality of products and services, indicating that an effective CRM system is important to maintain customer satisfaction and to identify areas for improvement (Hassan R. S. et al, 2015). Service providers aim for continuous engagement with their clients, and this requires a higher level of attention to the client's needs and preferences. In order to establish and maintain long-term relationships with clients, businesses must invest time and effort in building trust and understanding. This requires effective communication and responsiveness to the client's needs. Service providers, in particular, must go above and beyond to ensure that their clients are satisfied with the services provided. This includes anticipating their needs, providing personalized attention, and being proactive in addressing any issues that may arise. Ultimately, the success of a service provider depends on the strength of its client relationships. By investing in effective communication and providing exceptional service, service providers can build long-lasting relationships that benefit both the client and the business. (Chinnathurai. 2021).

Customers are not just a source of income but also long-term assets that require management and maintenance. It can be concluded that there is a strong correlation between Customer Relationship Management (CRM) and Customer Retention. Additionally, there is a significant influence of CRM on Customer Retention in the Creative Industry. In order to succeed in this industry, it is important for businesses to develop innovative strategies, unique concepts, and creative approaches to meet customer desires and needs. By implementing effective CRM strategies, businesses can build long-lasting relationships with customers and improve customer retention rates, ultimately leading to increased profitability and success in the market. (Damri D. M. et al, 2017).

V METHODOLOGY

The purpose of this study was to identify effective customer relationship management (CRM) methods for freelance audio-video content creators in Sri Lanka. The study utilized a combination of in-depth interviews and a literature survey to gather insights from 09 number of audio-video content creators who working as freelancers and 02 top managerial officials which are providing audio-video content creation services in Sri Lanka, as well as 09 customers who had previously obtained freelance services. The in-depth

interviews conducted with freelancers focused on the current workflows and customer relationship management practices used by them and conducted in-depth interviews with customers including individuals and companies to evaluate CRM methods used by freelancers. Furthermore, a literature survey was conducted to identify the most effective and standard CRM techniques that could be implemented by freelance audio-video content creators in Sri Lanka.

○ *Research Tools*

▪ *In-depth Interviews*

Interviewed 3-professional freelancers, 3-intermediate level freelancers, 3- beginner level freelancers and 2- top managerial officials (audio-video service providing companies) to understand the current workflow and how they manage customer relationship in their workflow. Further, interviewed customers and clients to evaluate current CRM methods and their experience.

▪ *Literature Survey*

Conducted a literature survey for understand what are the standard and effective CRM methods for freelance audio-video content creators and how they can manage customer retention.

○ *Population and Sampling*

▪ *In-depth Interviews with Freelancers and Founders of Companies*

In-depth interviews were conducted in order to collect qualitative data on how freelancers use CRM practices in their workflow. 11 people representing various levels of professions in audio-video content creation industry in Sri Lanka. Interviewees were chosen according to the convenient sampling method for the interviews as stated below.

▪ *Summery of Interviewees*

- F1- Professional Freelance Colorist / Video Editor
- F2- Professional Freelance Audio Designer
- F3- Professional Freelance Video Editor
- F4- Intermediate Level Freelance Video Editor
- F5- Intermediate Level Freelance Video Editor
- F6- Intermediate Level Freelance Video Editor
- F7- Beginner Level Freelance Video Editor / Audio Editor
- F8- Beginner Level Freelance Video Content Creator
- F9- Beginner Level Freelance Video Content Creator
- F10- Top Managerial Official at a Branding Company
- F11- Top Managerial Official at an Animation Studio

▪ *In-depth Interviews with Customers and Clients*

In-depth interviews were conducted in order to evaluate current CRM methods used by freelancers and customer experiences in their workflow. 09 number of clients and customers were representing various nature of businesses in Sri Lanka. Interviewees were chosen according to the

convenient sampling method for the interviews as stated below.

▪ *Summery of Interviewees*

- C1- Short Filmmaker
- C2- Top Managerial Official at an Animation Studio
- C3- Software Engineer
- C4- Top Managerial Official at a Game Design Company
- C5- Digital Media Marketing Executive
- C6- Post Production Manager
- C7- Professional Dancer / Youtuber
- C8- Branding Strategist
- C9- Top Managerial Official at a Cleaning Service

VI FINDINGS AND ANALYSIS

○ *Workflow*

The findings from the interviews with freelance audio-video content creators in Sri Lanka indicate that the workflow for content creation generally involves several key steps. This includes receiving the client brief, understanding the nature and scope of the project, submitting rough edits or drafts for client feedback, making necessary changes based on the feedback, and finally delivering the final product to the client. While the overall workflow is consistent among the interviewees, some variations exist, particularly for specialized tasks like 2D/3D animation.

One notable challenge reported by freelancers is that some clients request numerous changes even after the project has progressed to certain stages. This can be attributed to a lack of understanding about the workflow, which may arise from inadequate communication or not properly informing clients about the key steps involved. The study suggests that clearer communication at the project's outset, including explaining the workflow to clients, could minimize confusion and issues with change requests later on. By keeping clients informed about the project's progress and providing them with a clear understanding of the appropriate timing for requesting changes, freelancers can establish a smoother and more efficient working relationship with their clients.

According to the interviews done with freelancers and founders of companies, six participants unveiled that they faced many problems such as requesting too many changes and customers are not aware of the workflow. If customers are made aware of the working process, the various steps involved, and the pipeline of the project, it can help to reduce major issues and misunderstandings, particularly with regards to changes. This can enable customers to have a clearer understanding of the project's progress and the appropriate timing for requesting changes, which can ultimately lead to a smoother and more efficient working relationship between the freelancers and the customers.

○ *Current Communication Level*

The primary communication channels used by interviewees are WhatsApp, phone calls, email, and Video conferencing tools like Zoom and Google Meet are also used. The communication methods vary based on the project's requirements and the client's preferences. Ten number of participants uses WhatsApp for the communication.

One client prefers physical meetings, while others prefer to communicate online. Communication and trust are essential to successful relationships with freelancers. Clients who have issues with their freelancers tend to have problems with communication or differences in working styles.

The participants mentioned that they utilize Google Drive and WeTransfer to share files and deliver the final product to their clients.

The results indicate that there are problems with communication between freelancers and customers, and it is not at a satisfactory level.

○ *Customer Relationship Management Tools*

Most of the interviewees do not use CRM tools to manage client relationships. The research indicates that only two participants are familiar with Trello and Asana tools, and that some find them difficult to use. However, those who are familiar with these tools tend to appreciate their features and capabilities, and would welcome more user-friendly alternatives.

○ *Client Feedback*

Only seven number of participants track their client feedback and they use different methods to track those, including Google Docs, note-taking, WhatsApp, and email. Some of them also collect feedback through a Google Form or YouTube comments.

Generally, clients are satisfied with their freelancer's work, but there are occasional issues that need to be resolved through communication and compromise. Freelancers who are responsive to client requests and feedback tend to have better relationships with their clients.

It seems that some people may be in a rush to complete their work and move on to the next customer, which may result in them making changes without properly recording or noting down any feedback. This could potentially lead to a lack of communication or understanding between team members or clients, and may ultimately result in decreased satisfaction with the work being produced.

○ *Managing Client Expectations*

Interviewees manage client expectations by providing a timeline for the project's completion, discussing project

deliverables, and communicating any delays or issues that arise during the project.

It appears that many freelancers are being tasked with projects that require immediate completion, often within a week or less. Additionally, they may be juggling multiple clients simultaneously, which can make it challenging to meet deadlines and handle any unexpected changes or revisions that may arise during the project. This can create a stressful and demanding work environment for freelancers, as they must balance delivering quality work with managing client expectations and meeting tight timelines.

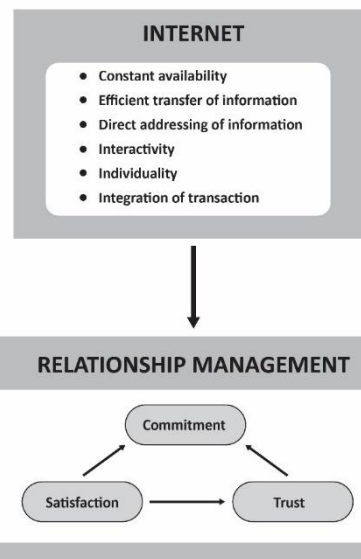
○ *Challenges*

Based on the research, it seems that many freelancers encounter various challenges in their work, including communication issues with clients, competition from other freelancers, difficulties with time management, clients who lack knowledge about the project requirements, a lack of understanding about the workflow, and budget issues. These challenges can make it challenging for freelancers to deliver high-quality work and meet client expectations, which can ultimately impact their success in the freelance marketplace.

○ *Customer Relation*

It appears that some freelancers have had negative experiences with losing clients due to poor communication and customer relationship management (CRM). These freelancers may not be utilizing effective client relationship building methods to maintain client retention, which could result in a loss of business over time. It is important for freelancers to prioritize strong communication and effective CRM practices to build trust with clients and establish long-term working relationships. This can help to ensure client satisfaction, improve the freelancer's reputation, and increase the likelihood of future business opportunities.

Based on the literature, it is suggested that client relationships through the internet are more effective. (Hans H., 2002). Further literature suggested that The Six Pillars of Customer Experience Model can be applied to the audio-video content creation industry in the following ways. (Taher A. 2022)



Frame of Reference for Client Relations Through the Internet

○ *Billing, Payment, Agreements, and Other Documents*

It seems that some freelancers may not be following proper documentation practices when it comes to invoicing and client agreements. Instead of using professional software for creating invoices and agreements, some freelancers may resort to sending soft copies of invoices through communication channels such as WhatsApp or email. Additionally, some freelancers may neglect to issue proper documentation altogether, leaving it up to the client to request invoices or other important documents. This lack of formal documentation and agreements could potentially lead to misunderstandings or disputes between the freelancer and the client. It is worth noting that some advertising agencies may follow more rigorous documentation practices, including the use of legal agreements and other formal documentation.

According to the research, freelancers who do not use agreements may encounter issues such as clients refusing to pay for changes or requesting excessive changes, as well as displaying unprofessional behavior. As a result, some freelancers are considering implementing agreements to protect themselves and ensure a more professional working relationship with their clients.

○ *Customer Satisfaction*

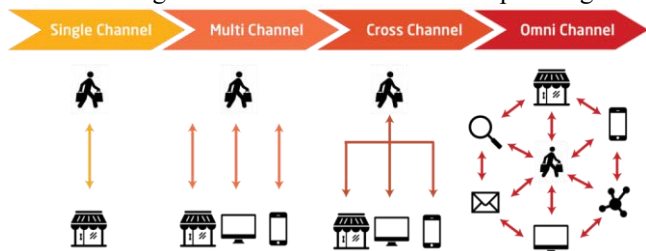
Some customers have had negative experiences working with freelancers in the past, as they were dissatisfied with the quality of the designs provided. They feel that some freelancers lack knowledge of design trends, theories, and

principles. As a result of these experiences, seven customers prefer to work with people they know, such as friends or those recommended by others. However, this approach can sometimes result in missing out on the most suitable freelancer for a particular project. This is because the customers may prioritize avoiding communication or working style issues with people, they are unfamiliar with over finding the most qualified freelancer for the job.

Based on the feedback from one participant, customers prefer to see a showreel to gain an understanding of the freelancer's style of work, level of quality, and professionalism. A showreel can help to establish trust between the customer and the freelancer by showcasing the freelancer's capabilities and previous work experience. This can help to reassure customers that they are working with a qualified and competent professional who is capable of delivering the desired results.

○ *Inclination of Freelancers and Customers*

During the interviews, all participants (both freelancers and customers) expressed a preference for using online tools, apps, and software that can be accessed on both mobile phones and computers/laptops to manage their work and maintain a high level of customer relationship management



(CRM). They believed that implementing such a system would lead to better client retention (CR) rates. However, they emphasized that the system must be user-friendly and accessible to both freelancers and customers with varying types of accounts.

○ *Standard CRM Types*

The literature shows four standard types of CRM. (Padhi S. 2017)

Operational CRM: Operational CRM (Customer Relationship Management) refers to the use of technology to automate and streamline customer-facing business processes, such as sales automation, marketing automation, and customer service. The goal of operational CRM is to improve the efficiency and effectiveness of these processes to enhance customer satisfaction and increase revenue.

Analytical CRM: Analytical CRM refers to the use of data analytics and business intelligence tools to analyze customer data and gain insights into customer behavior and preferences. This information is used to develop customer

segmentation strategies, targeted marketing campaigns, and personalized customer experiences.

Collaborative CRM: Collaborative CRM refers to the use of technology to facilitate communication and collaboration among different departments within a company that interacts with customers, such as sales, marketing, and customer service. The goal of collaborative CRM is to ensure that everyone who interacts with customers has access to the same information, enabling them to provide consistent and personalized experiences.

Interactive CRM: Interactive CRM refers to the use of technology to enable real-time interaction between customers and companies across multiple channels, such as social media, email, chat, and phone. The goal of interactive CRM is to improve customer engagement and provide customers with a seamless and consistent experience across all channels.

Among these, it is suggested that freelance audio-video content creators would find Operational CRM and Interactive CRM to be the most suitable for their needs.

○ *Suitable CRM Strategy*

Omni channel CRM may be a suitable approach for managing customer relationships in the freelance audio-video content creation industry. This approach involves integrating multiple communication channels such as email, phone, social media, and chat, to provide a seamless and consistent customer experience across all touchpoints. By implementing an omni channel CRM strategy, freelancers in the audio-video content creation industry can enhance their communication with clients and improve overall customer satisfaction. (Nasir, 2015), (Padhi S. 2017), (Gao, 2021)

Different Types of CRM Channels

VII CONCLUSION

Based on the findings and analysis of the both interview series with freelance audio-video content creators in Sri Lanka and their customers, it can be concluded that customer relationship management plays a crucial role in the success of their businesses. All interviewees had different approaches to managing their relationships with clients, but both highlighted the importance of communication, responsiveness, and building trust with clients.

The first interview series is emphasized the need to have clear communication with clients from the beginning and to manage their expectations throughout the project. This approach helped to establish trust with clients and ensure that they were satisfied with the final product. The second interview series is focused on building long-term relationships with clients by providing excellent customer service and going above and beyond their expectations. This

approach helped to foster repeat business and positive word-of-mouth recommendations.

Overall, it is clear that effective customer relationship management methods are essential for freelance audio-video content creators in Sri Lanka to succeed in their businesses. By prioritizing communication, responsiveness, trust-building, and excellent customer service, freelancers can establish and maintain strong relationships with their clients, leading to increased client satisfaction, repeat business, and positive referrals.

VIII RECOMENDATIONS

The study suggests to adopt an omni-channel CRM strategy by integrating various communication channels like email, social media, chat, and phone within professional CRM tools. With all communication centralized, freelancers can respond promptly to client inquiries and maintain consistent interactions.

It is recommended that freelance audio-video content creators consider adopting Operational CRM and Interactive CRM as they align exceptionally well with their specific requirements. Operational CRM will help streamline tasks and project tracking, while Interactive CRM will facilitate personalized client interactions. By integrating these approaches, content creators can enhance efficiency, engagement, and overall project success.

It is recommended to consider adopting a dedicated CRM system tailored to their specific needs of freelance audio-video content creators. Professional CRM tools like Trello or Asana can greatly assist in managing client relationships and project workflows. These platforms offer user-friendly interfaces, task management features, and collaboration capabilities, making them ideal for organizing project details, tracking progress, and communicating with clients.

It is recommended to incorporate a lock mechanism for each task in the workflow, requiring client confirmation upon task completion via email or a signed hard copy. This practice serves to prevent potential issues during subsequent changes. Additionally, it is advisable to adopt a flexible approach to the workflow for audio and video content creation. This entails the ability to adjust, add, remove, or modify steps based on project requirements, rather than adhering strictly to a fixed process. Such adaptability ensures a more responsive and tailored workflow, ultimately enhancing the efficiency and effectiveness of content creation endeavors.

The study is recommended to consider the “Six Pillars of Customer Experience Model” for freelance audio-video content creation industry. The Six Pillars of Customer Experience model is a framework used to assess and improve the quality of customer interactions with a business. (Taher A. 2022)

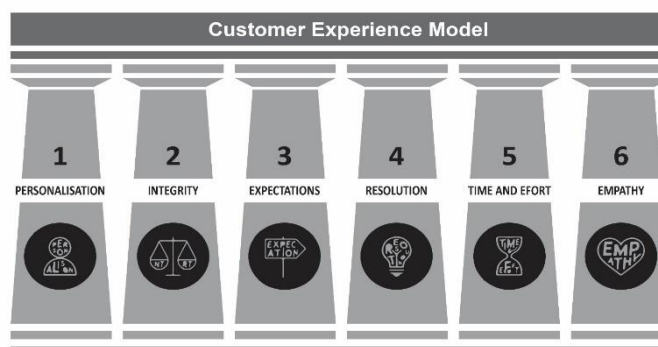


Fig. 4. Six Pillars of Customer Experience Model

The Six Pillars of Customer Experience Model can be applied to the audio-video content creation industry in the following ways.

In the realm of freelance audio-video content creation, a holistic approach involves several pivotal strategies. Firstly, "Personalization" stands out as a guiding principle—services meticulously tailored to individual client needs, with personalized recommendations spanning video style, music, and voice-over, adding a distinct touch to each project. Secondly, "Integrity" takes the forefront, emphasizing transparent communication regarding pricing, processes, and timelines. Providing a clear breakdown of fees, deliverables, and deadlines upfront establishes trust and professionalism. Thirdly, the art of "Expectation" management is paramount; understanding and aligning with client visions to deliver a product that matches their creative direction ensures satisfaction. Fourthly, a proactive approach to "Resolution" proves vital, ensuring responsive collaboration to address any project issues promptly. Fifthly, valuing clients' "Time and Effort" involves streamlined services such as online meetings, reducing in-person interactions and offering convenience. Lastly, "Empathy" forms the cornerstone, underpinned by understanding clients' perspectives and demonstrating genuine care, particularly during high-stress scenarios like tight deadlines. Together, these strategies not only enhance the freelance audio-video content creation experience but also nurture client relationships and yield exceptional project outcomes.

ACKNOWLEDGEMENT

I would like to express my heartfelt appreciation to Mr. Dilantha Ratnayake, my esteemed supervisor, the Head of the Department of Film and Television Production Technology at the University of Vocational Technology, Ratmalana, Sri Lanka. His invaluable guidance, support, and expert insights have been pivotal in shaping the course of this research. His dedication to academic excellence and commitment to fostering learning have truly been an inspiration throughout

this journey. Thank you for your unwavering encouragement and mentorship.

REFERENCES

- Adnan, M., Yaseen, M., Khan, A. U., & Khan, E. A. (2021). *Customer Relationship Management (CRM) and Brand Image Encourage Customer Retention; A mediating Role of Customer Engagement*. Webology, 18(6):4997-5012
- Alt, R., & Puschmann, T. (2004). *Successful Practices in Customer Relationship Management*. <https://doi.org/10.1109/hicss.2004.1265415>
- Hamid, A. A., Alshehhi, A., Abdullah, A., & Saad, E. (2022). *Key Success Factors for Customer Relationship Management (CRM) Projects Within SMEs*. ResearchGate.
- Hassan, R. S., Nawaz, A., Lashari, M. N., & Zafar, F. (2015). *Effect of Customer Relationship Management on Customer Satisfaction*. Procedia. Economics and Finance. [https://doi.org/10.1016/s2212-5671\(15\)00513-4](https://doi.org/10.1016/s2212-5671(15)00513-4)
- Jayashree, S., Shojaei, S., & Pahlavan-zadeh, S. (2010). *A Critical Analysis of Customer Relationship Management From Strategic Perspective*. <https://doi.org/10.13140/2.1.2799.5843>
- Kumar, A. (2021). *Analysing the Drivers of Customer Happiness at Authorized Workshops and Improving Retention*. Journal of Retailing and Consumer Services. <https://doi.org/10.1016/j.jretconser.2021.102619>
- Mishra, A., & Deepti, M. (2009). *Customer Relationship Management: Implementation Process Perspective*. ResearchGate.
- Bauer, H. H., Grether, M., & Leach, M. M. (2002). *Building Customer Relations Over the Internet*. *Industrial Marketing Management*. [https://doi.org/10.1016/s0019-8501\(01\)00186-9](https://doi.org/10.1016/s0019-8501(01)00186-9)
- Chinnathurai, G. D. (2021). *Freelancer -Client's relationship in digital marketing -A commercial friendship*. ResearchGate.
- Damri, D. M. (2017). *The Influence of Customer Relationship Management Through Customer Retention of Creative Industry in a Culinary Sub-Sector at Bandung City*.
- Gao, W., Li, W., Fan, H., & Jia, X. (2021). *How Customer Experience Incongruence Affects Omnichannel Customer Retention: The Moderating Role of Channel Characteristics*. Journal of Retailing and Consumer Services. <https://doi.org/10.1016/j.jretconser.2021.102487>
- Nasir, S. (2015). *Customer Relationship Management Strategies in the Digital Era*. *Advances in Marketing, Customer Relationship Management, and E-services Book Series*. <https://doi.org/10.4018/978-1-4666-8231-3>
- Padhi, S., Tripathy, N., & Tripathy, A. (2017). *New Era of Customer Relationship Management – Deliverance is the Key*. ResearchGate.
- Selvaraj, S., & Pitchaimani, M. (2022). *Customer Relationship Management*. ResearchGate.
- Taher, A. (2022). *Title: Customer Experience*. ResearchGate.
- View of Freelancer – Client's Relationship in Digital Marketing – A Commercial Friendship. (n.d.). <https://www.nveo.org/index.php/journal/article/view/1462/1270>

Exploring Narrative Subjects for Contemporary Sri Lankan Cinema

R.A.C. Chathuranga
Department of Film and Television
Production Technology
University of Vocational Technology
Rathmalana, Sri Lanka
ftpt19b206@uovt.ac.lk

T.M.C. Buddika
Department of Film and Television
Production Technology
University of Vocational Technology
Rathmalana, Sri Lanka
ftpt19b214@uovt.ac.lk

K.P.S.P. Kariyawasam
Department of Film and Television
Production Technology
University of Vocational Technology
Rathmalana, Sri Lanka
ftpt19b223@uovt.ac.lk

M.S. Niroshana
Department of Film and Television
Production Technology
University of Vocational Technology
Rathmalana, Sri Lanka
ftpt19b212@uovt.ac.lk

W.V.D. Fernando
Department of Film and Television
Production Technology
University of Vocational Technology
Rathmalana, Sri Lanka
ftpt19b219@uovt.ac.lk

H.A. Gayan Madushanka
Department of Film and Television
Production Technology
University of Vocational Technology
Rathmalana, Sri Lanka
gayan@uovt.ac.lk

Abstract—Film, as a highly interactive medium with the audience, relies significantly on narrative to engage viewers. This research aims to identify a narrative subject that resonates with contemporary Sri Lankan cinema. Additionally, the study investigates the most popular movie genre and story structures preferred by Sri Lankan moviegoers. To achieve these objectives, a mixed-methods approach was employed, combining survey, in-depth interviews, and content analysis. Quantitative data analysis was utilized to identify the most favored narrative subjects, film genres, and story structures among the Sri Lankan film audience. The results indicate that a majority of moviegoers in Sri Lanka prefer films centered around social factors as the narrative subject. Moreover, Linear Narrative emerges as the primary storytelling structure preferred by Sri Lankan audiences. These findings provide valuable insights for filmmakers and the local film industry to create engaging content that aligns with the preferences of the Sri Lankan moviegoing community.

Keywords—Sri Lankan Cinema, Narrative, Film Genre, Moviegoers, Film Preferences

INTRODUCTION

The preferences of film audiences are shaped by numerous factors, with one of the key components being the narrative subject. Over time, these preferences have evolved, leading to changes in the titles, structures, and genres of motion pictures since the inception of the moving picture on December 28, 1898, at the Grand Cafe in France (Senevi, 2018). This dynamic phenomenon is also evident in the context of Sri Lankan cinema, where audiences have been exposed to a diverse array of narrative subjects since the release of the first Sri Lankan film up until the present (2022).

Despite the acknowledgment of the evolving nature of audience preferences, there remains a research gap regarding the specific narrative subjects that resonate most with

contemporary Sri Lankan moviegoers. Understanding these preferences is vital for filmmakers and the local film industry to create engaging content that caters to the tastes of their target audience. Additionally, there is a need to explore the most popular film genre and story structures among Sri Lankan audiences, as these aspects play crucial roles in audience engagement and film success.

Therefore, the current study aims to address this research problem by investigating the most favorable narrative subjects among Sri Lankan moviegoers and identifying the preferred film genre and story structure for contemporary Sri Lankan films. By filling this research gap, the findings of this study will contribute valuable insights to the field of Sri Lankan cinema and aid in the development of compelling narratives that appeal to the evolving tastes of the audience.

SIGNIFICANCE OF THE STUDY

The study's significance lies in its ability to inform filmmakers and industry professionals about the preferences of contemporary Sri Lankan moviegoers. By identifying favored narrative subjects, genres, and story structures, the study contributes to creating culturally relevant and engaging films. It enhances the balance between artistic expression and commercial success, fosters societal reflection through film, and enriches academic discussions in the field. Ultimately, the study's insights can enhance audience engagement, guide educational curricula, and drive the development of a more dynamic and responsive local film industry.

OBJECTIVES

The objective of this research is to identify a narrative subject that resonates with contemporary Sri Lankan cinema

and investigate the most popular movie genre and story structures preferred by Sri Lankan moviegoers.

LITERATURE REVIEW

The research topic is directly related with the film viewership. With the findings of previous researches, investigated the audience's involvement to the film. When the audience is led to expect certain outcomes, they automatically feel things (Glebas, 2009). The right development of character, plot, theme, setting, atmosphere, point of view, and genre is more than merely providing an audience what they expect (Tatia, 2019).

According to the research on narrative strategies in contemporary Sri Lankan cinema by Deepika D. (2012), she has analyzed 05 movies produced after year 2000. It has found that influence of the world cinema is shadowing on contemporary Sri Lankan film narratives.

Manoj Pushpakumara Jinadasa of University of Kelaniya emphasized that modern teen and youth audience are heavily hallucinated and opiated by the romantic relationships and dreamy world that deeply narrated in the Indian commercial and political film (Jinadasa, 2016). This explore that the contemporary people still in a bond with Sri Lankan traditional cinema.

In her study, R. Sengupta of Jagiellonian University outline a possible theoretical structure for the future study of South Asian cinema, contextualize the intervening spaces between cinema and politics, particularly the realms of cinematic representation of religious or communal identities in South Asian cinema, categorize existing trends and observe transformations in the methodology of cinematic representation of identities (Sengupta, 2020).

With a better understanding of the importance of film narratives, a research gap on narrative subjects and story structures in films was identified. As per the references taken by books and researches the research topic formed as exploring narrative subjects for contemporary Sri Lankan cinema.

METHODOLOGY

Three methods were used in this study to gather information for the research. They include an online survey, in-depth interviews and content analysis.

Survey

According to the 2012 Census of Population and Housing report, the population of the Sri Lanka is 20359439. The study's sample population is a diverse group of people from various age groups in each district of Sri Lanka. In addition to that, the gender, marital status, and employment status are also specifically determined for the sample. The total sample size is 385. With a 95% confidence level and a 5% margin of error, the study results can be generalized to the entire population of Sri Lanka with a reasonable degree of certainty.

The sample for the study was obtained using a Random Sampling technique. This method employs an unbiased group of people who have an equal chance of being chosen from a subset of the total population.

Due to the fuel crisis in Sri Lanka, a Pre-prepared questionnaire with Likert scale and short answer questions was distributed via email through a Google Form. The test is done as a quantitative and qualitative analysis of particular data.

In-Depth Interviews

In-depth interviews were conducted in order to collect qualitative data on film narrative subjects, story structure, and film viewership. 13 people representing various professions in Sri Lankan film industry and social statuses were chosen according to the purposive sampling for the interviews as stated below.

Film Directors	- 02
Screenplay Writers	- 01
Film Producers	- 02
Lecturers/Mentors	- 02
Students	- 02
Cinephile Group Members	- 02
Film Critics	- 02

19) The Profiles of the interviewees

Mr. Jackson Anthony (Film Director)
 Mr. Vimukthi Jayasundara (Film Director)
 Mr. Boopathi Nalin (Screenplay Writer)
 Mr. Anusha Sanjeeva (Consultant - E.A.P. Films)
 Mr. Praveen Jayarathna (Dil Films)
 Mr. Dilantha Rathnayake (Head of the Department – Department of Film and Television Production Technology, University of Vocational Technology)
 Mr. Eranda Mahagama (Lecturer, University of Kelaniya)
 Mr. Geeth Asanka (Graduated Student of the University of Vocational Technology holding the Bachelor of Technology in Film and Television Production Technology)
 Mr. Dakshina Damruwan (Undergraduate Student of the Shreepali Campus)
 Mr. Taraka Baddage (Cinephile Group Member)
 Mr. Hasantha Dissanayake (Cinephile Group Member)
 Mr. Buddadasa Galappaththi (Film Critic)
 Mr. Aruna Gunarathna (Film Critic)

Content Analysis

After obtaining the three most popular movies from quantitative data collection via a Google form distributed throughout the island, content analysis was performed. The genre, narrative subject, narrative structure, length of the film, type of dialogue (simple or profoundly meaningful),

ending of the story (tragic or delighted), and mise-en-scène were all highly concentrated.

FINDINGS AND ANALYSIS

The Manner in Which Movies Are Watched People in Sri Lanka

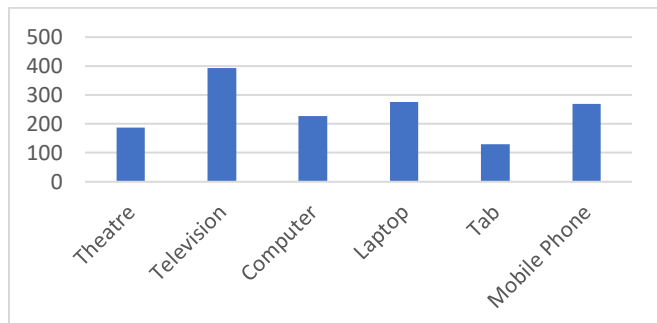


Fig. 30. How People Watch Movies in Sri Lanka

Findings from the research indicate that a considerable segment, specifically 26.5%, of the participants in the study preferred utilizing television as their primary platform for watching movies. Additionally, 18.6% of respondents expressed a preference for using laptops, while 18.1% opted for the convenience of watching movies on their mobile phones. Surprisingly, a mere 12.6% of the participants chose the traditional option of visiting theaters for their cinematic experiences.

A noteworthy observation is that the vast majority, amounting to 87.4% of the respondents, embraced alternative methods for consuming movies, indicating a substantial shift away from traditional theater attendance in favor of more flexible and personalized viewing options.

Preference of Narrative Subjects Among Sri Lankan Audience

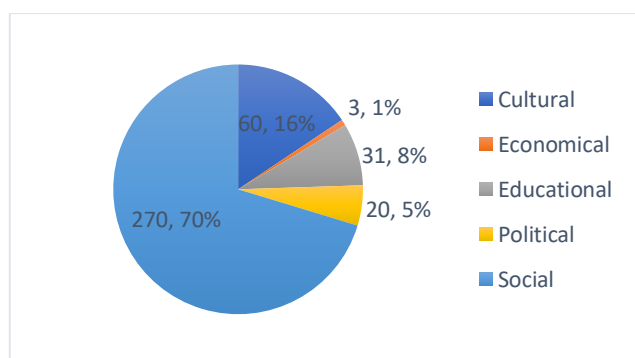


Fig. 31. Preference of Narrative Subjects Among Sri Lankan Film Audience

There are 70.3% of people prefer for a narrative subject related to social factor. 15.6% are like for cultural narrative subject and 8.1% people prefer on narrative subject of

education. Only 5.2% of people prefer on political narrative subject and just 0.8% people like for narrative subjects on economical factor.

20) Age-Wise Narrative Subjects Preferences

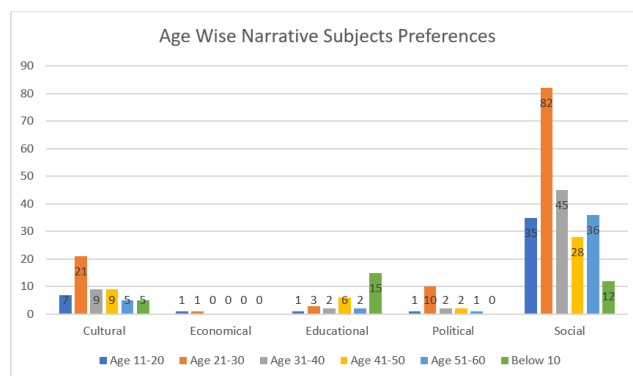


Fig. 32. Preference of Narrative Subjects Based on Age

Identify a unique factor that was shared by all age groups, as people of all ages preferred social as their favorite narrative subject. The least preference came with Economical narrative subject.

21) Gender-Wise Narrative Subjects Preferences

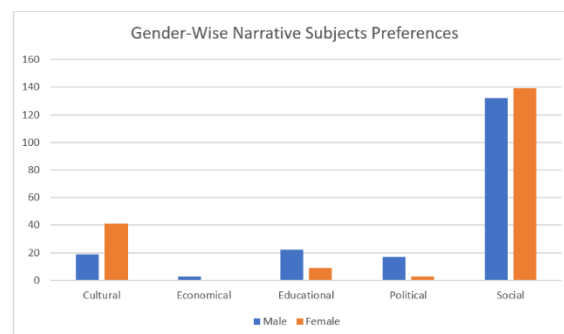


Fig. 33. Preference of Narrative Subjects Based on Gender

There is no considerable deviation on social narrative subject on both male and female gender. However, there is a significant difference between the genders in their preference for other narrative subjects. While males preferred cultural factors at around 10%, females preferred twice as much. But when it comes to political narratives, males have a 9% preference, while females have a 1.6% preference.

Preference of Film Genre Among Sri Lankan Audience

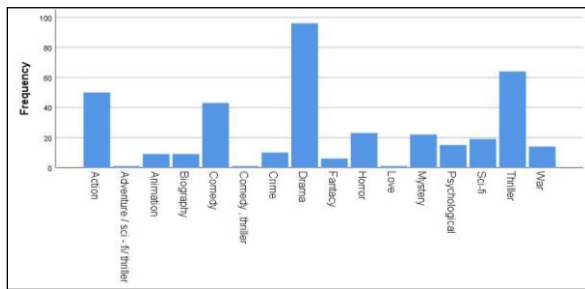


Fig. 34. Preference of Film Genre Among Sri Lankan Film Audience

According to the graph, there are four notable factors about the most preferable film genre among Sri Lankan moviegoers. Those are respectively Drama (25%), Thriller (17%), Action (13%) and Comedy (11%). Over 65% of preferences are with these four genres out of the sixteen genres considered

Preference of Story Structure

22) Preferences of the Story Ending

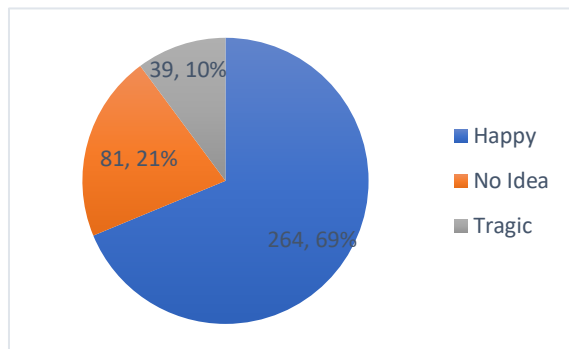


Fig. 35. Preference of the Story Ending

70% of people prefer happy endings in their movies. 10% of people like to tragic ends and rests have no idea about the factor.

23) Preferences of Story Conclusions

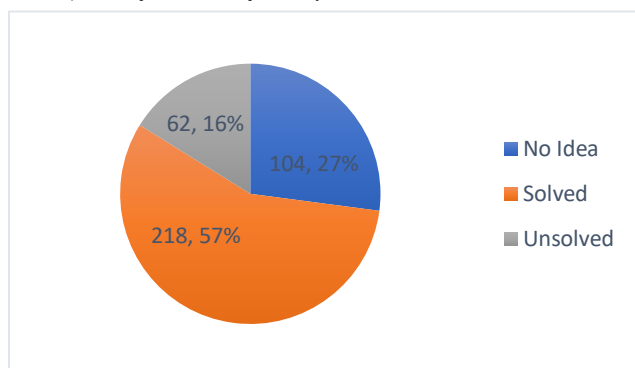


Fig. 36. Preference of StoryConclusions

57% of people prefer movies with solved conclusion and 16% prefer unsolved conclusion in movies. Rest of 27% have no idea about it.

In-Depth Interviews

The insights provided by the interviewees shed light on the vital role played by narrative subjects in driving film viewership in Sri Lanka. They unanimously emphasized that the success of a film greatly depends on the ability of its narrative to engage and captivate the audience. A well-crafted narrative subject, one that is relevant, relatable, and emotionally resonant, has the power to draw in moviegoers and create a lasting impact on their cinematic experience.

Among the common factors observed in Sri Lankan cinema, Linear Narratives emerged as a prominent storytelling style. The straightforward and chronological progression of events in linear narratives allows for a clear and easily comprehensible storyline, which appears to resonate well with Sri Lankan audiences. This preference for linear storytelling could be attributed to its simplicity, enabling viewers to stay connected with the plot and characters throughout the film.

Another significant theme explored in Sri Lankan cinema is Enlightenment. Films that delve into thought-provoking and intellectually stimulating topics tend to capture the attention of the audience, as they provide an opportunity for introspection and deeper contemplation. Such narratives often challenge societal norms, address moral dilemmas, and offer profound insights into human behavior and relationships.

Trends in filmmaking also play a crucial role in shaping the content of Sri Lankan cinema. The industry continuously adapts to changing viewer preferences and societal dynamics, leading to the emergence of specific themes and genres that gain popularity over time. Understanding these trends is essential for filmmakers to stay relevant and connect with their target audience effectively.

The exploration of diverse Themes and Genres is evident in Sri Lankan cinema. From social issues and cultural heritage to action-packed thrillers and heartwarming comedies, the industry offers a wide range of narratives to cater to diverse audience preferences. This variety not only enriches the cinematic experience but also reflects the cultural and societal diversity of Sri Lanka.

On the other hand, the film critic's observation about the disconnect between film academia and the general public's movie preferences raises an important point of consideration. While Arthouse films may be valued for their artistic merits and critical acclaim, they might not always align with the entertainment preferences of the broader audience. This discrepancy suggests the need for a balance between artistic expression and commercial viability in Sri Lankan cinema.

To bridge this gap and foster a better understanding of audience preferences, filmmakers and educators could collaborate more closely. Integrating elements of storytelling, narrative subjects, and audience engagement into film education could help create films that are both artistically commendable and appealing to the general public. Additionally, studying the success of commercial films that strike a chord with audiences can provide valuable insights for filmmakers aiming to create more impactful and engaging narratives.

Content Analysis

The questionnaire's findings revealed that three movies were particularly favored by the respondents: *'Harry Potter'* (2001), *'Suriya Arana'* (2004), and *'Jurassic Park'* (1993). Each of these films resonated with the audience for various reasons, showcasing the diversity of narrative subjects that appeal to Sri Lankan moviegoers.

'Harry Potter' captivated audiences with its enchanting narrative centered around the main character, Harry, and his magical powers and heroic feats. Beyond the surface, the film delves into a deeper subtext of social conflict, exploring themes of prejudice, discrimination, and the struggle for acceptance within a magical society. This blend of fantasy and social commentary drew audiences of all ages, sparking discussions on the importance of inclusivity and understanding in society.

'Suriya Arana' brought forth an intriguing social problem as an emerging cultural issue, within the context of religion. The film shed light on the challenges faced by individuals in a religious community, highlighting the complexities of traditional values and modernity. This exploration of cultural clashes and the quest for spiritual fulfillment resonated with the audience, sparking contemplation on the intricacies of identity and belief systems in contemporary Sri Lanka.

'Jurassic Park' belonging to the sci-fi and action genres, enthralled audiences with its captivating portrayal of dinosaurs brought back to life through genetic engineering. However, beneath the thrilling adventure, the film subtly conveyed a social problem, illustrating how the pursuit of capitalist ambitions can lead to the imposition of hegemony over nature and the potential consequences of playing with scientific boundaries. This thought-provoking subtext sparked discussions on ethical dilemmas and the responsibility of humans in their interactions with the environment.

Sri Lankan audiences prefer well-paced movies that strike a balance between storytelling and engagement. The fact that these films had happy endings and presented clear resolutions to their conflicts also resonated positively with the viewers. The preference for resolved conclusions may indicate that Sri

Lankan audiences find satisfaction in films that provide closure and a sense of fulfillment at the end.

CONCLUSION

The comprehensive research undertaken to understand the narrative subjects preferred by contemporary Sri Lankan cinema has yielded valuable insights into the moviegoers' preferences and the industry's prevailing trends. The survey results clearly indicate that a significant majority, 70.3% of moviegoers, favor movies with narrative subjects centered around social factors. This finding highlights the audience's inclination towards narratives that reflect and engage with societal issues, reflecting a desire for meaningful and relevant storytelling.

In addition to narrative subjects, the study explored the preferences for film genres, and the results indicate that Sri Lankan filmgoers have a diverse taste. The drama, thriller, action, and comedy genres emerged as the most popular choices among the respondents. This diversity in genre preferences suggests that Sri Lankan audiences enjoy a wide range of cinematic experiences, from emotionally engaging dramas to thrilling action-packed adventures and lighthearted comedies that offer moments of laughter and entertainment.

The in-depth interviews conducted with professionals from the Sri Lankan film industry further underscored the significance of linear narrative structures in local cinema. Linear narratives, with their straightforward and chronological storytelling, appear to resonate well with the audience, providing clarity and coherence in the unfolding of the plot.

The research also delved into the moviegoers' preferences for specific cinematic elements. Notably, 50% of respondents expressed a preference for movies with songs, highlighting the significance of music and song sequences in enhancing the cinematic experience for the audience.

Regarding color grading, the study revealed that 60% of participants preferred a colorful color grade. However, when comparing this with the preferences for thematic color grading, doubts were raised about the audience's understanding of this aspect. This finding suggests a potential area for further research and exploration to better comprehend the audience's perception and appreciation of color grading in films.

Finally, the content analysis of the three most favored movies, *'Harry Potter'*, *'Suriya Arana'*, and *'Jurassic Park'* provided valuable insights into the prevalent narrative subjects in these films. While *'Harry Potter'* portrayed magic and heroism on the surface, it effectively addressed social conflict in its subtext, resonating with the audience's desire for narratives that offer more than meets the eye. Similarly, *'Suriya Arana'* delved into social problems within a religious

context, captivating viewers with its exploration of cultural issues and spiritual dilemmas. *'Jurassic Park'* a sci-fi and action-packed adventure, cleverly conveyed a social problem of capitalist hegemony over nature, prompting thought-provoking discussions on ethics and human responsibility.

RECOMMENDATION

Given that about 70% of moviegoers prefer movies with narrative subjects centered around social factors, it is recommended to focus on crafting stories that address pressing societal issues and resonate with the audience's lived experiences.

Sri Lankan film audiences have diverse tastes, with drama, thriller, action, and comedy emerging as the most popular genres. It is suggested to filmmakers, continue to explore a wide range of genres to cater to the varied preferences of the audience. This approach allows for a rich cinematic experience and helps to expand the scope of local storytelling.

The study highlights the preference for linear narrative structures among Sri Lankan audiences. Filmmakers should continue to utilize this storytelling style to provide clarity and coherence in their narratives. Still, exploring other storytelling techniques, such as non-linear narratives or experimental storytelling, can also add novelty to the local film landscape.

The success of films like *'Harry Potter'*, *'Suriya Arana'*, and *'Jurassic Park'* which subtly address social problems in addition to their main themes, indicates that audiences appreciate narratives with deeper layers of meaning. The study suggests to continue to explore socially conscious subtexts to provide audiences with thought-provoking and enriching cinematic experiences.

REFERENCES

Allen, J. (1980). The Film Viewer as Consumer. Quarterly Review of Film Studies. <https://doi.org/10.1080/10509208009361066>

Braga, P. (2019). Mapping Subtext by Using Thematic Coordinates. JOMEC Journal. <https://doi.org/10.18573/jomec.187>

Cardwell, S. (2016). Film Structure and the Emotion System. ResearchGate.

Census of Population and Housing (2012). Department of Census and Statistics. (n.d.). <http://www.statistics.gov.lk>

Crick, P. (1977). Towards an Aesthetic of Film Narrative. <https://doi.org/10.1093/bjaesthetics/17.2.185>

Deepika, D. (2012). Narrative Strategies in Contemporary Sri Lankan Cinema. <http://archive.cmb.ac.lk:8080/xmlui/handle/70130/2326>

Deleyto, C. (1991). Focalisation in Film Narrative. ResearchGate.

Glebas, F. (2009). Directing the Story. UK: Elsevier Inc.

Hassan D., Abdullah N. Hajjibok Z. Salleh S. (2016). Determination of Factors That Influenced Film Audiences. ResearchGate.

Hidayat, M, Weda S. (2021). A Comparative Study of Narrative Structure in the Novel and Film *'The Jungle Book'*. Journal of English Linguistics and Literature Studies.

Jinadasa, M. P. (2016). Psychological and Philosophical Readings of the Spectatorship of Bollywood and Indian Tamil Film in Sri Lanka. <https://doi.org/10.13140/RG.2.1.4811.4801>

Nichols, E. (2017). Distracted Spectatorship, The Cinematic Experience and Franchise Films. <https://www.semanticscholar.org/paper/Distracted-spectatorship%2C-the-cinematic-experience-Nichols/63f750856b399319da3c67b3a7d6b34e3fe26d5f>

Rajadhyaksha, A. (2013). Why Film Narratives Exist. Inter-asia Cultural Studies, 14(1), 62–75. <https://doi.org/10.1080/14649373.2013.745973>

Robinson, A. (2010). An Overview of Contemporary Sri Lankan cinema. <https://doi.org/10.1080/14746689.2010.501557>

Senevi, H. S. (2017). The Paradigm Shift of Sri Lankan Cinema: A Study of Reflections and Repercussions in the Cinema after Introducing the Open Economy in 1977. ResearchGate.

Senevi, H. S. (2018). Film Genres (Sinhala). <https://doi.org/10.13140/RG.2.2.18411.03369>

Sengupta, R. (2020). Historical Continuities in South Asian Film Narratives: Contemporary Representations of Religious, Ethno-linguistic and Sexual Minorities. <https://doi.org/10.1177/2393861720923811>

Shanaz S. A. F, Nimalachandra K. M. D. C. (2010). Popular Film Genres in Sri Lanka. <http://repository.kln.ac.lk/handle/123456789/4737>

Somaratne, M. P. (2021). Sri Lankan Moviegoers in Covid-19 Pandemic Era. ResearchGate.

Tatia, S. (2019). Evolution of Bollywood: A Study on Taste and Preferences and Income-Expenditure Framework of Consumers. Ipmg. https://www.academia.edu/74442248/Evolution_of_Bollywood_A_Study_on_Taste_and_Preferences_and_Income_Expenditure_Framework_of_Consumers

Challenges in Budgeting for Freelance Video Editors in Sri Lanka

W.V.D. Fernando

Department of Film and Television Production Technology

University of Vocational Technology

Rathmalana, Sri Lanka

ftpt19b219@uovt.ac.lk

Abstract— This research endeavors to discern and explore the preliminary cost-related hurdles and budgeting complexities encountered by video editors in the management of video editing projects. The study employed a methodology centered on semi-structured interviews conducted with video editors in Sri Lanka, aimed at gathering pertinent data. The findings indicate that when budgeting, editors give top priority to a number of elements, including the complexity of the project, the editor's expertise and skill level, and the amount of time needed for editing. Editors often consider other factors, like the client's experience in the industry. The study suggests a number of approaches to deal with pre-costing issues and budgetary conundrums, including the maintenance of a comprehensive portfolio, the establishment of a Video Editors Community or Union, in-depth project discussions and pre-edit planning, and the utilization of a least-cost package rate system for budgeting.

Keywords— Video Editors, Budgeting, Freelance Video Editors, budgeting difficulties, Pre-costing issues, Costing Methods

I. INTRODUCTION

The freelance video editing industry has expanded significantly in recent years due to technological advancements and increased demand for video content. Despite this growth, freelance video editors encounter various challenges that can affect their productivity and work quality. These challenges include issues related to costing, understanding client expectations, and managing multiple tasks. These difficulties may lead to subpar work quality, leaving clients dissatisfied and impacting the editor's income. Clients play a crucial role in shaping the approach and outcomes of video editing projects. By being aware of these challenges, clients can effectively communicate their expectations, actively participate in the budgeting process, and provide clear project guidelines. Collaboration and understanding between clients and editors can lead to smoother project execution. Clients are also encouraged to consider the proposed solutions from this study, such as clear agreements and open communication, to enhance the overall project experience.

II. SIGNIFICANCE OF THE STUDY

This study's significance lies in its comprehensive exploration of pre-costing issues and budgeting challenges in video editing. By offering practical solutions, it empowers

editors to make informed decisions, streamlining processes, and enhancing project efficiency. These insights also hold the potential to shape industry standards, fostering transparency and growth. Moreover, the study emphasizes client-editor collaboration, promoting clear communication and well-defined project goals. In essence, this research has the power to revolutionize the video editing landscape by enhancing professionalism, collaboration, and project outcomes.

III. PROBLEM AND GAP

The research problem addressed in this study is the investigation of the factors and difficulties that freelance video editors face when budgeting for their editing projects. Despite the growth of the freelance video editing industry and technological improvements, freelance video editors still confront a number of difficulties that have an impact on the effectiveness and quality of their work.

These obstacles include being unable to effectively predict budgets, manage client expectations, balance multiple projects, and estimate costs. As a result, freelance video editors may find it challenging to deliver high-quality work, satisfy client needs, and earn a fair income. By researching the variables that affect the effectiveness of budgeting and editing for freelance video editors and identifying the typical issues, this study tries to address these problems.

IV. OBJECTIVES

- To identify the pre-estimate issues that freelance video editors face in the budgeting process.
- To investigate the competitive costing methods used by freelance video editors to determine the feasibility of their budgets.
- To investigate the competitive costing methods used by freelance video editors to determine the feasibility of their budgets.
- To determine the factors that influence the choice of competitive costing methods for freelance video editors.
- Identify the factors that impact the budgeting decisions made by freelance video editors.

V. LITERATURE REVIEW

The study found that after video-editing treatments, students' performance in terms of video-editing abilities improved (Yoestara & Ismail, 2023e). The Hitchcock system

uses computer analysis to identify the acceptability of video portions, allowing users to produce customized videos from raw footage (Girgensohn et al., 2000c). This study provides a solution for object level video editing tasks, including object removal, background inpainting, and novel view video synthesis, which performs better than state of the art techniques (Siddique & Lee, 2021b). The development of autonomous video editing, emphasizing the use of AI in both partial and full workflows, and examining related works from various aspects (Zhang et al., 2022). Reconfigurable video playback's significance in interactive video applications. It emphasizes how viewers or programmers can change video sequences, ideally in real time (Mackay & Davenport, 1989). Focuses on studies looking into how to use video editing to help novice teachers strengthen their reflective practice. The study that was conducted is a component of a bigger research on video-enhanced teacher reflection (Calandra et al., 2009).

Concentrates on the Hitchcock system, an easy-to-use video editing program that makes it simple to produce personalized videos from raw video material shot with a typical video camera. Hitchcock, in contrast to other video editing programs, uses automatic analysis to determine the suitability of the different segments within the raw video. (Girgensohn et al., 2000). Focuses on the difficulty of identifying the intrinsic reflectance and illumination images in a photograph or video (Bonneel et al., 2014).

The significance of budgeting in video production and brings attention to the parallels between the budgeting strategies used by video producers and those employed by other service sectors (Sweetow, 2011). The difficulty of budgeted selection in active learning, where the learner must choose a group of examples within an established supervision budget, is addressed in this work. The budget indicates the resources that are available for annotation, such as money or time (Vijayanarasimhan et al., 2010).

The research presented here helps us understand how deep semantic video segmentation trades off accuracy for speed. The suggested budget-aware approach provides a practical means of lowering computing expenses without sacrificing segmentation quality (Mahasseni et al., 2017). The research emphasizes the significance of developing user-friendly editing tools and integrating metadata to overcome the difficulties in video editing. By making use of metadata, video editing can be made simpler for beginners and more effective for the reuse and creation of video content (Casares et al., 2002).

The transformational potential of computational media production, driven by the incorporation of metadata, in automating and modifying video production processes is highlighted by this study. (Davis, 2003). This research offers a significant addition to the automated creation of video clips for editing needs. The framework enables the development of aesthetically pleasing sub-clips that can be smoothly incorporated into the editing process by emulating camera motions and applying cinematographic concepts (Gandhi et al., 2014). Techniques offers an effective way to produce compressed video summaries that maintain crucial information while adhering to bit budget restrictions (Li et al., 2005).

VI.METHODOLOGY

A qualitative research approach has been used for the study, which involve semi-structured interviews with video editors. To find patterns and themes in the data, thematic analysis approaches has been used. A targeted sample of freelance video editors was chosen based on their experience and skills.

The research only includes freelance video editors who have their own editing setup and at least two years of experience in the industry, in order to ensure that the findings are relevant and meaningful. This requirement is necessary to ensure that the participants are capable of offering insightful commentary on the budgetary and editing issues they confront and have a clear understanding of these challenges.

VII.Research Tools

1) Semi-structure Interviews

All 5 objectives are covered with Semi-structured interviews that were conducted to collect qualitative information about the viewpoints and experiences of video editors with regard to the budgeting and pre-costing obstacles faced by the video editing industry, as well as their suggestions for overcoming these issues.

VIII.Population and Sampling

1) Semi-structured Interviews with Freelance Video Editors and Company related Editors

The sample for this study will be made up of 10–15 freelance video editors who were chosen for their knowledge and experience in the field. Purposive sampling will be used to choose the sample, which involves selecting participants based on specified standards. The selection criteria were participants' expertise, experience as freelance video editors, having their own editing system, as well as their knowledge of editing and budgeting. This helped to ensure that the findings are accurate and meaningful, and to generalize.

IX.The Profiles of the interviews

- E1- Mr. Praveen Jayarathna (Professional Film Editor)
- E2- Mr. Lahiru Senevirathna (Professional Freelance Colorist / Video Editor)
- E3- Mr. Subodha Amarasinghe (Professional Freelance Video Editor)
- E4- Mr Pramesh Perera (Professional Freelance Video Editor/ Cinematographer)
- E5- Mr. Chathuranga Rathnaweera (Intermediate Level Freelance Video Editor/ Lecturer)
- E6- Mr. Saman Kariyawasam (Intermediate Level Freelance Video Editor/ Academic supportive staff member of film & tv subjects)
- E7- Mr. Mohomad Nifran (Intermediate Level Freelance Video Editor)
- E8- Mr. Lakmal Perera (Intermediate Level Freelance Video Editor)
- E9- Mr Prabath Godakanda (Beginner Level Freelance Video Content Creator)

E10- Mr Shehan Bashitha (Beginner Level Freelance Video Content Creator)

E11- Mr Chamod Dilshan (Beginner Level Freelance Video Content Creator)

X. FINDINGS AND ANALYSIS

XI. Costing Methods

a. Hourly Rate

Hourly rates are a common payment method among video editors, especially freelancers, as it compensates them for their time and skills. Overseas clients often prefer this approach, and it efficiently accounts for project duration. This method suits freelancers who handle multiple projects simultaneously, aligning income with work volume. Online platforms and some editors employ daily rates, accommodating clients seeking a fixed daily fee. Experience, project complexity, and other factors influence hourly rates, categorized as beginner, intermediate, and professional levels.

b. Project Base Fixed Rate

Fixed rates are a typical payment strategy for larger and longer projects. According to our research, fixed rates are more typically used in Sri Lanka than hourly rates. This is because they enable clients to budget for the full project without having to worry about hidden expenditures. Fixed rates can be usually higher than hourly rates because they consider the entire scope of the project rather than just the time spent on it.

c. Duration Wise Budget

Editors use duration-based budgeting, aligning their services with the final video's length. This approach varies with production types. This study finds that editors adopt Duration Wise methods when comprehensive video corrections are needed, simplifying the editing process. This benefits both parties by offering a realistic time estimate for the project.

d. Separate Budgets for Editor and Editing Table

Budgeting for video editing involves considering both the editing space and the editor's fees. This approach offers clients a clearer project budget by factoring in equipment expenses and editor costs. Some clients opt to separately engage an editor and an editing studio. They select a studio equipped with necessary accessories, pay the studio directly, and then have the editor work at the studio. This practice, common among professional clients, can streamline project management and yield advantages.

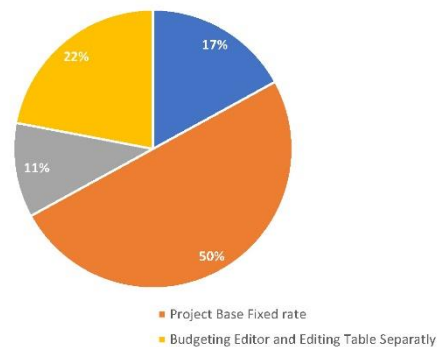


Fig. 1. The figure above indicates the percentage of time that various costing methods are used in video editing projects in Sri Lanka.

XII. Pre-Costing Issues/ Budgeting Challenges

a. Understanding and Explanation

Emphasize the challenges that develop in budgeting for video editing projects due to a lack of knowledge and communication between the client and the editor. The research findings indicate that clients often do not fully understand the complexity and time duration of editing projects, and their limited knowledge about the industry makes it difficult for them to comprehend the commercial value budget.

b. Low-Cost Competition

The findings imply that the industry is facing a significant amount of low-cost competition. The industry and industrial rates are impacted by some editors' continuing low price range. Professional editors face a serious challenge as a result of having to compete with low-cost alternatives, and clients frequently disagree on price because some editors continue to operate at a low rate in the industry.

c. Editors' Mistakes

Success in every industry depends heavily on the quality of work produced. The field of video editing is no restriction, and mistakes made by editors can result in dissatisfied consumers and have a detrimental effect on the sector as a whole. Study's conclusions show that mistakes made by amateur editors have an impact on professional editors as well as the industry.

d. Unexpected Challenges

"Unexpected Challenges" in video editing projects emphasizes the difficulties that can occur during the editing process and have an impact on the time and cost constraints. One of the most typical unforeseen issues is when clients make changes that affect the budget in the middle of the editing process. It is critical that clients understand that any changes to the project will have an impact on the budget and timeline.

e. Identifying the Value

It is critical to determine the worth of a video editing project in order to set a budget and expectations for both the client and the editor. Some clients, on the other hand, conceal the true value and commercial potential of their project in order to negotiate a low budget. This is a prevalent problem in the industry, and it has an impact on the overall quality of the finished product.

f. Current Issues

Current issues in Sri Lanka affect video editing project financing, mainly due to escalating electricity and PC equipment costs essential for the process. The surge in electricity costs has notably impacted project production, prompting editors to allocate more funds for electricity to ensure uninterrupted workstation operation.

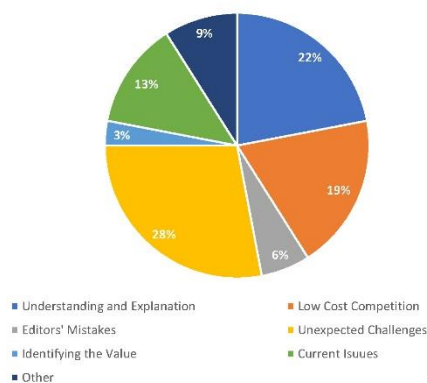


Fig. 2. The chart illustrates the categorized issues percentage that impact on the editors. The two main sectors in pre-costing issues and budgeting challenges faced by video editors are Unexpected Challenges and Understanding and Explanation.

XIII. Factors that Influence Freelance Video Editors' Budgeting Decisions

a. Most Important Factors

1. Industrial Rates

Determining a project's budget can be difficult, and one of the most crucial elements to consider is current industrial rates. Research findings imply that understanding current industry rates is critical when developing a budget for video editing projects. Clients frequently have preconceived notions about what they should pay for a specific project, and understanding the current market rate can assist video editors in making informed judgments about the rates they charge.

2. Commercial Value

Commercial value is a crucial thing. The findings imply that it is critical to assess whether an editing effort has commercial value or not, as this has a major effect on the costs. When budgeting, the ability to differentiate between a normal edit and a commercial edit is critical, as commercial

edits require a higher budget due to their potential to generate revenue. The ability to determine the commercial value of an editing work can influence pricing strategy as well as whether the project is accepted or rejected.

3. Production Type

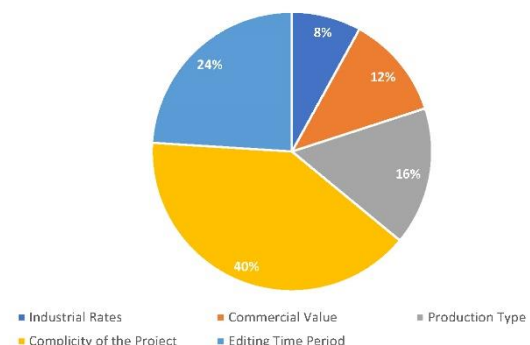
The type of production impacts the financial considerations for freelance video editors. According to the findings, recognizing the type of production is critical in estimating the budget of the editing work. This is due to the fact that different forms of production have varying industrial rates and hence demand varied amounts of budget allocation.

4. Complicity of the Project

One crucial element that has a big impact on how much freelance video editors spend is the project's complicity. The number of titles needed, the presence of trailers or teasers, custom animation, VFX elements, complex effects, color grading needs, image stabilization requirements, and the size and complexity of the video are just a few of the factors that affect how complex a project is. Each of these components makes the project more complex, which raises the budget needed to produce the desired outcome.

5. Editing Time Period

One of the most significant aspects to consider when budgeting for video editing work is the editing time period. The amount of time required to execute the project, which can range from a few hours to several weeks or even months, depends on the project's complexity. Understanding the



editing period is critical because it directly influences the project's budget.

Fig. 3. The chart indicated the percentage of the most important factors that editors take into consideration when deciding on a budget for their video editing projects. Five sections make up the chart, each of which represents a different factor.

b. Additional Factors

1. Rushers Amount

The number of rushers, or raw material that needs to be processed, is an important consideration for establishing the budget for a video editing project, especially some

editors. The more rushers there are, the more time and work it takes to pick and modify them, raising the project's final cost. As a result, while developing a budget for a video editing work, it is critical to consider the number of rushers.

2. Duration of the Edit

The duration of the edit is a significant component that influences freelance video editors' financial decisions. The duration of the finished edit is closely related to the amount of work required to complete the project. Longer videos require more time and work to edit, and so cost more. As a result, while determining the budget for an editing project, video editors must carefully evaluate the duration of the final product.

3. Editing Table

An important thing that affects budgeting choices in the field of video editing is the editing table or PC equipment. A powerful computer that can handle high-quality video footage is required for effective video editing, which is a computer-intensive operation. The quantity and complexity of the video that needs to be edited will determine the sort of editing equipment needed. The advent of 4K footage has significantly enhanced video resolutions in the present, necessitating the use of sophisticated PC editing table equipment.

4. Camera Count

This is especially true for discussions and television shows when the participants' conversation is frequently recorded by several cameras. The cost of the project may ultimately rise with the usage of more cameras because there will be more material to edit and it will take longer to do so.

5. Editor's Experience

Budgeting for a video editing job is heavily influenced by the editor's experience. Some clients favor working with editors who have a lot of industry experience. For instance, clients might seek out an editor with film editing experience if the project is a movie. Professional clients, on the other hand, could choose an editor based on their prior project-related experience.

6. Editor's Creativity Level

Editing is more than just putting together clips; it is also about storytelling, creativity, and skill. When it comes to budgeting, an editor's level of creativity is critical to consider. The higher the price, the more creative the editor.

7. Emergency Projects

Emergency projects require rapid attention and frequently necessitate the editor working extra, overnight, or on weekends. In such instances, the editor must put all other work aside and concentrate completely on the emergency project until it is completed.

8. Resolution

Resolution is important in video editing because it impacts the amount of time and effort required to edit footage. Video resolution has become a significant element in the budgeting process for video editing projects in today's world of high-definition and ultra-high-definition content.

9. Outsource Buying

There are numerous things that must be considered when creating a video. In addition to the actual filming and editing, extra components are frequently required to bring the video to life. Music tracks, stock footage, vocal narration, graphic design, visual effects, and other elements may be included. When it comes to budgeting for these extra features, it can be beneficial to consider outsourcing and purchasing services or products.

10. Internet Cost

In the current world, when digital media is widely used, clients frequently provide footage online. This means that while creating their budgets, editors must account for internet expenses. The volume of data that must be collected and uploaded might have a big impact on the project's overall cost.

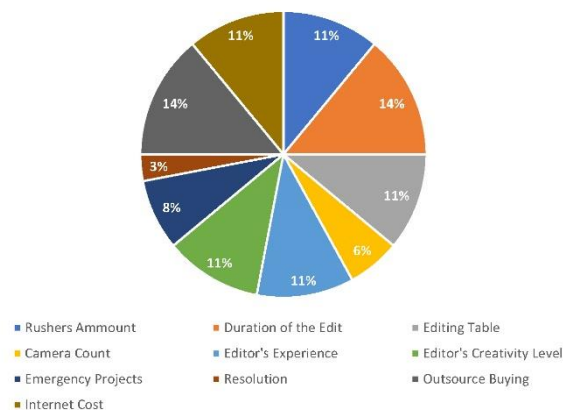
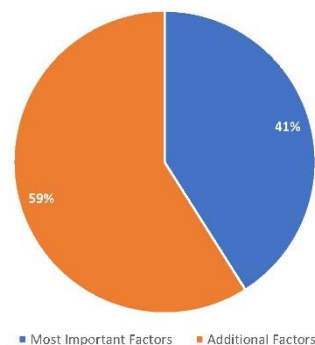


Fig. 4. The chart illustrates the percentage of additional factors considered by editors while making budgeting decisions. The chart is organized into ten



sections, each indicating a factor considered by editors.

Fig. 5. The chart represents the breakdown of the variables that editors take into consideration while deciding on their budgets, with 41% representing the Most Important Factors and 59% representing the Additional Factors. That shows editors mainly take their decisions considering Additional Factors instead of Most Important Factor.

XIV.Solutions

This study found various obstacles and issues that editors experience when evaluating project costs after completing research for this study. The survey identifies budgeting method dispute solutions mainly such as *Understanding the Industry Rates*, *Over Budgeting*, *Signing a Clear Agreement*, *Creating Video Editors Community or Union*, *Pilot Edit/ Samples Edit*, *Reference/ Portfolio* and some other additional solutions.

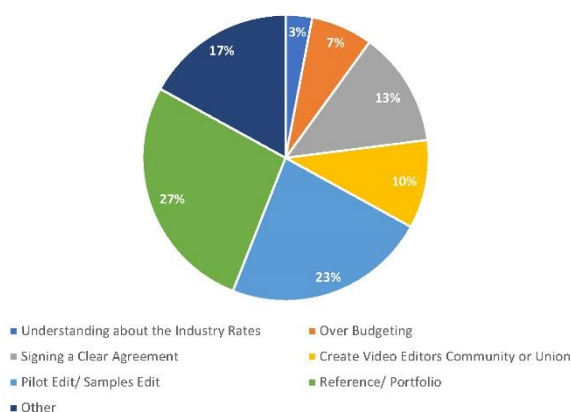


Fig. 6. The chart represents the percentage of editors recommended solutions considering budgeting decision difficulties and pre-costing issues. The chart is organized into seven sections, each indicating a solution recommended by editors.

XV.CONCLUSION

The analysis of data collected from Sri Lankan editors underscores the importance of addressing pre-costing and budgeting challenges for successful video editing projects. Editors prioritize factors like project complexity, production type, and experience levels when making budgeting decisions. Additional considerations include editing duration, editor creativity, and unforeseen changes during the process. Survey results indicate that poor client communication, inadequate field knowledge, and project planning issues contribute to budgeting complications. Editors propose solutions such as clear agreements, organized editing and portfolio maintenance, community or union formation, understanding client types, and enhancing industry knowledge. They suggest strategies like least cost package rates, upfront payments, and effective client communication. Pre-costing and budgeting hold crucial roles in video editing, demanding thorough assessment of multiple criteria to ensure project success. The editors' recommendations offer potential remedies to overcome pre-costing and budgeting challenges, ultimately enhancing the effectiveness and triumph of video editing endeavors in Sri Lanka.

XVI.RECOMMENDATION

1. Video editors should keep a portfolio of their previous work to help clients make budgeting decisions. The portfolio should be updated on a regular basis to reflect new content and editing trends.
2. Video editors should use a costing approach that is appropriate for the client's industry understanding.
3. Maintaining a least cost package rate structure for budgeting can make budgeting decisions easy for both the editor and the consumer.
4. To prevent payment concerns, editors should take half of the budget as an advance payment or a portion of the total amount.
5. Editors should consider developing a detailed project plan and storyboard. This can make sure that the editing is done quickly and effectively and that the finished result satisfies the client's needs.
6. The Sri Lankan film industry might adopt a more organized method of editing, with several editors specialized in various kinds of scenes. This can help raise the industry's editing standards and improve the quality of the final output for audiences.
7. Establish a standardized price model through a community or union: Based on the findings, it is suggested that a standardized pricing model be created that accounts for the varied costs associated with editing projects. This can assist editors in providing consistent and accurate pricing estimates, reducing disagreements with clients and maintaining long-term partnerships.

REFERENCES

- [36] Yoestara, M., & Ismail, N. M. (2023b). Employing video-editing skill in designing materials for Speaking class. *EnJourMe (English Journal of Merdeka) : Culture, Language, and Teaching of English*, 7(2), 241–253. <https://doi.org/10.26905/enjourme.v7i2.8817>
- [37] Jackson, W. (2016). Digital Video Editing Fundamentals. *Digital Video Editing Fundamentals*. <https://doi.org/10.1007/978-1-4842-1866-2>
- [38] Girgensohn, A., Boreczky, J., Chiu, P., Doherty, J., Foote, J., Golovchinsky, G., Uchihashi, S., & Wilcox, L. (2000b). A semi-automatic approach to home video editing. *Proceedings of the 13th Annual ACM Symposium on User Interface Software and Technology - UIST '00*. <https://doi.org/10.1145/354401.354415>
- [39] Grant, A. E., Brown, T., & Nachlinger, H. (2010c). Accelerating Technologies: The Diffusion of Nonlinear Video Editing. *Electronic News*, 4(4), 188–202. <https://doi.org/10.1177/1931243110390339>
- [40] Jensen, B., & Laursen, B. (2000). Musculoskeletal Workload during Non-Linear Video Editing. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, 44(6), 636–639. <https://doi.org/10.1177/154193120004400625>
- [41] Siddique, A., & Lee, S. (2021). Object-Wise Video Editing. *Applied Sciences*, 11(2), 671. <https://doi.org/10.3390/app11020671>

- [42] Aronda, Samuel & Alaka, Benard. (2020). Online Freelance Hiring & Search Platform for Students and Startups. <https://10.13140/RG.2.2.32399.74405>
- [43] Zhang, X.; Li, Y.; Han, Y.; Wen, J. AI Video Editing: a Survey. *Preprints* 2022, 2022010016 (doi: 10.20944/preprints202201.0016.v2).
- [44] Narayanamma, Vummadisetty & Reddy, R. (2019). VIDEO EDITING OPTIONS -OVER VIEW.
- [45] Mackay, W. E., & Davenport, G. (1989). Virtual video editing in interactive multimedia applications. *Communications of the ACM*, 32(7), 802–810. <https://doi.org/10.1145/65445.65447>
- [46] Calandra, B., Brantley-Dias, L., Lee, J. D., & Fox, D. L. (2009). Using Video Editing to Cultivate Novice Teachers' Practice. *Journal of Research on Technology in Education*, 42(1), 73–94. <https://doi.org/10.1080/15391523.2009.10782542>
- [47] Girgensohn, A., Boreczky, J., Chiu, P., Doherty, J., Foote, J., Golovchinsky, G., Uchihashi, S., & Wilcox, L. D. (2000). *A semi automatic approach to home video editing*. <https://doi.org/10.1145/354401.354415>
- [48] Bonneel, N., Sunkavalli, K., Tompkin, J., Sun, D., Paris, S., & Pfister, H. (2014). Interactive intrinsic video editing. *ACM Transactions on Graphics*, 33(6), 1–10. <https://doi.org/10.1145/2661229.2661253>
- [49] Sweetow, S. (2011). Budgeting the Corporate Video Production. In *Elsevier eBooks* (pp. 51–59). <https://doi.org/10.1016/b978-0-240-81341-7.00004-0>
- [50] Vijayanarasimhan, S., Jain, P., & Grauman, K. (2010). *Far-sighted active learning on a budget for image and video recognition*. <https://doi.org/10.1109/cvpr.2010.5540055>
- [51] Mahasseni, B., Todorovic, S., & Fern, A. (2017). *Budget-Aware Deep Semantic Video Segmentation*. <https://doi.org/10.1109/cvpr.2017.224>
- [52] Casares, J. A., Long, A. C., Myers, B. A., Bhatnagar, R., Stevens, S. M., Dabbish, L., Yocum, D., & Corbett, A. T. (2002). *Simplifying video editing using metadata*. <https://doi.org/10.1145/778712.778737>
- [53] Davis, M. M. (2003). Editing out video editing. *IEEE MultiMedia*, 10(2), 54–64. <https://doi.org/10.1109/mmul.2003.1195161>
- [54] Dancyger, K. (1993). *The Technique of Film and Video Editing: History, Theory, and Practice*. https://openlibrary.org/books/OL17051943M/The_technique_of_film_and_video_editing
- [55] Gandhi, V., Ronfard, R., & Gleicher, M. (2014). *Multi-clip video editing from a single viewpoint*. <https://doi.org/10.1145/2668904.2668936>
- [56] Li, Z., Schuster, Z., Katsaggelos, L., & Gandhi, B. K. (2005). *Optimal video summarization with a bit budget constraint*. <https://doi.org/10.1109/icip.2004.1418830>

Use of Access Control Systems in Government Organizations in Sri Lanka

H.M.M.S Doratiyawa

Faculty of Technology

University of Colombo

Sri Lanka

manulasachinthana@gmail.com

D.M.L.M Dissanayake

Department of Statistics and Computer Science

Faculty of Science, University of Kelaniya

Sri Lanka

maheshikad@kln.ac.lk

discussed in this paper. The usage of these devices and mechanisms in Sri Lankan government sector organizations was discussed in this paper.

Abstract— *In the context of the Sri Lankan government sector number of government organizations are moving their manual systems to computer-based information systems today. Information security is a significant challenge in the organizational information systems environment. The use of the Access Control mechanism of the Sri Lankan government sector was studied in this study. Physical access control and logical access controls are the most significant types of access control mechanisms. Data collection was done through a structured questionnaire. The senior information security officer of the organization was the resource person for the study. In this study, access control mechanism using the username and password combination, defined access levels in the information systems, protecting the physical facility using fingerprint/biometrics, availability of security guards in the premises, sensitive documents secured with unauthorized access, availability of CCTV in the premises were considered as access control factors. Among these factors, the most used access control mechanism is the “defined access levels” for accessing information systems. 94.4 % of organizations have used this mechanism for their information security. The usage of fingerprint and other biometric devices for access control is significantly low in the Sri Lankan Government Sector. So, this factor needs to be developed to improve access control in government organizations.*

Keywords—Access control, Information security, Government organizations

I INTRODUCTION

Information security is a serious challenge in organizational internet and network-connected information systems environments. In the context of the Sri Lankan government sector, a number of government organizations are moving their manual systems to computer-based information systems today [1]. A considerable percentage of these information systems are connected to the internet. Even if it is not connected to the internet, it will definitely connect with the intranet of the organization. Access Controlling mechanisms of using the username and password combination, defined/establish access levels in the information systems, protecting the physical facility using Fingerprint/biometrics for entering important hardware device's locations, availability of security guards in the premises, sensitive documents (hard copies) are secured with unauthorized access, availability of CCTV (closed circuit television) in the premises are the measurement that was

II BACKGROUND

The rapid development of information technology, computers, and network connections have reformed the technique that people perceive the world [2]. Enhancement in the usage of information technology has been connected with improved use of the internet [3]. According to the Information Communication Technology Agency of Sri Lanka (ICTA), through the development of technology, there has been a major growth in information security threats that websites are present as a subject. There are a number of elementary principles that are to be followed by government organizations to mitigate or avoid websites became attacked [1]. According to Sri Lanka Computer Emergency Readiness Team (SLCERT), there is a number of information security incidents occurred in the year 2020 [4]. As an example,

- 1) 1115 incidents in Information Content Security.
- 2) 59 incidents in Intrusions.
- 3) 99 cases in Fraud etc.

Numerous researchers believe that the several existing technological solutions on the market like anti-virus software, intrusion detection systems, authentication, and firewalls do not guarantee information security and have boundaries in assuring protected systems [5]. Access Control can be executed using numerous mechanisms. Passwords, PIN (Personal Identification Numbers), Security tokens, Biometrics, etc. These are used to ensure the performance of authentication and authorization of system access [9]. Layered Defense and Multifactor Authentication are used as modern access control mechanism in the Information Systems [7].

There are two major types of access control mechanisms available. Physical access control and logical access control are those two types [5].

o Physical Access Control

Physical Access Control is a mechanism that giving of permission to access the resources in a restricted place where information system implemented or stored. It can be a

physical lock with a key or might be combine of this kind of key and software controlled physical access [6]. For secure the infrastructures, organizations use electronic access controls. Organizations use Access Card Readers, user credentials, using security guards in the premises, use of CCTV, auditing the users and documenting and tracking the users who are accessing to the restricted business locations and proprietary areas, like data centers [7].

○ Logical Access Control

Logical Access Control means authorization to an information system resources with integration by different user levels [7]. These types of access controllers are presented inside the Operating Systems, Databases, and Software Applications. Logical Access control works according to authentication and authorization mechanisms. Users want to claim their identity by username and password, IP address, or any other authentication mechanism. Frequently used mechanisms to achieve this is using Directory services and protocols like LDAP (Local Directory Access Protocol) and the SAML (Security Assertion Markup Language) through web browsers or web applications [8].

III METHODOLOGY

This research used descriptive techniques for designing the research. Descriptive research design can be use in fact-finding, formulating principles, knowledge formulation, and formulating solutions for identified problems. Through this design, variables can be deliberate in a deep manner to recognize the answer to the available problem [9].

○ Population

According to the government information center (GIC – 01/01/2022), there are 22 authorities, 73 Departments, 19 Boards, 18 Commissions, 15 corporations, 07 Bureaus, 15 Institute and Institutions, 21 other government organizations, 17 Universities, 09 Government Banks available in Sri Lanka. The summation of these organizations is 216. That means the population size for this study is 216. Then 216 government organizations' senior information security officers or the officers who is accountable for information security will be the resource person for this study. All government Authorities, Departments, Boards, Commissions, Corporations, Bureaus, Institutes & Institutions, Universities, and Banks are considered government organizations in this study. Semi-government organizations and political organizations are not included in this study [10].

○ Sampling

Probability sampling was used in this study to do the sampling in the study. The sampling Technique used in this study is the Simple Random Sampling Technique. All are government organizations and generally, they are following common programs and procedures like similar standards, protocols, rules and regulations, and government policies for their operations. This population can be considered as a normally distributed sample statistically. So simple random sampling is a decent technique for sampling these government sector organizations [11].

The sample size was calculated by using the formula that is represented as follows (1).

$$n = \frac{N}{1 + N(e)^2}$$

Where n is the sample size, N is the population size, and e is the level of precision. Then N=216, e=0.1 (10%), the sample size according to the calculation is 69. After adding 10% of the non-responsive rate the sample size was 76 responders.

○ Research Design

In this study following Access Control sub categories are examined.

1. Using Username and Password combination for authorization the Information Systems.
2. Access Levels are defined/establish in the information Systems according to their job category/Management level.
3. The information systems physical facilities are under lock.
4. Finger print or other devices are used to open the doors/entrance to the hardware devices.
5. Security guards are available in the site to protect important information systems physical facilities.
6. The institute's sensitive documents (Hard Copies) are secured to prevent unauthorized access.
7. Closed Circuit Television (CCTV) are available to monitor the sensitive areas such as Server Rooms/Data Centers.

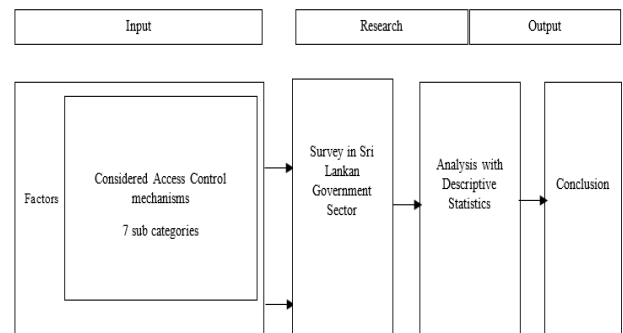


Fig. 1: Research Design

IV ANALYSIS

In this study, a few important demographic information was collected from the respondents. Before representing the Access Control related analysis following important demographic information will present in this paper.

○ Gender of the Respondents

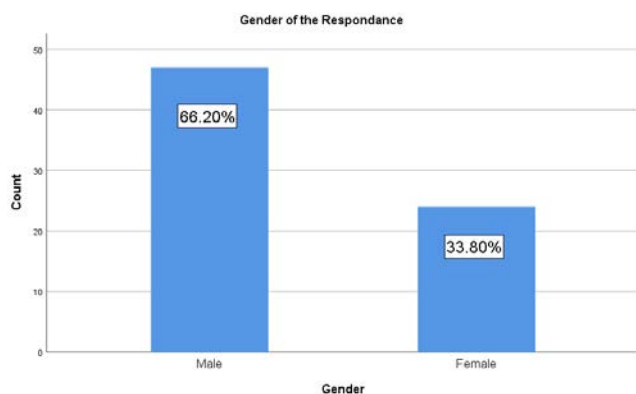


Fig. 2: Gender of the Respondent

The majority of the respondents in this study according to the graph are Male which is 66.2 % (nearly 2/3 of the respondents). The Female percentage is 33.8 % (nearly 1/3 of the respondents).

○ Number of Employees in the Respondent's Organization

The number of employees in the organization is a fact that showing the size of the organization that they are working with. Also, then it will give an indication of how much this organization is affecting the people in the country. According to the response received 40.85 % are large-scale (more than 250 employees) organizations, 35.21% is medium scale (50-250) organizations, 19.72% are small-scale (10-49) organizations, and 4.23% are very small organizations.

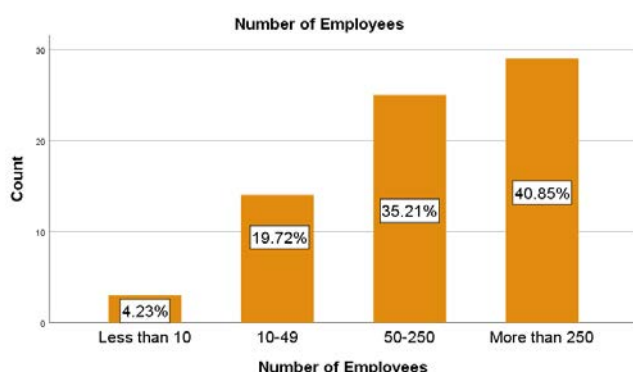


Fig. 3: Number of Employees

○ Access Control

According to the literature review, Access controls are a major factor in information security success in a number of organizations. Then here focusing on the success of access control mechanisms in government organizations in Sri Lanka. The Likert scale questions are used for collecting the information where, 5 = Strongly Agree, 4 = Agree, 3 = Undecided, 2 = Disagree, 1 = Strongly Disagree. The percentage values of each response were calculated to give a better understanding of the response rate that was collected through this study. The percentage values of the respondent are presented here in Table I.

According to the responses that were received 55.3 % Strongly agree and 36.6 % Agree on the Organizational use of the Username and Password combination for authorization of the Information Systems. Only 7.0 % of the respondent have been say that they had Undecided about the Username and Password used by the organizations. Furthermore, no one is Disagreeing about this point of information security. So, we can summarize that in Sri Lankan government sector they are widely using (Almost all organizations) this mechanism for information security success of their organization.

Responses for the Access Levels are defined/established in the information Systems according to their job category/Management level in the Organization showing that 52.1 % and 42.3 % Strongly agree and Agree respectively. While only 5.6 % have Undecided about the question and no one Disagree about the matter. That means the Sri Lankan government sector is using Access Levels of their organization for managing information systems security. According to the position/management level of the organization employees have different types of access levels in their organizations' information systems.

According to the responses that were received for information systems physical facilities are under lock, 33.8 % Strongly agree and 40.8 % Agree on this matter. While 19.7 % are Undecided about the matter and 5.6 % disagree about the issue. So, for these physical facilities that are under lock matter, more respondents are saying that their physical facilities are under lock and only a very less number of responses saying they do not have that type of locking practice in their information system.

In the next question fingerprint or other devices are used to open the doors/entrance to the hardware devices, Strongly agree and Agree answers are 35.2 % and 32.4 % respectively. 19.7 % are undecided and 12.7 % Disagree about the matter. So, compared with other matters this practice is not used by 12.7 % of the organizations. But a large number of organizations are using (more than two-thirds) this Fingerprint or other similar types of devices.

The question of whether security guards are available on the site to protect important information systems and physical facilities in the organization has got responses of 31.0 % Strongly agree and 47.9 % Agree on responses. That means more than three-fourths of the respondents agree with these questions. That means they are using security guards to protect their information system facilities. While 9.9 % have no idea (Undecided) and 11.3 % Disagree with the question.

Regarding the next question of whether the institute's sensitive documents (Hard Copies) are secured to prevent unauthorized access has 40.8 % and 46.5 % of say Strongly agree and Agree respectively. That means more than 80 % of the respondents agree with this statement. They have mechanisms to protect their sensitive documents stored in the organizations. 8.5 % and 4.2 % have responses as Undecided and Disagree respectively.

Regarding the usage of CCTV in sensitive areas, the responses are 45.1 % Strongly agree and 31 % agreed about the statement. It reveals that, three-fourths of the respondents

agree about CCTV camera usage in the organization. Furthermore, 12.7 % Undecided, and 11.3 % are Disagree/do not use CCTV cameras in their organizations for protecting the Server rooms/Data centers..

V CONCLUSION

Among the studied factors most used access control mechanism is defining/establishing access levels for accessing the information systems. 94.4 % of organizations have used this mechanism for their information security. The second used mechanism is to use the username and password combinations for accessing their information systems which is having 92.9 % of responses. The less used factor is using fingerprints and other biometric devices for access control. This factor needs to be developed in the Sri Lankan government sector. Furthermore, 66.2 % of information security officers in the government sector are males.

REFERENCES

- “Information and Communication Technology Agency,” ICTA, <https://www.icta.lk/connected-government/> (accessed Jun. 14, 2023).
- S. M. Galvez, J. D. Shackman, I. R. Guzman, and S. M. Ho, “Factors affecting individual information security practices,” *Proceedings of the 2015 ACM SIGMIS Conference on Computers and People Research*, 2015. doi:10.1145/2751957.2751966.
- I. Al-Shanfari, W. Yassin, and R. Abdullah, “Identify of factors affecting information security awareness and weight analysis process,” *International Journal of Engineering and Advanced Technology*, vol. 9, no. 3, pp. 534–542, 2020. doi:10.35940/ijeat.c4775.029320.
- “Sri Lanka CERT: CC,” Sri Lanka CERT | CC, <https://cert.gov.lk/> (accessed Jun. 15, 2023).
- N. Sohrabi Safa, R. Von Solms, and S. Furnell, “Information security policy compliance model in organizations,” *Computers & Security*, vol. 56, pp. 70–82, 2016. doi:10.1016/j.cose.2015.10.006
- L. Collins, “Securing the infrastructure,” *Cyber Security and IT Infrastructure Protection*, pp. 247–267, 2014. doi:10.1016/b978-0-12-416681-3.00010-0.
- N. Skandhakumar, F. Salim, J. Reid, and E. Dawson, “Physical Access Control Administration using building information models,” *Cyberspace Safety and Security*, pp. 236–250, 2012. doi:10.1007/978-3-642-35362-8_19.
- S. Mishra, “Organizational objectives for information security governance: A value focused assessment,” *Information & Computer Security*, vol. 23, no. 2, pp. 122–144, 2015. doi:10.1108/ics-02-2014-0016.
- Herath and H. R. Rao, “Encouraging information security behaviors in organizations: Role of penalties, pressures and perceived effectiveness,” *Decision Support Systems*, vol. 47, no. 2, pp. 154–165, 2009. doi:10.1016/j.dss.2009.02.005.
- “Information and Communication Technology Agency,” ICTA, <https://www.icta.lk/connected-government/> (accessed Jun. 26, 2023).
- G. D. Israel, Determining Sample Size.

TABLE I. RESPONSES FOR ACCESS CONTROL

No		Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
1	Organization is using Username and Password combination for authorization the Information Systems.	56.3 %	36.6 %	7.0 %	0.0 %	0.0 %
2	Access Levels are defined/establish in the information Systems according the their job category/Management level in the Organization.	52.1 %	42.3 %	5.6 %	0.0 %	0.0 %
3	The information systems physical facilities are under lock.	33.8 %	40.8 %	19.7 %	5.6 %	0.0 %
4	Finger print or other devices are used to open the doors/entrance to the hardware devices.	35.2 %	32.4 %	19.7 %	11.3 %	1.4 %
5	Security guards are available in the site to protect important information systems physical facilities in the organization.	31.0 %	47.9 %	9.9 %	11.3 %	0.0 %
6	The institute’s sensitive documents (Hard Copies) are secured to prevent unauthorized access.	40.8 %	46.5 %	8.5 %	4.2 %	0.0 %
7	Closed Circuit Television (CCTV) are available to monitor the sensitive areas such as Server Rooms/Data Centers.	45.1 %	31.0 %	12.7 %	8.5 %	2.8 %

The Factors Effecting Number of Runs Gain in Sri Lanka vs India One Day International Matches and Forecasting

P. H. S. S. Wijayarathna
Department of Network Technology
Faculty of Information Technology
University of Vocational Technology
Sri Lanka

srimanwi@yahoo.com, srimanwi@gmail.com

Abstract – *In this article, try to find the factors effect to no of runs /team total acquired by the Sri Lanka and India. This article limits the analysis to only matches between Sri Lanka and India. Cricket is one of the world-famous sports such as Rugby, Football and Basketball. Winning the match is important and it could depend on various factors such as the Age of the player, Player performance, playing ground, playing country, support of the crowd, Toss, playing day or day and night. Performance against the opposite team, Batting Style, Toss won or lost, match played as day or Day and night, Bowlers Name, No of Balls and Average. This article discusses the factors depend upon the number of runs taken by the each team. That will effect to the winning of the Team. The main target or aim of this article is to identify the factors effect to the no of runs taken by the each team. The important thing here is individual player total collectively makes the final team total.*

Keywords – Cricket, Factors effect to the number of runs, One Day International (ODI) Match, Asian cricket

I. INTRODUCTION

Cricket is an unpredictable game till delivers the last over or the last ball in the match. Sri Lanka and India are the most popular fighters in ODI Cricket in the Asian region.

The sport Cricket was introduced in England in the 16th century. This event has around 400 years of history. This game will played between two teams [01]. The person called the match referee is the decision maker of the considered match. At the beginning of the match, two captains of the two teams will meet in the middle of the ground to toss a coin with the match referee to decide the session. The two captains exchange the list of players and each team consists of eleven players and one nominated as an extra player. The one captain will call the Head or Tail in the toss and decide the session. The winning captain will decide whether his team will bat first or second, the first team playing in the first session is called as batting team and the team playing in the second session is called as fielding team [01]. The players who are in the ground in the first session are called as fielding team and they are fielders and also they will bat in the second session.

Cricket [03] plays in three formats and those are Test, One Day International (ODI) and Twenty 20 call as T20 matches. Test matches will play five days and 2 consecutive innings for both teams. The ODI matches are called 50 overs matches and will play only 100 overs and 50 overs for each team. The

T20 matches will play only 40 overs and 20 overs for each team.

The ODI matches are played in different time slots call as Day time matches and Day and Night matches. Daytime matches normally start at 9.00 – 9.30 AM and play till 5.00 – 5.30 PM and Day and Night matches normally start at 2.30 – 3.00 PM and play till 10.00 – 11.00 PM. The match end time depends on the over rate of both teams.

In One Day International cricket match, each team gets a fixed number of Overs. The over consists of six balls and the maximum number of overs per session is fifty (50). The ball was delivered by the second batting team. The first batting team faces the ball and tries to get maximum runs. The player who faces the ball is called a batsman and the player who delivered the ball is called the bowler. Each bowler can deliver a maximum of ten overs.

The batsman can get runs by hitting the ball [01]. The line established to mark the playing area is called the boundary line. The two wickets are placed middle of the ground to mark the batting area. Each wicket consists of three sticks are called stumps. The bowler will aim the wicket and throw the ball. The player who faces the ball is called a striker and the other player is called a no striker. The batsman hits the ball and it goes over the boundary line player gets six runs and the ball hits the ground before crossing the line and gets four runs otherwise two batsmen have to run in between two wickets to get runs. The maximum number of runs can get by running between the wickets is four (04). The batsman can dismiss for many reasons such as the bowler throws the ball and directly hits the wicket (Ball out), the batsman covers the wicket with the legs and the ball directly hits the legs without hitting the bat or before hitting the bat (Leg before wicket {LBW}), the batsman hit the ball and fielder catch the ball before hits the ground (catch), while they are running between the wickets fielder throw the ball and hit the wicket before the batsmen reach the batting crease. (Run Out).

The fielding side should bowl out the batting team within the 50 overs. They should get ten wickets to bowl out the batting team. The last batsman cannot bat because there should be two batsmen on the ground in the given time.

The One Day International match is played between two teams and each team bats only 50 overs and tries to get maximum runs within those 50 overs. After the 50 overs, the

session is over. The batting team balled out or lost their 10 wickets before the 50 overs session was also over. The 1st batting team gets their maximum in their 50 overs and the 2nd batting team tries to get the runs taken by the 1st batting team. If the 2nd batting team just passes the 1st batting team's total by one run, the 2nd batting team will win and otherwise 1st batting team will win the match.

II. LITERATURE REVIEW

Bandulasiri [02] discusses the advantage of a match is played in the home ground of the considered team. He discusses that as "home field" advantage. This paper also discusses how the toss winning will effect to the day or day and night match.

Swetha and Saravananan KN [04] divide the attributes that affect the no of runs in two forms and discuss those attributes as Pre-game attributes and In-game attributes which effect to the cricket match winning. They consider attributes are Pitch, Toss, Team Strength, Past records, Home ground advantage, Current performance and Weather.

Tejinder Singh, Vishal Singla and Parteek Bhatia [05] use two methods for their prediction. In the first method, they predict the first innings total based on the current run rate. They also consider the no of wickets lost, the batting team and the place of match playing. In the second method predict the second inning total using the same attributes.

Mahesh Fernando, Ananda Manage and Stephen Scariano [06]. This article discusses three factors such as "Home field advantage", "winning the toss" and "team superiority" is how effect to the ODI day match

Bandulasiri [02] discusses the advantage of "home field" or home ground, Swetha and Saravananan KN [04] discuss the Pre-game attributes and In-game attributes such as Pitch, Toss, Team Strength, Past records, Home ground advantage, Current performance and Weather. Tejinder Singh, Vishal Singla and Parteek Bhatia [05] use two methods to forecast the first innings total and the second innings total using the current run rate and no of wickets fallen in each inning. Mahesh Fernando, Ananda Manage and Stephen Scariano [06]. discuss the "Home field advantage", "winning the toss" and "team superiority" in their articles.

III. METHODOLOGY

This paper used 26 attributes and analysis was done to find the factors effect to the no of runs. Other articles use less no of attributes to find the dependencies to no of runs and this article use different 26 attributes against the number of run to find the factors effect to the no of runs.

This analysis is conducted by using Match no 2550 played on 23.03.2007 to Match No 4312 played on 23.07.2021. There are 67 number of matches were considered and the results were used to find the dependencies. The dependent factors were found by using WEKA 3.8.3 analytical Software. The method used is the Best First Method for finding the dependent factors. This paper tries to find the factors which effect to the number of runs against Sri Lanka and India.

Factors

To win the ODI match, the team should be able to collect maximum runs within the limited 50 overs. The match winning will be decided by the no. of runs gained by each team. The number of runs depends on some factors, this research tries to find the best effected factors which are significant with the no of runs. The factors which can influence the number of runs can be Year, Match No, Month, Date, Team of the player, Player Name, Batting Style, Age, Opposite Team, 1st Batting Team, 2nd Batting Team, Ground, Playing Country, In Country or Outside, In Sub Continent or Outside, Match Won or Lost, Toss Won or Lost, Day or Day and Night, No of Wickets, Batting or Chasing, Batting Position, How Out, Bowlers Name, No of Runs, No of Balls and Average.

Variable No 01 - Year

The variable Year represents the calendar year of the considered match was played. The Year variable is used to categorize the match by year. The Year variable is also used to calculate the player's age at the time of the match played.

Variable No 02 - Match No

The variable Match Number is used to identify the matches separately. The match number is unique for each match and every ODI match has a separate match number.

Variable No 03 - Month

The variable Month represents the month, which is the considered match that was played. The variable Month is also used to calculate the player's age. Tropical countries like Sri Lanka can experience seasons such as Dry and Wet seasons. The non tropical country has four seasons such as Winter, Spring, Autumn and summer. The month variable is used to identify the season is effected to the batsman's performance

Variable No 04 - Date

The variable Date shows the date when the considered match was played. In addition to that, it also represents the respective month and the year.

Variable No 05 - Team of the player

The variable Team of the player is the Country or the Team the player belongs to, for example, team can be Australia, England, South Africa, Sri Lanka and India like cricket playing countries.

Variable No 06 - Player Name

The variable Player Name is used to identify each batsman separately. There are many hundreds of batsman's is considered for this analysis. Each batsman has a separate batsman identifying number also

Variable No 07 - Batting Style

The variable Batting Style is used to identify batsman is a Right handed batsman or a Left handed batsman. There are only two batting styles such as left handed and right handed and it may effect to the performance of the batsman.

Variable No 08 - Age

The Age variable represents the batsman's age at the time the considered match was played. The player's performance may depend on the experience of the player and it can be verified using the age of the player.

Variable No 09 - Opposite Team

The Opposite Team variable represents the team that is played against the considered batsman representing the team. The batsman's performance may depend on the opposite team and it can be verified using the opposite team factor of the player.

Variable No 10 - 1st Batting Team

The variable 1st Batting Team is used to identify the team that was batting first in the considered match.

Variable No 11 - 2nd Batting Team

The variable 2nd Batting Team is used to identify the team who was batting second in the considered match

Variable No 12 - Ground

The ground variable represents the ground, the match was played. In this analysis, more than a hundred grounds were considered. The considered grounds are placed in many different countries and those grounds are distributed all around the world.

Variable No 13 - Playing Country

The variable Playing Country is represented country which is the considered match was played. The different countries has different climate and weather conditions and those conditions may effect to the player's performance.

Variable No 14 - In Country or Outside

The variable In Country or Outside represents the match that was played in the considered batsman's own country or outside the considered batsman's country. The match is played inside the considered batsman playing country is called In Country and otherwise, it is called Outside.

Variable No 15 - In Sub Continent or Outside

The variable In Sub Continent or Outside represents the match that was played in the Sub Continent which considered batsman represent or other sub-continent. The match is playing inside the Sub Continent which considered batsman playing country belongs is call In Sub Continent and otherwise it is call outside.

Variable No 16 - Match Won or Lost

The variable Match Won or Lost represents the considered match was won by the considered batsman playing team or lost them. The batsman belongs to one team out of the two teams those who played the match and the winning team batsman are considered as won and the loose team players get lost

Variable No 17 - Toss Won or Lost

The variable Toss Won or Lost represents the considered batsman playing team won the toss or not. The considering batman playing team won the toss also implies the batsmen who represent the considering team won the toss.

Variable No 18 - Day or Day and Night

The variable Day or Day and Night represents match that is played as a daytime match or a Day and night match.

Variable No 19 - No of Wickets

The variable No of Wickets is how many wickets fallen in each team within the considered match

Variable No 20 - Batting or Chasing

The variable Batting or Chasing represents the considering batsman playing team is select batting or chasing after winning the toss. The toss winning team captain selects to bat first or he invites the opposite team captain to bat first. The team who is batting first is considered as batting and the second batting team is considered as chasing team.

Variable No 21 - Batting Position

The variable Batting Position represents the considered batsman batting position in the batting order. The Batting Position is representing the number 01 to number 11. The first 03 or 04 batsmen are call as top order batsmen and middle 03 or 04 batsmen are call as middle order batsmen and the last 03 or 04 batsmen are call as low order.

Variable No 22 - How Out

The variable How Out is the player out by Catch, Ball hit the wicket, Leg Before Wicket (LBW) or Run Out.

Variable No 23 - Bowlers Name

The variable Bowler's Name represents the player who delivered the ball to the batsman. The bowler represents the opposite team of the batsman.

Variable No 24 - No of Runs

The variable No of Runs represents the no. of runs taken by the considered batsman in a batting team against the individual bowler in the opposite team in a considered match.

Variable No 25 - No of Balls

The variable No of Balls represents the number of balls faced by the considered batsman in a batting team against the individual bowler in the opposite team in a considered match.

Variable No 26 - Average

The variable Average is the average of each batsman (No of Runs/No of Balls) in the considered match.

This research identified the above-mentioned 26 variables that can be effected the No of Runs. The above 26 variables were analyzed using Weka 3.8.3 to find which factors depend on the No of Runs using the best first method.

In this research, try to find the factors that effect to the becoming match using available data.

For finding the dependent factors analysis available data. The data is collected from the Entertainment and Sports Programming Network (ESPN) [08] websites which are freely available on the Internet.

IV. ANALYSIS

This research analyzed the available data collected from the website using the best first method to find the factors that can be effected the no of runs in the next match. The analysis results are displayed in TABLE 1.

For this analysis, the researcher used Match No. 2550 played on 23.03.2007 to the Match No. 4312 played on 23.07.2021. There are 67 matches were considered and the results are displayed in TABLE 1.

TABLE 1. Mates No. vs Dependent variables

Match No.	Dependent variables
2550	In Country or Outside, No of Wickets, Batting or Chasing, How Out, No of Balls and Average
2676	In Country or Outside, Day or Day and Night, No of Wickets, How Out, No of Balls and Average
2681	Year, 1st Batting Team, 2nd Batting Team, No of Wickets, How Out, No of Balls and Average
2686	Year, 1st Batting Team, 2nd Batting Team, No of Wickets, How Out, No of Balls and Average
2732	Year, Team of the Player, Opposite Team, 1st Batting Team, 2nd Batting Team, No of Wickets, How Out, No of Balls and Average
2735	Year, Month, Team of the Player, 1st Batting Team, 2nd Batting Team, No of Wickets, How Out, No of Balls and Average
2742	Year, Batting Style, 1st Batting Team, 2nd Batting Team, No of Wickets, How Out, No of Balls and Average
2745	Batting Style, Day or Day and Night, No of Wickets, How Out, No of Balls and Average
2750	Batting Style, Playing Country, Day or Day and Night, No of Wickets, How Out, No of Balls and Average
2755	Batting Style, Playing Country, Day or Day and Night, No of Wickets, No of Balls and Average
2756	Batting Style, Playing Country, Day or Day and Night, No of Wickets, No of Balls and Average
2806	Batting Style, Ground, Playing Country, No of Wickets, No of Balls and Average
2810	Batting Style, Playing Country, No of Wickets, No of Balls and Average
2813	Team of the Player, Batting Style, Playing Country, No of Wickets, No of Balls and Average
2815	Team of the Player, Batting Style, Playing Country, No of Wickets, No of Balls and Average.
2818	Year, Team of the Player, Batting Style, No of Wickets, No of Balls and Average
2887	Year, Batting Style, Match Won or Lost, No of Wickets, No of Balls and Average
2889	Year, Batting Style, Match Won or Lost, No of Wickets, No of Balls and Average
2932	Year, Batting Style, 1st Batting Team, Match Won or Lost, No of Wickets, No of Balls and Average
2933	Year, Batting Style, 1st Batting Team, 2nd

	Batting Team, No of Wickets, Batting Position, No of Balls and Average
2934	Year, Batting Style, 1st Batting Team, 2nd Batting Team, No of Wickets, Batting Position, No of Balls and Average
2935	Year, 1st Batting Team, 2nd Batting Team, Playing Country, Toss Won or Lost, No of Wickets, Batting Position, No of Balls and Average
2936	Year, Batting Style, 1st Batting Team, 2nd Batting Team, Playing Country, Toss Won or Lost, No of Wickets, Batting Position, No of Balls and Average
2938	Year, 1st Batting Team, 2nd Batting Team, Toss Won or Lost, No of Wickets, Batting Position, No of Balls and Average
2941	Year, 1st Batting Team, 2nd Batting Team, Toss Won or Lost, No of Wickets, Batting Position, No of Balls and Average
2943	Year, Batting Style, 1st Batting Team, 2nd Batting Team, Toss Won or Lost, No of Wickets, No of Balls and Average
2983	Year, Batting Style, Age, 1st Batting Team, 2nd Batting Team, Toss Won or Lost, No of Wickets, No of Balls and Average
2988	Year, Batting Style, Age, 1st Batting Team, 2nd Batting Team, No of Wickets, No of Balls and Average
2999	Year, Batting Style, 1st Batting Team, 2nd Batting Team, No of Wickets, No of Balls and Average
3001	Year, Batting Style, 1st Batting Team, No of Wickets, No of Balls and Average
3032	Year, Batting Style, 1st Batting Team, No of Wickets, No of Balls and Average
3038	Year, Batting Style, 1st Batting Team, Playing Country, No of Wickets, No of Balls and Average
3040	Year, Batting Style, 1st Batting Team, Playing Country, No of Wickets, No of Balls and Average
3148	Batting Style, Age, 1st Batting Team, 2nd Batting Team, Playing Country, No of Wickets, No of Balls and Average
3233	Year, Batting Style, Age, Playing Country, No of Wickets, No of Balls and Average
3239	Batting Style, Age, 1st Batting Team, Playing Country, No of Wickets, No of Balls and Average
3246	Age, 1st Batting Team, Playing Country, No of Wickets, No of Balls and Average
3251	Age, 1st Batting Team, Playing Country, No of Wickets, No of Balls and Average

3259	Year, Age, Playing Country, No of Wickets, How Out, No of Balls and Average
3291	Year, Age, Playing Country, No of Wickets, No of Balls and Average
3292	Year, Age, 1st Batting Team, No of Wickets, No of Balls and Average
3293	Year, Batting Style, Age, Playing Country, No of Wickets, No of Balls and Average
3294	Year, Batting Style, Age, Playing Country, No of Wickets, No of Balls and Average
3295	Year, Batting Style, Age, Playing Country, No of Wickets, No of Balls and Average
3376	Year, Batting Style, Age, Playing Country, No of Wickets, No of Balls and Average
3382	Age, Playing Country Day or Day and Night, No of Wickets, No of Balls and Average
3387	Batting Style, Age, Playing Country, Match Won or Lost, No of Wickets, Bowlers Name, No of Balls and Average
3388	Batting Style, Age, Playing Country, Day or Day and Night, No of Wickets, Bowlers Name, No of Balls and Average
3476	Batting Style, Age, Playing Country, Day or Day and Night, No of Wickets, Bowlers Name, No of Balls and Average
3539	Batting Style, Age, Playing Country, Day or Day and Night, No of Wickets, Bowlers Name, No of Balls and Average
3540	Batting Style, Age, Playing Country, Match Won or Lost, Day or Day and Night, No of Wickets, No of Balls and Average
3543	Batting Style, Age, Playing Country, Match Won or Lost, Day or Day and Night, No of Wickets, Bowlers Name, No of Balls and Average
3544	Batting Style, Age, Playing Country, Match Won or Lost, Day or Day and Night, No of Wickets, No of Balls and Average
3547	Age, Playing Country, In Country or Outside, Day or Day and Night, No of Wickets, No of Balls and Average
3882	Age, Playing Country, In Country or Outside, Day or Day and Night, No of Wickets, Bowlers Name, No of Balls and Average
3905	Age, Playing Country, In Country or Outside, Day or Day and Night, No of Wickets, No of Balls and Average
3906	Age, Playing Country, Day or Day and Night, No of Wickets, Bowlers Name, No of Balls and Average

3907	Age, Playing Country, Match Won or Lost, Day or Day and Night, No of Wickets, Bowlers Name, No of Balls and Average
3908	Age, Playing Country, Match Won or Lost, Day or Day and Night, No of Wickets, Bowlers Name, No of Balls and Average
3909	Age, Playing Country, Match Won or Lost, Day or Day and Night, No of Wickets, Bowlers Name, No of Balls and Average
3939	Age, Playing Country, Match Won or Lost, Day or Day and Night, No of Wickets, Bowlers Name, No of Balls and Average
3941	Age, Playing Country, Match Won or Lost, Day or Day and Night, No of Wickets, Bowlers Name, No of Balls and Average
3942	Age, Playing Country, Match Won or Lost, Day or Day and Night, No of Wickets, Bowlers Name, No of Balls and Average
4187	Age, Playing Country, Match Won or Lost, Day or Day and Night, No of Wickets, Bowlers Name, No of Balls and Average
4307	Age, Playing Country, Match Won or Lost, Day or Day and Night, No of Wickets, Bowlers Name, No of Balls and Average
4309	Age, Playing Country, Match Won or Lost, Day or Day and Night, No of Wickets, Bowlers Name, No of Balls and Average
4312	Age, Playing Country, Match Won or Lost, Day or Day and Night, No of Wickets, Bowlers Name, No of Balls and Average

TABLE 1 displayed the results and those results are summarized in TABLE 2. TABLE 2 displayed the variables are dependent on the no. of runs in each match played against Sri Lanka and India. It will display how much weight in each variable with no of runs.

TABLE 2. WEIGHT OF THE VARIABLES

No.	Variable	Weight
1	Year	31
2	Match No	00
3	Month	01
4	Date	00
5	Team of the Player	05
6	Player Name	00
7	Batting Style	38
8	Age	36

9	Opposite Team	01
10	1 st Batting Team	25
11	2 nd Batting Team	16
12	Ground	01
13	Playing Country	44
14	In Country or Outside	05
15	In Sub Continent or Outside	00
16	Match Won or Lost	17
17	Toss Won or Lost	06
18	Day or Day and Night	26
19	No of Wickets	67
20	Batting or Chasing	01
21	Batting Position	06
22	How Out	10
23	Bowlers Name	17
24	No. of Runs	57
25	No of Balls	67
26	Average	67

Here, the variables No of Wickets, No of Balls and Average are 100% those depend on the no of runs. On the other hand, Match No, Date, Player Name and In Sub Continent or Outside 100% depend on the no of runs.

The variable Playing Country 66% depends on the no of runs and Batting Style and Age are depending on 57% and 54% respectively. The variable Year, Day or Day and Night and 1st Batting Team depend on 46%, 39% and 37% respectively.

The variable 2nd Batting Team 24%, Match won or lost 25% and Bowlers Name 25% dependent on the no. of runs. The variable How Out depends on 15% and other variables are less than 10% dependent.

The variable No of Wickets, No of Balls, Average, Playing Country, Batting Style and Age are highly dependent on the variable no of runs. The variable Year, Day or Day and Night and 1st Batting Team also depend on the no of runs.

The variables 2nd Batting Team, Match won or lost, and Bowlers Name also can be considered.

Then developed the model using Weka and used the linear Regression method to calculate the individual runs taken by the each player.

The model is,

$$\text{No of Runs} = \text{Age} + \text{No of Wickets} + \text{No of Balls} + \text{Average} + (\text{Co Value})$$

$$\text{No of Runs} = (\text{Value given by the analysis} * \text{Player's Age}) + (\text{Value given by the analysis} * \text{No of Wickets fallen in former matches considered player plays}) + (\text{Value given by the analysis} * \text{No of Balls faced by considered player}) + (\text{Value given by the analysis} * \text{Average runs per match}) + (\text{Co Value given by the analysis})$$

This model applies to each player in the team and calculates the team total by adding each player's gain no of runs.

V. CONCLUSION

In this analysis consider the ODI matches which played Sri Lanka against India from March 2007 to July 2021. The match no 2550 to 4312 are played against Sri Lanka and India. After analysis of the above factors against the No of Runs by using the Best First method by Weka 3.8.3 find some factors are dependent on the No of Runs out of 26 variables.

Those variables are No of Wickets, No of Balls, Average, Playing Country, Batting Style, Age, Year, Day or Day and Night, 1st Batting Team, 2nd Batting Team, Match won or lost, and Bowlers Name.

Finally, we can decide the above selected /identified variable only depends with no. of runs or team total in Sri Lanka vs India matches.

The developed model will apply to each player and calculate the no of runs taken by the individual player. Then can calculate the team total by adding the runs gained by the individual player in the considered match by using the below model.

$$\text{No of Runs} = \text{Age} + \text{No of Wickets} + \text{No of Balls} + \text{Average} + (\text{Co Value})$$

REFERENCES

- [01]. <https://simple.wikipedia.org/wiki/Cricket>
- [02]. https://en.wikipedia.org/wiki/One_Day_International
- [03]. Ananda Bandulasiri, Ph.D. "Predicting the winner in One Day International Cricket"
- [04]. Swetha and Saravananan KN, "Analysis on Attributes Deciding Cricket Winning"
- [05]. Tejinder Singh, Vishal Singla and Parteek Bhatia "Score and Winning Prediction in Cricket through data mining"
- [06]. Mahesh Fernando, Ananda Manage and Stephen Scariano "Is the home-field advantage in limited overs one-day international cricket only for day matches?"
- [07]. The Entertainment and Sports Programming Network (ESPN) <http://www.espnricinfo.com/>

Selection of Optimum Image Compression Technique for Mobile Communication

W.L.S. Wickramaarachchi
Department of Mechanical Engineering
Faculty of Engineering
General Sir John Kotelawala Defence
University
Ratmalana, Sri Lanka,
38-eng-0021@kdu.ac.lk

W.S.P. Fernando
Department of Mechanical Engineering
Faculty of Engineering
General Sir John Kotelawala Defence
University
Ratmalana, Sri Lanka
wspfernando@kdu.ac.lk

M.K.A.J. Maldeniya
Department of Mathematics
Faculty of Engineering
General Sir John Kotelawala Defence
University
Ratmalana, Sri Lanka
amilam@kdu.ac.lk

Abstract—With the rapid growth in mobile communication technologies the transmission of high quality images have issues in handling resource consumption and the quality. The resource consumption is indicated by the bandwidth and energy consumption. In this research an optimum image compression technique depending on the mobile transmission capacity, type of the image and the average download time was presented. The research was conducted for five mobile communication standards, namely; GSM, GPRS, UMTS, HSPA and LTE where for each channel two image compression methodologies were analyzed. They are wavelet image compression technique and seam carving. The optimum compression was calculated based on entropy and PSNR of the compressed image. In this project the image types are defined as texture images with a complex background and images with clear cut background as for an object. The results show the effectiveness of the proposed methodology and MatLabTM was used for the comparisons

Keywords— Mobile communication, channel capacity, compression, wavelet, seam carving

INTRODUCTION

The rapid growth of wireless communication systems has increased the demand for robust multimedia transmission with better quality, coverage and more power and bandwidth efficiency. The restriction of the wireless communication channels like limited bandwidth increases the demand for more reliable and better quality multimedia communication systems where the current research was focused specifically to develop transmission techniques for images that do not consume more bandwidth for achieving better quality images. In order to have a reliable image transmission with the real-time requirement requires low bit-rate, low delay and low complexity which maintain good image quality. The solution for the problem of reliable real time transmission of high-quality images through wireless communication channels can be achieved by applying the proper compression technique depending on the mobile transmission capacity, type of the image and the download time of the file. For this research mobile communication channel standards were selected namely, GSM, GPRS, UMTS, HSPA and LTE with their average data rates selected as 9.6 Kbps, 130 Kbps, 2 Mbps, 7 Mbps and 10 Mbps respectively. The image compression was done by wavelet based method and seam carving where Meyer and Coiflet 2

wavelets were used for implementing wavelet based image compression. For all the communication channels a reasonable overhead of 15% was considered. Several studies [1], [2] have been conducted to select compression parameters based on mobile network bandwidths based on single compression technique.

In this research an empirical method was proposed to select the optimum compression technique to transmit a high quality image in a mobile communication channel under given conditions and constraints such as channel capacity, image type and download time.

The paper is organized as follows: In Section 2, Literature Review, Section 3 considers the system overview and methodology and in Section 4 described results and discussion where Section 5, conclusion of the project is given. Section 6 is the references.

LITERATURE REVIEW

Image compression in mobile devices for wireless transmission is a critical aspect of modern communication and data transfer. Mobile devices have limited processing power, storage, and bandwidth, so optimizing image data before transmitting it over wireless networks is essential. As shown in [13], developing an adaptive compression algorithm for mobile devices to reduce the transmission energy of images through wireless networks is a crucial step in optimizing mobile data transfer. However the algorithm suffers from selecting the best compression method under varying channel capacities.

Using an "Exact Image Compression Algorithm (ICA)" in [14] for compressing still images before transmitting them via a wireless channel can be an efficient way to reduce the amount of data transmitted and thus save bandwidth and transmission energy. It's worth noting that "Exact Image Compression" typically results in larger file sizes compared to lossy compression methods like JPEG. As a result, it may not always be the best choice for scenarios with severe bandwidth or storage constraints. The choice of compression method should depend on the specific use case, available resources, and the acceptable trade-off between image quality and file size.

METHODOLOGY

One of the problems that makes wireless communication of multimedia complicated is the large amount of data that needs to be transmitted with limited resources. However, multimedia data can be compressed in a lossy manner, leading to very efficient communication.

In lossy compression, information is lost, but is tolerated as it gives a high compression ratio. If n_1 and n_2 denote the number of bits in original and encoded images respectively, then the compression ratio C_R can be expressed by equation (1).

$$C_R = \frac{n_1}{n_2} \quad (1)$$

The goal of this project is to find the optimized image compression technique, based on the type of image and the channel capacity. The overview of the system is given in Fig. 1

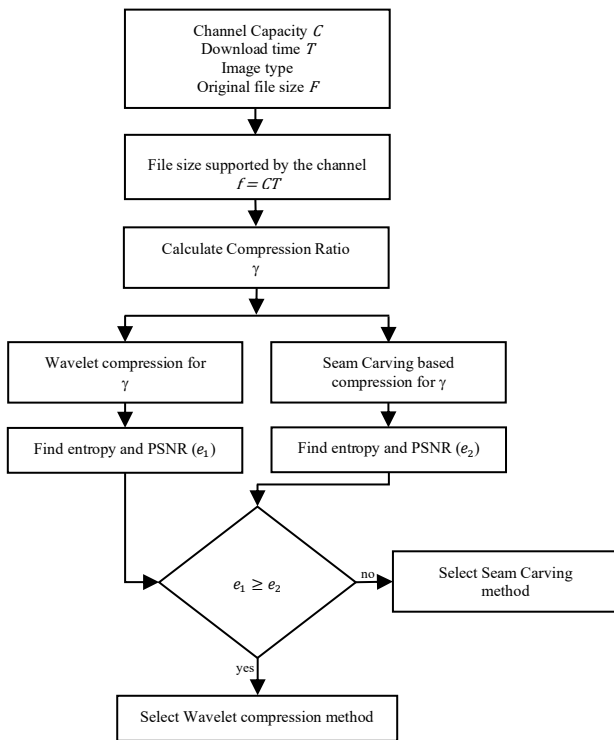


Fig. 1: Overview of the system

Discrete Wavelet based Image Compression

The rapid advancement in wavelet technology has led to very advanced standards for image compression which is based on Discrete Wavelet Transform (DWT). It has brought a new surge of interest in wavelets and also towards advancement and faster computational algorithms for storing and transmission of images. In the second stage of image compression, the transformed wavelet coefficients will be quantified. Then the encoding of the quantized coefficients is

done and after that the data is stored. To reconstruct the image, decoding is done and then by inverting the quantized coefficients inverse wavelet transform was applied [3], [4]

Wavelet involves pair of transform: one to represent the high frequencies or detailed parts of an image and one for the low frequencies or smooth parts of an image. In this paper, three families of wavelets being used for the compression of images namely Haar, Meyer and Coiflet 2 wavelets. Equations (3) and (4) shows the Haar Scale and Wavelet functions. Then the equations (5) and (6) shows the Meyer Scale and Wavelet functions.

1. Haar scale and Wavelet function

$$\phi(t) = \begin{cases} 1 & \text{if } 0 \leq t \leq 1 \\ 0 & \text{otherwise} \end{cases} \quad (3)$$

The function $\phi(t)$ is called the Haar scaling function and $\psi(t)$ is called the Haar wavelet and is defined as,

$$\psi(t) = \begin{cases} 1 & \text{if } 0 \leq t \leq 0.5 \\ -1 & 0.5 \leq t \leq 1.0 \end{cases} \quad (4)$$

2. Meyer scale and Wavelet function

The Fourier transform of $\Phi(\omega)$ of the scaling function $\phi(t)$ is defined as,

$$\Phi(\omega) = \begin{cases} 1 & \omega \leq 2\pi/3 \\ \cos\left[\frac{\pi}{2} v\left(\frac{3}{4\pi}|\omega| - 1\right)\right] & 2\pi/3 < \omega \leq 4\pi/3 \\ 0 & \text{Otherwise} \end{cases} \quad (5)$$

$\psi(\omega)$ is defined as the Fourier of wavelet function.

$$\psi(\omega) = e^{i\omega/2} [\Phi(\omega + 2\pi) - \Phi(\omega - 2\pi)] \Phi(\omega/2) \quad (6)$$

3. Coiflet 2

Coiflet wavelets are obtained by imposing vanishing moment conditions on both scaling and wavelet functions.

Seam Carving

Seam Carving is a technique of targeting image compression and resizing based on detection of seams from the energy function of the image. The method aims at finding seams of minimum energy and manipulating the image using them [5].

Effective resizing of images not only use geometric constraints, but also consider the image content as well. The conventional image resizing consists of cropping or evenly down sampling that lead to loss of important features or distortion. This method enables us to remove pixel from uninteresting parts of the image while preserving its important content, and cropping resulted in loss of important features of the image.

An outline of the seam carving algorithm is listed below

1. Generating an Energy Map which can be based on gradient maps, entropy or HoG (Histogram of Gaussian) method.
2. Dynamic Programming is used to find the cumulative energy of a path taken from the top and left till the pixel(i, j). The cumulative energy function is defined by equation (7):

$$M(i, j) = e(i, j) + \min(M(i-1, j-1), M(i-1, j+1)) \quad (7)$$

3. To detect the optimal seam, the cumulative energy map was considered, and the Pixel with the lowest value of $M(i, j)$ in the last row or last column was picked and traced back to get the optimal seam. Back tracing in x direction can be represented mathematically as :

$$S^x = \{S_i^x\}_{i=1}^n = \{x(i), i\}_{i=1}^n, \quad (8)$$

where $\forall i, |x(i) - x(i-1)| \leq 1$

Similarly, this can be extended to y direction.

Then the optimal seam was used to perform the resizing of an image. This was done by removing the optimal seams. To increase the image size we can insert the copy of optimal seams in the image appropriately

RESULTS AND DISCUSSION

The experimental evaluation of the proposed method was carried out on four high resolution images of file size varying between 2 MB to 11 MB. These images are belonging to the types of highly textured images with a complex background (type 1) and images with clear cut background with an object (type 2). For each of these channels an overhead of 15% was added. The objective of this research is to find the compression ratios which can achieve download time of 10s. However, for GSM channel the required image size for transmission for the largest image i.e.; 11 MB was estimated as 122.5 KB with a compression level of 99%. And the time estimated was about two minutes. For other channels the required download time was achieved with lesser compression level. For GPRS, UMTS, HSPA and LTE the image should be compressed to 150 KB, 2.3 MB, 8.1 MB and 11 MB with compression level of 81%, 5%, 1.5% and 1% respectively for the same image mentioned. The test images belonging to the respective image classes described above are shown in Fig.2.

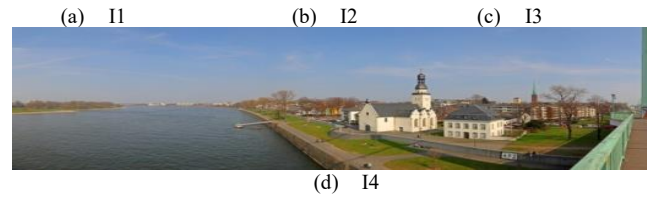


Fig. 2: Test images for different types

The proposed method was used to predict the appropriate compression technique for different classes of images namely the high textured image (Type 1), an image with of high contrast (Type 2), and image with single object and a dominated plain background (Type 3) and an image with large amount of background information (Type 4) by analyzing the amount of information remained at different compression levels. The experiments were performed on still images using DWT and Seam Carving methods at different compression quality levels such as 99%, 50% and 20%. The four test images belonging to the respective image classes described above are shown in Fig.2.

For a download time of 10s, the compression ratio was evaluated with respect to channel capacity and image size. However for GSM under the maximum compression level of 99% this could not be achieved for the 11 MB image. For GSM a download time of 120s was set. Fig. 3(a) shows the compression ratio variation with respect to image size and channel capacity for channels except GSM, where Fig. 3(b) gives compression ratio variation for GSM.

Plot for GPRS, UMTS, HSPA and LTE, gamma vs Image file size and Channel Capacity for download time of 10s

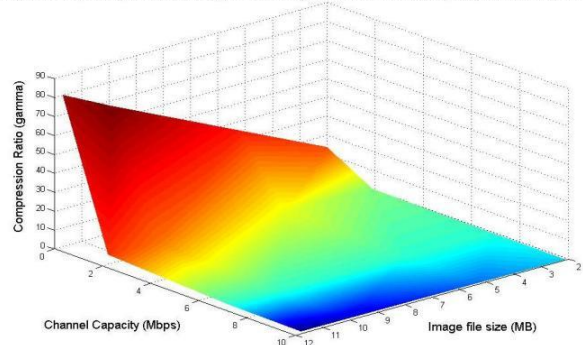


Fig. 3 (a): Compression Ratio vs Image size and Channel Capacity for GPRS, UMTS, HSPA, LTE for download time of 10s

Similarly, download time was analysed with respect to image size and channel capacity. In this case compression ratio was set at 50%. Fig 4 shows the variation of download time for all the channels GSM, GPRS, UMTS, HSPA and LTE.

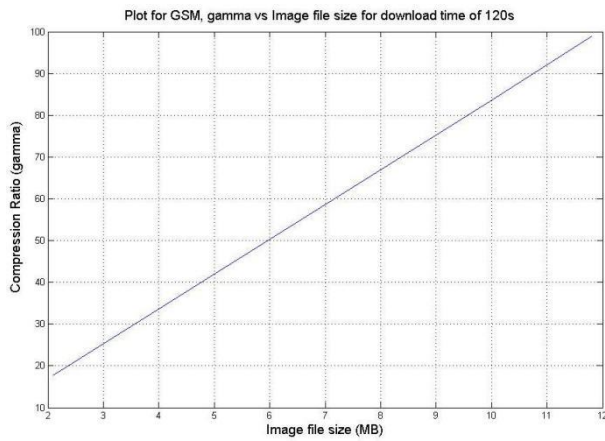


Fig. 3 (b): Compression Ratio vs Image size and Channel Capacity for GSM for download time of 120s

Plot for Download time for GSM, GPRS, UMTS, HSPA and LTE Channels with Compression ratio of 50%

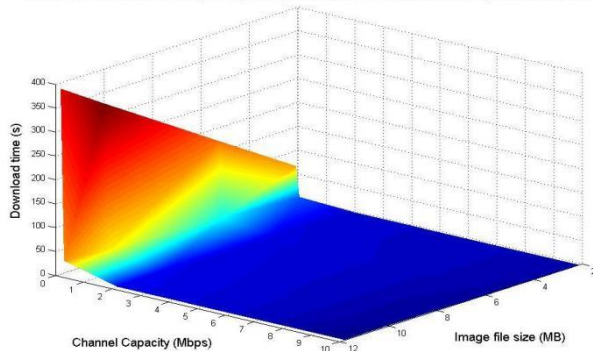


Fig. 4: Download time vs Image size and Channel Capacity for mobile communication channels.

In each of these images compression was carried out using wavelet transform based method and seam carving. For wavelet transform based method Meyer and Coiflet 2 wavelets were used. Fig. 5 shows the results of compressing I₁ at compression levels 95%, 70% and 35% using wavelet based method and seam carving. Fig. 5 (a), (b), (c) is compression result with Meyer wavelet where as Fig. 5 (d), (e), (f) shows the compression result with coiflet 2.

Fig. 6 shows the results of compressing I₂ at compression levels 95%, 70% and 35% using wavelet based method and seam carving. Fig. 6 (a), (b), (c) is compression result with Meyer wavelet where as Fig. 6 (d), (e), (f) shows the compression result with coiflet 2

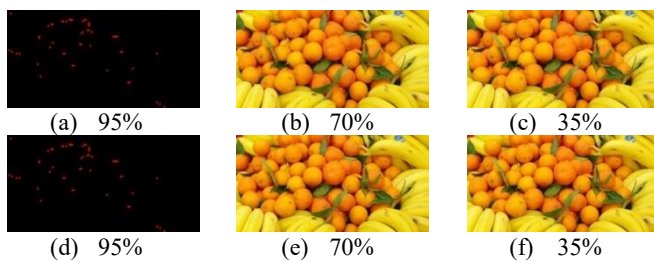


Fig. 5: Compression of I₁ at different compression levels

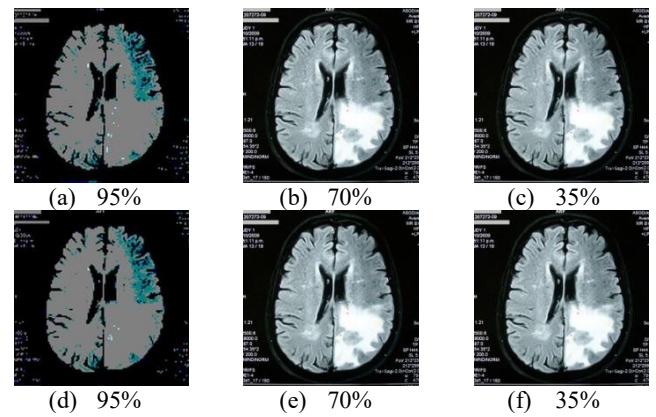


Fig. Fig. 7 shows the results of compressing I₃ at compression levels 95%, 70% and 35% using wavelet based method and seam carving. Fig. 7 (a), (b), (c) is compression result with Meyer wavelet whereas Fig. 7 (d), (e), (f) show the compression result with coiflet 2.

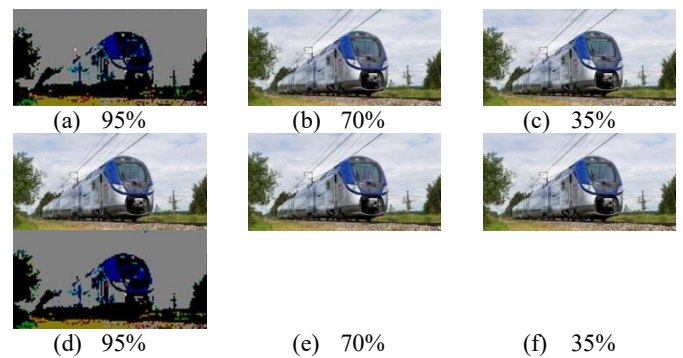


Fig. 7: Compression of I₃ at different compression levels



Fig. 8: Compression of I₄ at different compression levels

Fig. 8 shows the results of compressing I₄ at compression levels 95%, 70% and 35% using wavelet based method and seam carving. Fig. 8 (a), (b), (c) is compression result with Meyer wavelet where as Fig. 8 (d), (e), (f) shows the compression result with coiflet 2.

From these compressed images entropy and PSNR were analysed; where entropy was selected as the metric for measuring information loss after compression [8],[9],[10],[11],[12]. The Fig. 9, shows the graph for the variation of entropy value with respect to compression ratio and the four images on Meyer wavelet at different compression level.

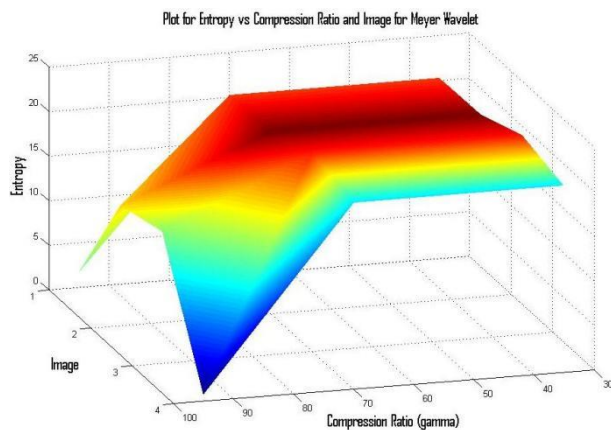


Fig. 9: Plot for Entropy vs Compression Ratio and Image for Meyer Wavelet

The Fig. 10, shows the graph for the variation of entropy value with respect to compression ratio and the four images on Coiflet2 wavelet at different compression level.

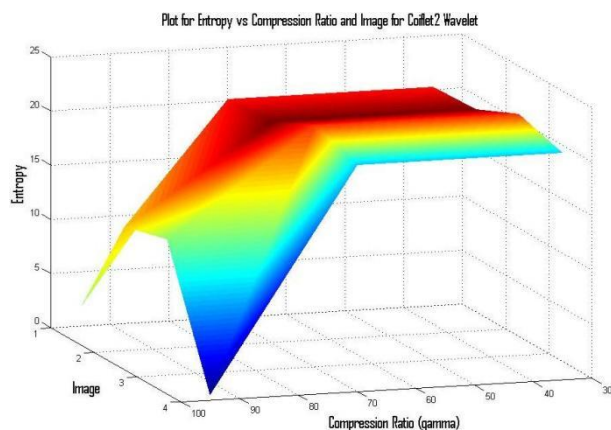


Fig. 10: Plot for Entropy vs Compression Ratio and Image for Coiflet2 Wavelet

From the two graphs it is evident that for Meyer and coiflet 2 compression, the entropy variation follows a similar pattern. The seam carving method shows relatively high entropy values at high compression rates, with compared to wavelet based method.

A similar analysis was done on seam carving where the variation of entropy value with respect to compression ratio and the four images at different compression level was shown in Fig. 11

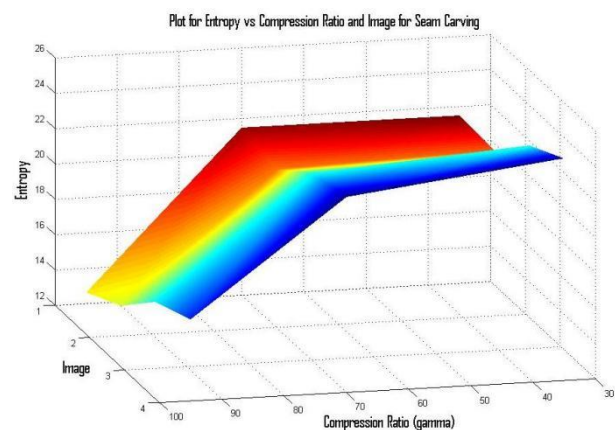


Fig. 11: Plot for Entropy vs Compression Ratio and Image for Seam Carving.

Fig. 12, shows the variation of entropy with respect compression ratio for wavelet and seam carving methods on image I₁. For the wavelet based method Meyer and Coiflet2 have given almost similar entropy values while seam carving preserves more information.

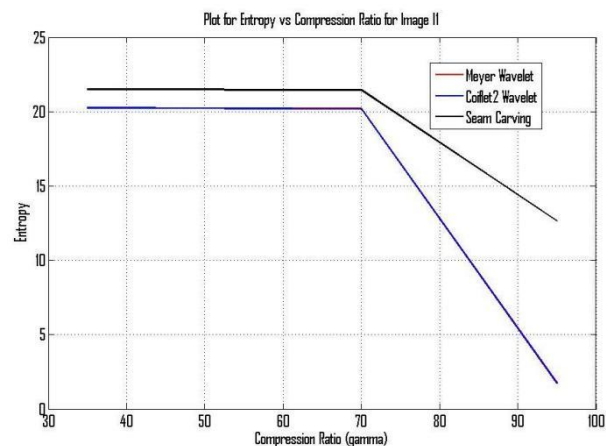


Fig. 12: Plot for Entropy vs Compression Ratio for Image I₁

According to results obtained for image I₂, which is shown in Fig. 13, similar pattern of entropy variation can be obtained, where seam carving technique has outperformed the wavelet based method at high compression rates.

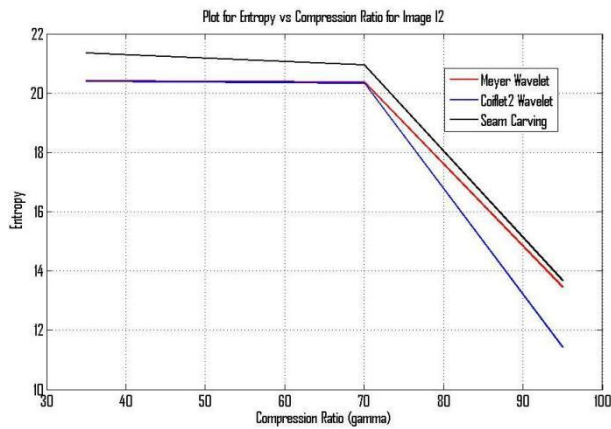


Fig. 13: Plot for Entropy vs Compression Ratio for Image I₂

CONCLUSION

In this research, an optimum image compression technique based on the mobile transmission capacity, type of the image and the average download time was developed. The research was conducted targeting five mobile communication standards namely; GSM, GPRS, UMTS, HSPA and LTE where, for each channel the two image compression methodologies were tested using wavelet and seam carving. Based on the results obtained, under high compression rates the seam carving method has outperformed the wavelet based method by preserving the highest entropy in case of image type 3 and 4. When the compression rate becomes medium and low, the entropy difference between the two methods becomes low which performs well for images of type 1 and 2..

REFERENCES

- [57] Taylor C. and Dey S, "Adaptive Image Compression for Wireless Multimedia Communication," ICC, 2001.
- [58] Dong-Gi Lee and Dey, S., "Adaptive and Energy Efficient Wavelet Image Compression for Mobile Multimedia Data Services," ICC, 2002.
- [59] Chandler D.M., Hemami S., "Additivity Models for Suprathreshold Distortion in Quantized Wavelet Coded Images", Human Vision and Electronic Imaging Conference, San Jose, CA, USA, SPIE Vol. 4662, May 2002, pp105-118.
- [60] Kabir M., "Image compression using lifting based wavelet transform coupled with SPIHT algorithm", in Proceedings of the Int. Conf. on Informatics, Electronics and Vision 2013.
- [61] Goswami J.C., Noble B., and Chan A.K., "Fundamentals of Wavelets," John Wiley, New York, 1999.
- [62] Mallet S.G., "A Theory for Multiresolution Signal Decomposition: The Wavelet Representation", IEEE Trans. Pattern Anal. Machine Intell, vol 11, no. 7, pp. 674-693, 1989.
- [63] Avidan S. and Shamir A., ACM Transactions on Graphics (TOG) - Proceedings of ACM SIGGRAPH 2007.
- [64] Kumari S. and Vijay R. "Image Quality Estimation by Entropy and Redundancy Calculation for Various Wavelet Families". International Journal of Computer Information Systems and Industrial Management Applications. Volume 4, pp. 027-034, 2012.
- [65] Moivre A., "Image Quality Metrics: PSNR vs SSIM", Proceedings of the International Conference on Pattern Recognition, 2010.
- [66] Saffor A. and Ramli A., A Comparative Study of Image Compression Between JPEG and WAVELET, Malaysian Journal of Computer Science, Vol. 14 No. 1, pp. 39-45, 2001.
- [67] Gonzales R.C. et.al., Digital Image Processing using MATLAB, 2nded., Pearson Education, 2009.
- [68] Li Z.N. and Drew M.S., Fundamentals of Multimedia, New Jersey: Pearson Education, 2005.
- [69] Nimmagadda Y, Kumar K. and Lu Y., Energy-efficient Image Compression in Mobile Devices for Wireless Transmission. IEEE International Conference on Multimedia and Expo, ICME 2009.
- [70] Reaz M. Akter M. and Yasin M., Image Compression System for Mobile Communication. Journal of Circuits, Systems, and Computers Vol. 15, No. 5 (2006) 777-815.

Gap Analysis of The Standard Propagation Model with The LTE Band 38 in Sub Urban Region

L.P.S.S Dissanayake
Network Technology Department
University of Vocational Technology
Ratmalana, Sri Lanka
suranga@uovt.ac.lk

Abstract— The standard propagation model (SPM) calibration or tuning approach can be used for effective and efficient network planning for optimum region coverage. SPM functions in field implementation to improve the accuracy of predictions based on proper coverage planning outcomes. This study presents a straightforward optimization approach utilizing the ATOLL planning tool for the Standard Propagation Model (SPM). A series of measurement campaigns were undertaken to gather data on Received Signal Strength from commercial base stations operating at a frequency of 2600 MHz. The assessment was conducted to evaluate the predictive accuracy of the standard propagation model. The model exhibited significant levels of prediction errors. The optimization technique encompasses the use of various components, including the Digital Terrain Model, clutter classes, clutter heights, vector maps, scanned photos, and Web Map Service. The weight of the clutter loss on each pixel, from the pixel with the receiver in the direction of the transmitter up to the specified maximum distance, was calculated using a logarithmic weighting formula. The standard propagation model is widely employed for generating forecasts to assess predated coverage. However, it is necessary to further refine it in order to align with each specific region and get precise predictions. The utilization of gap analysis is vital in order to detect the factors of divergence during the fine-tuning phase.

Keywords— LTE, Propagation Model, Model Tuning, Coverage Simulation

INTRODUCTION

In order to achieve optimal and proficient planning of a radio access network, it is imperative to possess a comprehensive understanding of the distinct attributes pertaining to the propagation of radio waves inside a developed urban setting. The propagation of electromagnetic (EM) waves is influenced by various factors, including the antecedent effects of reflections, diffractions, and scatterings. These effects are particularly significant in metropolitan areas due to the presence of physical impediments, also known as clutter, in the propagation environment. The phenomenon of transmitted electromagnetic waves interacting with various structures such as building walls, billboards, and artificial objects, as well as the bodies of moving entities, often leads to the reception of multiple replicas of the transmitted signals at the receiving end. This occurrence can be referred to as multipath. Signal fading occurs when many copies of a signal

reach a mobile station from various directions, each with distinct temporal delays.

The link budget must be determined before any coverage planning can begin. The Maximum Allowed Path Loss (MAPL) in downlink and uplink communication is estimated using this Link budget calculation. If we know the radius of a cell and run a link budget calculation, we can deduce how many eNodeBs we'll need to cover it. Reviewing the surrounding environment and the propagation model allows one to make a rough approximation of the cell radius. For this procedure to succeed, precise.

each eNodeB's cell coverage and radius are predicted based on the actual propagation model conditions. In this research, we used radio planning software to fine-tune the parameters K1-K7 of the standard propagation model (SPM) formula based on actual measurement data from driving tests conducted at the 2600 MHz frequency.

The SPM (Site-Specific Propagation Model) was derived from the Hata model, which is a widely used formula for predicting route loss in wireless communication systems. [1]. Empirical modeling of path loss throughout the frequency range of 1500 to 2000 MHz. This phenomenon pertains to the attenuation of a signal on a global scale when it is received within a distance range of 1-20 kilometers. In order to accurately model the impact of factor K on signal transmission, the SPM Equation necessitates the precise configuration of specific parameters. By adjusting or refining the propagation model, the Signal Propagation Model (SPM) has the potential to enhance the accuracy and dependability of predictions within a planning network that utilizes ATOLL 9955[2]. By adjusting a formula in the model of propagation, calibration calculations can produce results that are very similar to the true measurements. Previous studies have used field measurements and GIS data to fine-tune the SPM model for built-up and urban settings.

LITERATURE REVIEW

Okumura Hata Model

Hata's propagation model serves as the foundational framework for propagation models that are extensively employed in the cellular sector. One of the primary

advantages of Hata's model lies in its inherent simplicity. One of the primary limitations of this system is the imposition of restrictions on the permissible values of certain parameters. The Okumura-Hata model is well recognized as the predominant propagation model employed in macro-cell environments for the purposes of predicting coverage simulation and path loss computation. The model incorporates the utilization of free space loss as one of its components. The Okumura-Hata model is classified as an empirical model, indicating that it relies on field measurements as its foundation. The validity of Hata's basic model extends to the frequency range of 150-1500 MHz [3]. Hata developed empirical methods to estimate propagation path loss by utilizing Okumura's report, which includes graphical representations of median field strength as a function of distance [4]. The utilization of this empirical model offers a simplified approach to path loss computation due to its closed-form formula, which does not rely on empirical curves for the various parameters.

Cost Hata Model

COST 231 is an enhanced iteration of Hata's model that focuses on higher frequencies. This improvement was achieved from an analysis of Okumura's propagation graphs inside the upper-frequency range. The COST-231 model, often known as the CostHata model, is a widely used model in the field. The Hata model's extended version can be used to frequencies that range up to 2000 MHz [5]. This model utilizes empirical formulas incorporating several correction factors to estimate the signal strength.

This study examines many elements that influence diverse settings, utilizing field measurements conducted by Okumura in Japan. The statistical formulas and correction factors utilized in the model were obtained through the process of observing and analyzing the measured propagation data. Okumura created a set of curves based on the collected measurements in order to forecast propagation loss under different scenarios. In addition to urban losses, Okumura incorporated a range of loss components into the analysis. The study examines the impact of street orientations, topographical variations, and the presence of mixed land and marine routes on the urban environment.

Hata's propagation model is the foundational framework for other propagation models extensively employed within the cellular industry. The primary appeal of Hata's model lies in its inherent simplicity, whereas its primary limitation stems from the imposed restrictions on certain parameter ranges. The Okumura-Hata model is a widely recognized propagation model that is commonly utilized in macro-cell environments to estimate the median attenuation of radio signals. The model incorporates the utilization of free space loss as one of its components.

SPM Model

Radio wave propagation can be modeled empirically using a mathematical formula that considers factors such as altitude, distance, frequency, and other environmental factors. Okumura-Hata, COST 231, and Standard Propagation Models are only a few of the propagation models utilized in cellular network design.

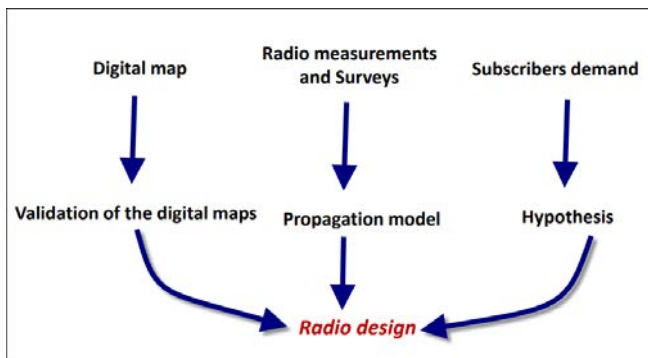
The study employs the SPM propagation model with equation (1) below as the network planning propagation model [6][7].

$$L_{model} = K_1 + K_2 \log(d) + K_3 \log(H_{T_{eff}}) + K_4 \times \text{Diffraction loss} + K_5 \log(d) \times \log(H_{T_{eff}}) + K_6 (H_{R_{eff}}) + K_7 \log(H_{R_{eff}}) K_{clutter} f(clutter) \quad (1)$$

Table I : Parameter Description

Factor	Description
L_{model}	total pathloss at the d distance
K_1	constant offset
K_2	multiplying factor for $\log(d)$
K_3	multiplying factor for $\log(H_{T_{eff}})$
K_4	multiplying factor for diffraction calculation
K_5	multiplying factor for $\log(H_{T_{eff}})\log(d)$
K_6	multiplying factor for $H_{R_{eff}}$
K_7	multiplying factor for $\log(H_{R_{eff}})$
d	distance between the receiver and the transmitter (m)
$H_{T_{eff}}$	effective height of the transmitter antenna (m)
$H_{R_{eff}}$	effective mobile antenna height (m)
$K_{clutter}$	multiplying factor for $f(clutter)$
$f_{(clutter)}$	average of weighted losses due to clutter

Active measurement designs, rather than theoretical predictions, will be the future of wireless path loss prediction. Geostatistical techniques that emphasize robust sample designs and explicitly model the spatial structure of observations, in particular, are considered as promising. Theoretical models offer useful physical insights into electromagnetic transmission. However, because the majority of these models are based on unrealistic assumptions, they must be tested by experiments. Despite the fact that the cost and time required to conduct measurements increases in complex systems, the measurement-based approach has proven to be effective and productive [8]



. Fig. 1: Coverage planning inputs

DTM, clutter classes, clutter heights, vector maps, scanned pictures, and WMS are all used in the optimization process. The weight of the clutter loss on each pixel from the pixel with the receiver in the direction of the transmitter was calculated using a logarithmic weighting function, up to the given maximum distance. Based on Fig1.process has shown promise in terms of high accuracy and low prediction mistakes.

Phase 1:

Model Name	K1	K2	K3	K4	K5
Standard Model	18.5	42	10	0.5	-6.93
Sub Urban Model	22.89	39.93	5	0.5	-4.48

Gather the necessary drive test data using extensive field measurements. The process of log file collection using the TEMS DT kit.

Phase 2:

The basic radio frequency (RF) parameters, namely the reference signal received power (RSRP) and main cell identity (PCI), are extracted using field test measurements, specifically drive test data. The RSRP measurement refers to the received signal reference power, while PCI stands for the received signal dominant cell. The ACTIX post-processing tool can be utilized to obtain the necessary data.

Phase 3:

The CW measurement points are extracted using the ATOLL 9955 RNP tool by entering DT log information in CSV format.

Phase 4:

Involves fine-tuning the specific propagation model for each selected site using the assistance of extracted continuous wave (CW) measurements. An identical procedure should be followed for each individual spot.

Phase 5:

The identification of the most influential "K" variables for the final tuning of the model was based on the evaluation of initial parameter tuning outcomes and comparison with the standard model (SPM model) for path loss calculation.

Phase 6:

The final model was determined by selecting the "K" factors identified in the Stage 5 study. The final propagation model is refined by incorporating variable factors, namely K1, K2, K4, and K5, while keeping all other parameters fixed at their standard model values.

Phase 7:

The path loss was calculated by considering the height of the transmitting antenna ($h=40$) and the distance (d) ranging from 100m to 3000m, for both the standard propagation model (SPM) and the recently adjusted suburban model. Identified the path-loss delta between SPM and the recently adjusted suburban model.

Phase 8 :

Analyze the usable region and range of the SPM model that can be used in suburban regions in Sri Lanka. figured out which variables were most likely to cause the SPM model's results to diverge from reality.

RESULTS AND DISCUSSION

Table II : K1 to K5 parameters

According to the findings shown in Table 1, it is observed that the SPM models K1, K2, and K3 exhibit significant deviations from the parameters of the tune-up model.

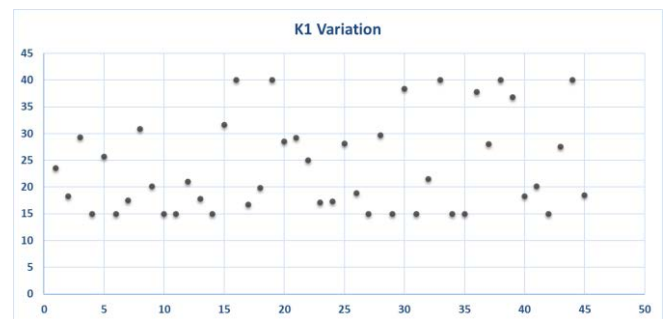


Fig. 2: K1 variation of sample sites

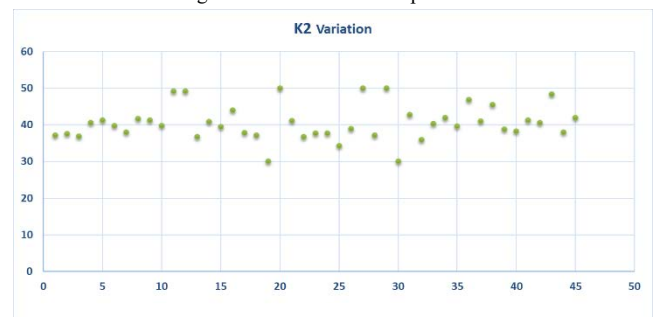


Fig. 3: K2 variation of sample sites

The examination of the K1 and K2 parameters for the sample sites reveals a pattern of scattered behavior.

Table III: Pathloss vs. Distance of SPM and Sub Urban Model

Distance	Standard Model Pathloss	Sub Urban Model Pathloss
100m	97	97
200m	106	107
400m	115	117
600m	121	122
800m	125	126
1000m	128	130
1200m	130	132
1400m	132	134
1600m	134	136
1800m	136	138
2000m	137	140
2500m	140	143
3000m	142	145

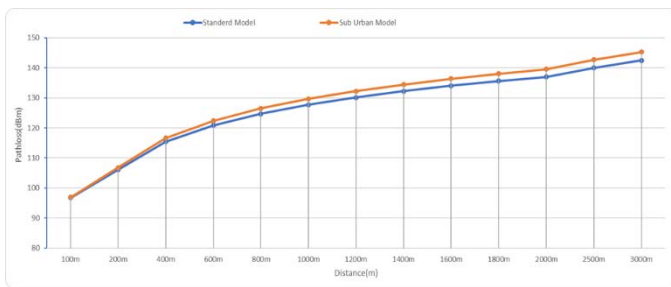


Fig. 4: Pathloss Variation with Distance of SPM and Sub-Urban Model

According to the path loss study of both models, it is observed that within a radius of 600m, both models exhibit similar coverage. However, beyond this radius, the standard model demonstrates excessive coverage.

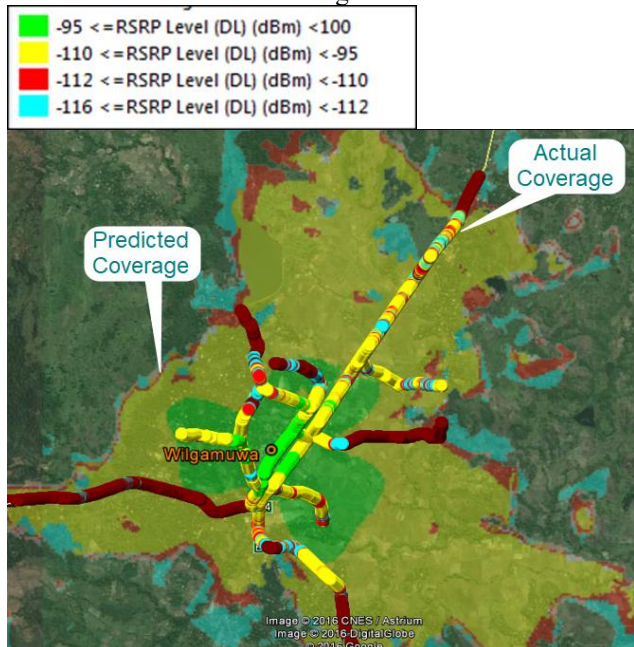


Fig. 4: Deviation of actual and predicted coverage

The path loss between two antennas is the ratio of transmitted to received power, which is commonly stated in dB. It comprises all potential loss factors caused by interactions between the propagating wave and any objects between the transmitting and receiving antennas. The radio signal is weakened due to path loss during radio wave propagation over a channel, and fading processes occur.

While there are many different mechanisms underlying the propagation of electromagnetic waves, they are commonly attributed to the following: diffraction, reflection, refraction, and scattering. Inside structures, the path between the transmitter and the receiver may be either non-line-of-sight (NLOS) or line-of-sight (LOS). The electromagnetic waves travel along diverse courses of differing lengths when radio systems lack a line of sight (LOS) and the presence of walls and floors results in significant diffraction loss and many reflections from various objects. As the distance between the transmitter and receiver grows, the interaction between these waves results in multipath fading at a particular place and a drop in field strength. Analyzing fig 4 clearly shows that the SPM model creates coverage simulations based on standard parameters, and that in order to produce an accurate prediction, the gap must be identified and precise tuning must be performed..

CONCLUSION

A propagation model for the LTE 2600MHz TDD band in Sri Lanka can be developed by employing various sets of field measurements conducted in the target regions. These measurements can be subjected to pre- and post-processing techniques to refine the model. The utilization of the tune-up model enables the generation of forecasts that exhibit a level of accuracy that is in line with expectations.

According to the findings in Table 1, the SPM models K1, K2, and K3 display considerable deviations from the tune-up model values. Also, the K1,K2 and K3 values for the sample sites reflect a pattern of dispersed behavior. Based on the analysis of the K1 to K5 parameter and the variation pattern observed in the K1 and K2 sample sites, it can be concluded that the divergence in path loss of the standard propagation model primarily arises from improper settings of the K1, K2, and K3 parameters. In addition to that, the digital terrain models of Sri Lanka that are now being used need to be updated in order to reduce the amount of variance. However, the normal propagation model will work fine for the coverage simulation as long as the radius does not go above 600 meters.

REFERENCES

- [1] COST 231 Project: Urban Transmission Loss Models for Mobile Radio in the 900 and 1800 MHz band, COST 231 TD (90) 119 Rev. 2, The Hague, Netherlands (1991)
- [2] Forsk: ATOLL 3.2.0 Radio Planning and Optimization Software, France. www.forsk.comSPM Tuning for Path Loss Predictions in Built-Up Environments 375

- [3] Z. Nadir, M. Bait-Suwailam, and M. Idrees 2016, "Pathloss Measurements and Prediction using Statistical Models," in MATEC Web of Conferences.
- [4] N. V. K. Ramesh, K. S. Kumar, D. V. Ratnam 2015, A. Hussain, Y. V. S. Jaswanth, and P. S. Chaitanya, "Comparative Analysis Of Path Loss Attenuation At Outdoor For 1.8Ghz, 2.1 Ghz In Urban Environment," Journal of Theoretical and Applied Information Technology, vol. 82, p. 85.
- [5] M. Kumari, T. Yadav, P. Yadav, P. K. Sharma and D. Sharma, "Comparative Study of Path Loss Models in Different Environments", IJEST, vol. 3, no. 4, (2011) April, pp.4683-4690.
- [6] Forsk. 2016. "Atoll 3.3.2 User Manual for Radio Networks," France
- [7] M. A. Amanaf, E. S. Nugraha, and D. Kurnianto. 2018. "Analisis Simulasi Model COST-231 Multiwall Pathloss Indoor Berbasis Wireless Sensor Network pada Aplikasi Absensi Mahasiswa dengan Tag RFID Menggunakan RPS (Radiowave Propagation Simulator).Analysis of Wireless Sensor Network-based Indoor COST-231 Mult," vol. 16, no. 1, pp. 17–26.
- [8] C. Phillips, D. Sicker and D. Grunwald, "A survey of wireless path loss prediction and coverage mapping methods", IEEE Commun. Surveys Tuts., vol. 15, no. 1, pp. 255-270, 1st Quart. 2013.

Developing a Conceptual Framework for ICT Integration in the Sri Lankan Agriculture Sector

P.A.M.L. Pannala

*Department of Multimedia and Web Technology,
Faculty of Information Systems, University of Vocational Technology
Sri Lanka*

Abstract - Information and Communication Technology (ICT) integrated to Agriculture is one of the most important tasks in order to achieve sustainable agriculture. Agriculture is one of the important sectors and the key issues to be addressed these days are the food sustainability and security. The recent COVID-19 pandemic has also reiterated the importance of food security for a developing nation such as Sri Lanka's. This COVID-19 has made us all dependent on digital technology, but we have to consider for increasing investment in technologies to help small-scale farmers that will yield far-reaching benefits long after the pandemic has passed. Permanent Crop Clinic Programme (PCCP) which is a plant pest and disease diagnostic and recommendation service implemented through the farmer group structure. According to the PCCP concept, the aim of the PCC is to provide beer advice on pest management to farmers when their crops are ill. The main objective of the proposed study is to develop a framework for ICT integration in agriculture taking into account the Sri Lankan agricultural sector observing the PCC program objectives. To enhance the research, a systematic review of the literature will be conducted to identify various domains and approaches of research, existing frameworks for ICT integration and global invasiveness for ICT integration in the agriculture sector. The Study will also survey major barriers and challenges in ICT integration and enhance local productivity, access market information and boost the GDP percentage gain from agriculture in the Sri Lankan economy.

Keywords: *ICT integration, Agriculture, Sri Lanka, Permanent Crop Clinic Programme, GDP (Gross domestic product)*

I. INTRODUCTION

Information and Communication Technology (ICT) is widely used for sharing information. It encompasses various devices, networks, mobiles, services, applications, sensors, and basic tools like mobile telephones, radios, televisions, and satellites. ICT is rapidly developing worldwide, leading organizations and individuals to focus on providing products and services using ICT approaches [1]. In the agricultural sector, integrating ICT is crucial for achieving sustainable development in Sri Lanka. Sustainable agriculture aims to produce long-term crops and livestock while minimizing environmental impact and improving the economic stability and quality of farming

activities [3]. ICT in agriculture, also known as e-agriculture, involves the innovative use of ICT in rural areas, encompassing conceptualization, design, development, evaluation, and application [4]. The text explores how farmers have embraced the modern agricultural sector and its extension services. It examines their participation, institutional contribution, and the procedures used in crop clinics. Additionally, it delves into farmers' perspectives on crop clinics, focusing on the content's relevance and appropriateness, the significance of crop clinics as an educational program for farmers, and their role in promoting sustainable agriculture [5].

The text analyzes the integration of farmers into the modern agricultural sector and its extension services, including their involvement, institutional support, and the methods employed in crop clinics. It also investigates farmers' viewpoints on crop clinics, emphasizing the importance and suitability of the content, the value of crop clinics as an educational initiative for farmers, and their role in advancing sustainable agriculture.

The Permanent Crop Clinic program, known as PCCP, is a farmer group structure called Crop Clinics (CCs) that provides a plant pest and disease diagnostic and recommendation service. This program brings accurate and up-to-date information to farmers in developing countries, enabling them to effectively care for their crops. Similar to a health center for humans, plant health clinics advise farmers on pests and diseases. Farmers bring samples of their diseased plants to plant doctors who diagnose and prescribe safe, affordable, and locally available pest management solutions. PCCP was launched in Sri Lanka after global plant clinic training in 2009, linking various stakeholders in the country's plant health system.

II. METHODOLOGY

Computing and Information System can improve the effectiveness and efficiency of the organization [11]. This study takes an explorative approach to address the under-investigated problem of ICT integration in the agriculture sector in Sri Lanka. By focusing on discovering the main limitations and barriers to integrating ICT in agriculture in the rural areas of Sri Lanka, this study provides suitable solutions to help

farmers and increase ICT literacy in the agricultural departments of every region.

The major objective of this research study is to introduce a conceptual framework for promoting ICT integration in the agricultural sector in Sri Lanka. To conduct this research, the limitations and barriers of integrating ICT in rural farmers should be identified. Additionally, the latest technologies, methods, and frameworks introduced by the government and past research studies should be identified. Meeting with agricultural officers to discuss their service problems and the problems faced by farmers will provide insight into the current situation and common issues in the agricultural field. This information will help identify areas where ICT integration can solve these problems in Sri Lanka's agricultural sector.

The Permanent Crop Clinic Program is studied in parallel to gain a comprehensive understanding of its benefits for farmers and how ICT is integrated to enhance its effectiveness. Finding solutions to these issues is crucial for improving the sustainability of the agriculture sector and the well-being of farmers. Information and Communication Systems have employed various research methodologies to investigate these problems, with the main objective being to identify the current state of the farming domain. The methodology used in this research study is illustrated in

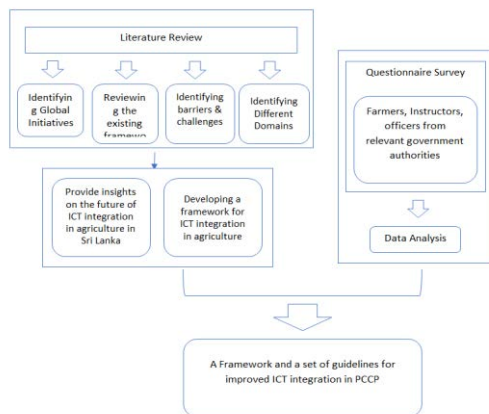


Figure 1: Methodology of the research study

Figure 1.

III. DATA COLLECTION AND ANALYSIS

A. Primary Data

The questionnaire was designed according to the individual and organizational factors of the staff of the Gannoruwa Agriculture Department. Questionnaires were distributed manually and through an online survey tool. The survey was conducted to identify issues faced by the farmers and also identify the status of the ICT knowledge of the farmers and the agriculture staff and the current status of the usage of ICT devices.

B. Secondary data

Secondary data for this research study were collected through various data collection methods,

including research reports, data from the Department of Agriculture and Seed Certification and Plant Protection Centre, seminar papers, articles from journals, and the

	A	B	C
1	Research Type	Number of Researches	
2	Big Data at Different Scales from Field, Farm, to Global	13	
3	Wearable Computing	3	
4	Drones and Low Cost Satellites, Micro-satellites	4	
5	Weed and Pest Management through Integrated Systems	3	
6	Farm Management Information Systems (FMIS)	10	
7	GPS - Multisatellite	3	
8	Controller Area Networking/ Sensor Networks/ Grid Computing	10	
9	Smart Farming	3	
10	Weather prediction	4	
11	Telematics	2	
12	Automation, Robotics, Autonomous, Linked Tools, Equipment and process Monitoring	6	
13	Photometry	1	
14	Information on Production Techniques	2	
15	Irrigation, Fertigation and Prescriptive Planting	8	
16	Other	9	
17	Total	81	
18			

Figure 2: Summary Table of past researches

Internet. The validity and reliability of the research findings were assessed using questionnaires, interviews, and relevant literature. Additionally, the study utilized the SPSS analyzing tool for statistical analysis.

IV. RESULTS AND FINDINGS

When considering past research studies on ICT integration in agriculture, numerous studies have been conducted worldwide on technology development, application development, and model development in

the agricultural sector. The figures provided summarize a few of these studies and help identify the different domains related to the study.

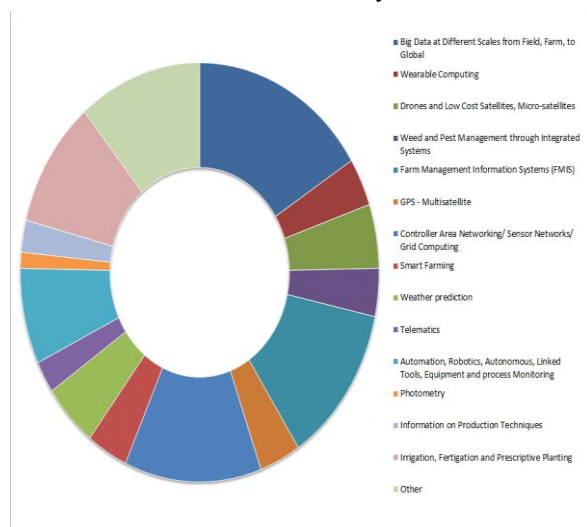


Figure 3: Pie Chart of Past Researches

Most of the research studies have focused on integrating new innovative technologies into the

agricultural sector. The recent COVID-19 pandemic has led to a shift in people producing their own food and preferring locally sourced products. As a result, the latest research has explored how to effectively use modern technologies such as drones, sensors, and ICT tools to manage harvesting periods, reduce wastage, and ensure better market prices. These studies primarily revolve around big data and aim to provide effective solutions for farmers and agriculture officers. The goals include improving the technical education and skills of farmers, increasing internet connectivity in rural farming areas, and promoting the use of smart technology among farmers.

A. Integration ICT PCCP

Most farmers in the PCCP come with either a diseased crop or a photo of the affected crop. Integrating image processing systems into the PCCP would greatly benefit farmers as they would be able to identify crop diseases or pest infections without having to meet with AI experts. Additionally, there is a vast database related to the PCCP that can be utilized. By developing an ICT-based system, farmers can access solutions for specific crop illnesses without the need for physical meetings with plant doctors. This integration of ICT into the PCCP would help farmers enhance their agricultural products and reduce time wasted on in-person meetings.

The Permanent Crop Clinic Program currently relies on manual data entry due to a lack of ICT knowledge among Agriculture officers and farmers. To address this, I recommend that the government provide workshops, training sessions, and conferences focused on ICT-based systems for the agriculture sector. Additionally, there are existing ICT-based systems that are underutilized, so it is important to motivate agriculture staff to increase their usage of these tools. The government should conduct regular training sessions for staff to ensure they are equipped with the

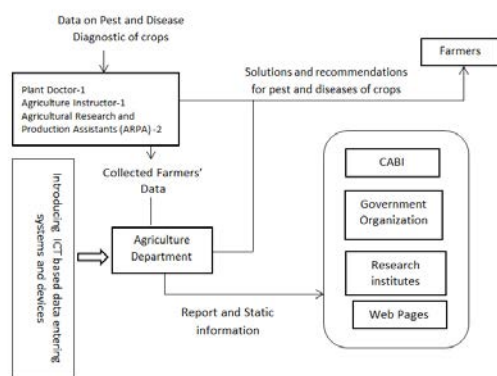


Figure 4: Integrating ICT to PCCP

necessary skills to integrate ICT into the program.

B. Questionnaire Survey Analysing

The collected data from the questionnaire was analyzed using SPSS version 20, a specialized tool designed for analyzing scientific data related to social science. This tool is capable of handling a wide range of data variable formats. The analysis of the collected data

is presented in this section, including a comparison of each response based on the importance of the questions.

C. Demographic Analysis

These variables were analyzed using the tool to analyze and recognize the pattern of respondents and other effects of them to the other results.

The analysis of the responses for these demographic variables reveals that 66.7% of the individuals are male and 33.3% are female. The majority of respondents hold a Bachelor's degree (43.3%), followed by those with a Master's degree (33.3%). Additionally, 10% have a postgraduate degree, while only 6.7% have a diploma or certificate of vocational training. Among the respondents, 30% have a professional ICT qualification, while 70% do not.

Demographic variable		Count	Percentage (%)
Age	30-39 years	8	6.7
	40-49 years	11	20.0
	50-59 years	9	40.0
	60 years or older	2	26.7
Education	Vocational Training/ Certificate/ Diploma	4	6.7
	Bachelor's Degree	13	43.3
	Master Degree	10	33.3
	Post Graduate Degree	3	10.0
Gender	Male	20	66.7
	Female	10	33.3
Designation	Additional Director	2	6.7
	Assistant Director	9	26.7
	Agriculture Officer	4	13.3
	Agriculture Instructor	13	43.3
	Development Officer	2	10.0
Years of work experience	1-5 years	2	6.7
	6-10 years	6	20.0
	11-15 years	12	40.0
	16-20 years	8	26.7
	Over 20 years	2	6.7
ICT Literacy	Having ICT professional qualification	9	30.0
	Not having ICT professional qualification	21	70.0

Table 1: Demographic analysis

In terms of job roles, the majority are designated as Agriculture Instructors (43.3%), followed by Assistant Directors (26.7%) and Agriculture Officers (13.3%). All respondents have at least one year of experience, with 40% having 11-15 years, 26.7% having 16-20 years, 20% having 6-10 years, and 6.7% having over 20 years of experience. This study encompasses a diverse range of experience levels.

V. DISCUSSION AND CONCLUSION

The growth of ICT in the last decade has presented numerous opportunities to address challenges in agriculture. ICT can be integrated into various activities within the agriculture sector, including communication within organizations, sharing farming knowledge with farmers, resolving crop-related issues, and improving technology adoption among farmers. To facilitate these activities, government intervention is necessary. Governments should establish policies, rules, and regulations to promote the integration of ICT in the agriculture sector. By doing so, the government can serve as a foundation for the effective and reliable development of Sri Lanka's agriculture sector. The following visual representation illustrates the role of

ICT in the agriculture sector, depicting how ICT is integrated into various agricultural activities.

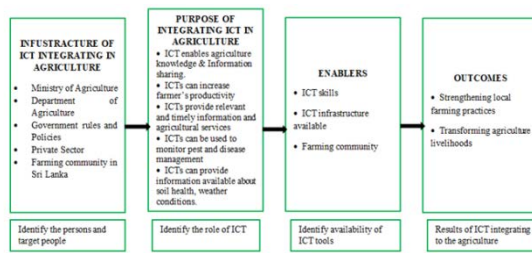
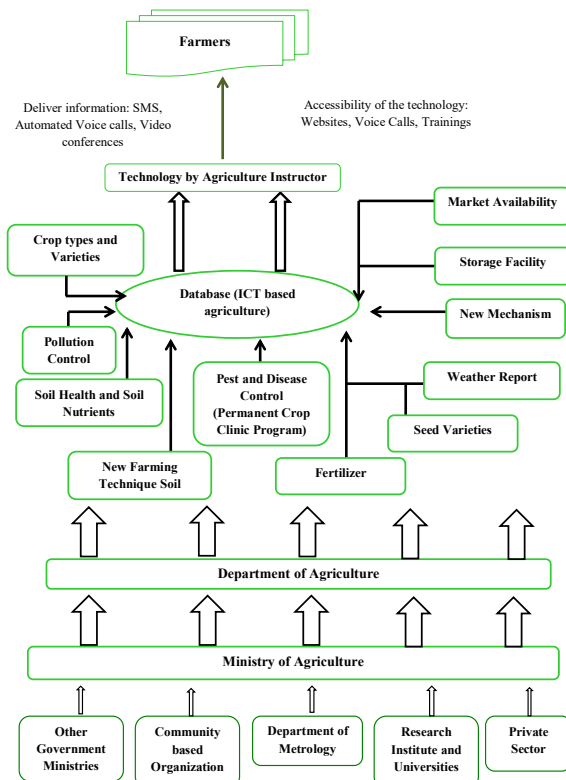


Figure 5 : Roll of ICT in Agriculture Sector

According to the findings, accurate and reliable information is crucial for farmers and those involved in the farming industry to effectively manage their activities. The lack of visibility in information regarding crop selection, cultivation, and sales has led to a decline in the farming sector, which in turn impacts the economic growth of the country and the overall lifestyle of individuals. Therefore, it is imperative to ensure timely access to accurate information for informed decision-making within the farming community. However, the scattered storage of agricultural data across various departments and private organizations poses a challenge in accessing the right information at the right time.

A. Proposed Framework

According to the findings were conducted by interviews and survey questionnaires among the farmers and agricultural staff members, a conceptual framework has been created to overcome the identified limitations and barriers to ICT integration in Sri Lanka. The



following framework shows the concept of that proposed framework.

VI. RECOMMENDATIONS FOR FURTHER RESEARCH

Researchers are continuously conducting numerous similar studies due to the absence of a comprehensive database that exclusively includes all the research conducted on the integration of ICT in agriculture. To address this limitation, this research proposes the establishment and maintenance of a database specifically for agricultural journals and online books related to agriculture. This database would serve as a platform for knowledge sharing and benefit individuals interested in the agricultural sector.

REFERENCES

- [1] J. Steward, "Northumbria Research Link," *Nrl.Northumbria.Ac.Uk*, vol. 24, no. August, pp. 23–35, 2002, doi: 10.1108/17410391111097438.
- [2] K. K. P. Subashini, "Empowerment of Farmers Through ICT Literacy," pp. 13–15, 2017.
- [3] "SUSTAINABLE AGRICULTURE How to shape the future of farming?" [Online]. Available: https://solarimpulse.com/sustainable-agriculturesolutions?utm_term=innovations+in+agriculture&utm_campaign=Solutions&utm_source=adwords&utm_medium=ppc&hsa_acc=1409680977&hsa_cam=1418806209&hsa_grp=71516820665&hsa_ad=355784258386&hsa_src=g&hsa_tgt=kwd-298.
- [4] *e-Agriculture Promising Practice UPTAKE: driving adoption of agri-technologies through information and communication technologies (ICT)*.
- [5] S Afr. Jnl. Agric. Ext. vol.43 n.2 Pretoria 2015, "Effect of Information Communication Technology (ICT) on agricultural information access among extension officers in North West Province South Africa."
- [6] L. N. C. De Silva, J. S. Goonetillake, G. N. Wikramanayake, and A. Ginige, "Towards using ICT to enhance flow of information to aid farmer sustainability in Sri Lanka," *ACIS 2012 Proc. 23rd Australas. Conf. Inf. Syst.*, no. December, 2012.
- [7] "e-Agriculture." .
- [8] M. Chhanikar, R. Thakare, A. Tapre, and S. Thorat, "Crop Prediction and Disease Detection," pp. 249–252, 2019.
- [9] K. T. Kehinde and E. M. Agwu, "Application of ICT to agriculture as a panacea to unemployment in Nigeria," *Int. J. Adv. Multidiscip. Research Rev.*, vol. 3, no. 4, pp. 26–48, 2015, doi: 10.1109/IRI.2014.7051882.
- [10] S. A. Canuto, D. Engenharias, F. Augusto, S. Sggs, and D. Engenharias, "ICT management in the agro-industry A Management System Applied to Mushroom Harvest," no. 1.
- [11] S. Y. R. Esearch, "Design Science in Information Systems Research," no. September 2014, 2004.

TVET and Resilient Industries: Industrial management practices, and Hospitality

!

Application of Creative Tourism Performs in Sri Lankan Ramayana Tourism to Achieve Creative Economic Development

U.A.D. Premarathna
Division of Management Studies
University College of Ratmalana
Ratmalana, Colombo
dhanushapremarathne@ucr.ac.lk

R.S.S.W. Archchi
Department of Tourism Studies
Sabaragamuwa University of Sri Lanka
Belihuloya, Sri Lanka
rangana@mgt.sab.ac.lk

Abstract— *The creative economy is a paradigm for developing an economy through value creation and innovation. Creative tourism is a model developed under the creative economy to enhance tourist experiences through creative tourism experiences. This study has been conducted to understand the opportunities and issues of developing creative tourism experiences to achieve economic development related to Ramayana tourism in Sri Lanka. Sri Lanka Tourism Promotion Bureau launched the Ramayanaya Trail with the private sector to target the Indian market over to Sri Lanka for religious reasons and other travel purposes. The study was conducted under the qualitative research approach to achieve the research objectives; to identify the opportunities to develop creative Ramayana tourism products in Sri Lanka to achieve economic development and to understand issues of developing creative Ramayana tourism products in Sri Lanka. By considering Ramayana tourism in Sri Lanka as a single case, the case study research design has been adopted for this study. The sample population includes tour operators and travel agents in Sri Lanka who are contributing to Ramayana tourism. 20 qualitative interviews were conducted to collect primary data from the sample and by the field observations, the findings of primary data collection were further verified. This study is important for the future development of Ramayana trail tourism between Sri Lanka and India.*

Keywords— *Ramayana, creative, economy, tourism, development*

I INTRODUCTION

The creative economy is a key driver of economic growth in the global context. Creative tourism is a platform to enhance tourist experiences through innovative ideas, experiences, activities, environments, processes and persons to add value to tourism products. Ramayana Tourism, Ramayana Yathra or Ramayana trail is a special interest tourism segment under the cultural and religious tourism nowadays. According to Valmiki's Ramayana epic, India and Sri Lanka have a significant relationship with the transferring of Ramayana characters among each country. Ramayana sites in Sri Lanka

include the places considered captive places of Seetha, Ramayana battlefields and places related to King

Ravana. The scope of this study is focused on exploring opportunities to develop creative tourism with Sri Lanka

Ramayana tourism. The purpose of this study is to adopt the creative tourism concept, one of the recent trends for Sri Lanka Ramayana tourism to achieve creative economic development by gaining the objectives; to identify the opportunities to develop creative Ramayana tourism products in Sri Lanka and, to understand issues of developing creative Ramayana tourism products in Sri Lanka.

II LITERATURE REVIEW

The concept of creative economy emphasizes a paradigm of economic development and innovation by value creation in creative ideas transformed in to products or services (Insuasti, Burbano, Medranda, Rodríguez, & Guerrero, 2022). Creative economy is acting as a relationship role between creativity and economies by elaborating how people earn money from creative ideas (Suciu, 2008). According to (Levickaitė, 2011), the creative economy is based on ideas based capital rather than the physical capital in business industries. Advertising, Architecture, Art, crafts, Design, Fashion, Film, Music, performing arts, Publishing, Research & Development, Toys and games, software, Television & radio and computer games are the fifteen creative industries sectors and areas listed by (Howkins, 2007) which can be merged with creative economic performances. Creative economy is a key driver of long-term economic development, including relationships with creative supply chains, creative technology, regional development and global competitiveness (Deloitte, 2021).

Creative tourism is a new form of tourism that the potential to change existing models of tourism development and to make a contribution to diversifying and innovating the tourist experience (Richards G., 2009). Richards explains further the meaning of creative tourism as; "tourism which offers visitors the opportunity to develop their creative potential through active participation in learning experiences which are characteristic of the holiday destination where they are

undertaken” (Richards , 2015). In the same source, Richards has highlighted 3 key principles of creative tourism; offering opportunities for personal creative development, increasing engagement by enabling visitors and their hosts to be creative together and linking the creative activities to the destination. The model of innovative tourism product development for the development of new tourism products is based on three fundamental components; identifying destinations’ core resources on which innovative tourism products should be based; determining the transformative experiences provided by these products, and establishing the design of product development processes (Santos, Ferreira, Costa, & António , 2020). According to Stipanović and Rudan , creative tourism can be recognized as a special form of tourism that creates a new dimension and authentic experience that meets the modern traveler’s need for creativity and participation in various workshops, educational programs and a variety of creative activities including arts, heritage, nature, and the destination’s peculiarities (Stipanović & Rudan , 2014). Al-Ababneh has explained four areas of creativity; creative person, creative product, creative process, and creative environment. According to the author, creativity means “the production of novel and useful ideas in any domain”, which refers to the generation of ideas and it can be considered as a strategy for innovation and promotion. Therefore, Al-Ababneh explained creativity can impact tourism as a creative area, tourism products, skills development and performance development. “Tourism links to creativity through several creative activities in destinations that can create ‘special interest tourists’ or tourists consuming creative performances” (Al-Ababneh, 2017). According to the author the concept of creative tourism can be linked with special interest tourism and the concept of niche markets of tourism.

Sadeghnia & Amiryazdani have explained creative tourism as an opportunity for understanding the religious and spiritual beliefs of a destination (Sadeghnia & Amiryazdani , 2018). According to the authors, a creative tourist is mostly concerned with meeting his spiritual needs and he seeks self-knowledge and not mere pleasure, creative tourism refreshes the religious tradition of the self and the other. Thus, a creative tourist can be explained as a new spiritual seeker in contemporary tourism traveling to seek existential experiences. According to Hassani and Bastenegar (2016), a pilgrimage-destination journey is a unique experience for tourists because it gives the spiritual experience a social dimension and also gives the social experience a spiritual aspect. The travelers gain spiritual experiences by reaching destinations and locations which are immortal and dignifying with the social-spiritual relationship (Hassani & Bastenegar , 2016)

Sri Lanka has a distinctive significance on the Ramayana tourism concept since it was the land of two principal characters; Ravana and Vibishana in Sri Lanka who have a high significance value related to Valmiki’s Ramayana with a variety of related Sri Lankan attractions with Ramayana trail. According to Krishnaswami (2017), the concept of the ‘Ramayana trail’ can be defined as the places on the land (India and Sri Lanka) that walked Rama and Seetha

(Krishnaswami, 2016). According to the latest statistical analysis of the ten major source markets, tourists from India represented a large number of international arrivals. In 2017 there were 384,628 Indian tourists arriving with an 18.17 percent share. This is increased in 2018 as 424,887 of arrivals and 18.2 percentage shares (Annual Statistical Report, 2017). According to the Sri Lanka Tourism Promotion Bureau (2015), Sri Lanka tourism has taken this advantage to promote Ramayana as a tourism product in Sri Lanka since 2004. The survey findings (Council, 2020) estimate that 238,586 workers are involved in the creative industries in Sri Lanka. With 8,208 million employed workers at the national level, that amounts to almost three percent (2.9 percent) of the economically active workforce.

Kasempholkoon (2011) has explained the significance of the concept of ‘creativity’ to the economy of Thailand. Under the concept of ‘creative economy’, Thailand’s tourism has adopted the creative tourism concept to add value and enhance the visitor experience on ‘Ramakian’, the Ramayana epic-based tourism products in Thailand. According to the author, Thailand has invented a variety of creative Ramayana tourism products including; cultural performances, food & beverages, new Ramayana stories, commercial brands, computer games and other local products with relevance ‘Hanuman’ the monkey colonel who considered an epic hero of Ramayana in the Thai context. Fernando and Sarangi (2017) have done their study related to Ramayana tourism in Sri Lanka and the authors have recommended their suggestions to promote Sri Lankan Ramayana Tourism combined with other prominent niche tourism markets.

Objectives of the study

With the factors identified by the literature study, the researcher developed the first research questions for this study to identify opportunities to develop creative tourism performances with Ramayana tourism in the Sri Lankan context to achieve economic benefits with the viewpoint of creative tourism. The second research question also focused on the investigation of the issues of developing creative Ramayana tourism products and services in Sri Lanka. The first question of the study is developed as; ‘What are the opportunities to develop creative Ramayana tourism products in Sri Lanka to achieve economic development?’ and the second research question is developed as; ‘What are the issues of developing creative Ramayana tourism products in Sri Lanka?’. Based on these two research questions, the researcher has developed the two research objectives of this study as follows; to identify the opportunities to develop creative Ramayana tourism products in Sri Lanka to achieve economic development; and, to understand issues of developing creative Ramayana tourism products in Sri Lanka.

III THE METHODOLOGY OF THE STUDY

This study has adopted the qualitative research approach to understand the significance of amalgamating Ramayana tourism and creative tourism concepts through the experiences, views and ideas of particular respondent groups. Through the case study research design,

the researcher was able to achieve the objectives of the study in the Sri Lankan context by direct intensive observations of Ramayana tourism in the Sri Lankan context as one case. The population is included with 20 respondents including tour operators, travel agents and tourist guide lecturers who contribute to Ramayana tourism in the Sri Lankan context. Among nonprobability sampling techniques, the researcher adopts multiple sampling techniques including purposive sampling to define the sample as per the research purpose and snowball sampling to identify the most relevant respondents who are actively contributing to the research area. Semi-structured interviews with above mentioned stakeholders of Ramayana tourism and participant observations in Ramayana sites were implemented during the primary data collection. Under the inductive analysis approach, the researcher has adopted the content analysis tool to determine the existence of certain words, themes, or concepts within qualitative data from interviews and field observations.

IV FINDINGS AND DISCUSSIONS

A. Core Resources for Ramayana Tourism in Sri Lanka

According to the model of innovative tourism (Santos, Ferreira, Costa, & António, 2020) new tourism product development is based on identifying destinations' core resources on which innovative tourism products should be based. Thus, the study has been focused on understanding the core resources of existing Ramayana tourism in the Sri Lankan context which can also be considered also the opportunities for Ramayana tourism. The Ramayana is an ancient Sanskrit epic written by sage Valmiki around 500 BCE to 100 BCE which follows Prince Rama's (from Ayodhya city of modern Northern India) quest to rescue his beloved wife Sita from the clutches of Ravana (in Lankapura/Sri Lanka) with the help of an army of monkeys of Hanuman (Wight, 2014).

By the comparison with Kasempholkoon's study (2011) has been done in the Thailand context; among the core resources of Sri Lankan Ramayana tourism, the density of Ramayana legend-related sites can be positioned at the first place. Kasempholkoon (2011) has included the main 3 regions of Thailand which has a significant role in Thailand's Ramayana tourism. The Sri Lankan Ramayana trail includes more than 44 Ramayana tourism sites related to Ramayana characters including Rama, Seetha, Lakshman, Hanuman and Ravana (Duraismamy, 2014). Ramayana tourism is expanded geographically in the South Asian Region including Sri Lanka and India with the direct relevance with Valmiki's Ramayana epic. Further, Thailand, Laos and Vietnam also promote Ramayana tourism even those destinations have no direct relevancy with Valmiki's Ramayana epic. In this advantage, the over 44 Ramayana-related sites can be

considered as the core resource of Ramayana tourism in Sri Lanka. The above 44 included highly devoted Hindu and Buddhist temples known as; Munneshwaram temple-Chilaw, Manaweri temple- Chilaw, Thirukoneshvaram temple-Trincomalee, Divurumpola temple- Welimada, Seetha Amman temple- Seethaeliya, Gayathree Peedam- Hawaeliya, Sri Bhakta Hanuman temple – Ramboda, Vibhishana Shrine-Kelaniya temple, Panchamuga Anjanair Temple – Wellawatta which are highly devoted by Hindu pilgrimage tourists from India. This is another unique factor, enhances the value of core Ramayana resource locations in Sri Lanka.

Tourism statistical details from 2009 to 2019 continuously provide the evidence for the highest arrival of the Indian tourist market, which has taken the number one of the top ten source tourist markets of Sri Lanka. This is another core resource to implement creative Ramayana tourism in Sri Lanka. The findings of qualitative interviews with tour operators and tourist guide lecturers have expanded the level of tourist markets that can be attracted for Ramayana tourism in Sri Lanka. When it considers other potential core market resources for Ramayana tourism; Hindu devotees who believe Ramayana in Malaysia and Singapore have been mentioned by a considerable number of respondents. In additionally, South Africa, the United Kingdom, France and the United States of America are the potential markets mentioned by the respondents. Self (2010) has explained the movement of the Hindu population from India to other regions in the world and at the present. The high-end Hindu tourist markets of the above countries are another core resource for profitable creative Ramayana tourism developments in Sri Lanka. As per the map, the Ramayana site distribution of Sri Lanka has covered all provinces in Sri Lanka and the majority of sites are distributed in Uva, Central, Southern, Northern and Wayamba provinces which included rural areas to be developed. Creative economy is a key driver of long-term economic development and regional development to meet global competitiveness (Deloitte, 2021) thus, above mentioned core resources for creative Ramayana tourism can be recognized as key opportunities to perform creative economic development in Sri Lanka.

	tourist attractions	tourism
New-Invented Ramayana performances	“Hanuman Meets Seven Heroes” by Chaiyo Film (Thailand) and Tsuburaya Production (Japan) in 1974, which created by mixing both Hanuman character as King Rama’s great soldier with Japanese hero character.	‘Ravana-The untold legend A Ballet-Opera’ - scripted by Bhadradi Mahinda Jayathilaka which performed on January 2018 at the first time. Not linked with creative Ramayana tourism promotion.
Community based tourism activities	Tha Hin village in Lopburi province stands from times to times the famous homemade chalk soil industry. People there promote their chalk soil industry by the “belonging” Ramayana tales: King Rama’s arrow fell in Lopburi land then the soil there became white chalk soil.	Not found community based tourism activities related with Ramayana tourism programs
Innovated food services	Rama taking bath (rice with cooked pork and Thai morning glory in gravy), Lakshman taking bath (a recipe made from noodles) and Seetha taking bath (a recipe made from pure vegetable and gravy) are three innovated food products with main Ramayana characters	Sri Lankan tour packages promote Indian and other food services. Not found innovated food services linked with Ramayana
Commercial brands	“Hanuman battery” (Hanuman in his star-spring yawn character), “Hanuman match” (flying Hanuman) or “Hanuman rice pack”	Not found innovated commercial brands with Ramayana characters
Video games and comics	Video games and epics with epic hero Hanuman	No innovations observed linked with Ramayana tourism
Souvenirs	Innovated souvenirs reflecting key Ramayana characters; Hanuman, Rama,	Sri Bhaktha Hanuman temple of Ramboda and Seetha Amman temple innovated souvenirs for

	Seetha and Tosokan (Ravana) are available with a range of verities (key tags, mugs, t-shirts, ornaments and masks)	visitors (Hanuman statues & commemorative plates) other attractions have no innovated souvenir varieties.
Leisure and adventure activities	Ramayana themed water park in Na Chom Thian	Flying Ravana zipping line adventures in Ella – an innovative adventure tourism experience

Source: (Kasempholkoon, 2011) and (primary data collection, 2022)

The summary of the above table shows the availability of transformative tourism products and services in Thailand which provides new experiences for tourists and recent performances of Sri Lankan Ramayana tourism.

Transformative experiences by creative environments:

According to Al-Ababneh (2017), the creative environment of tourist attraction is another important factor that, influence on visitor’s experiences in creative tourism. Kasempholkoon (2011) has elaborated on how creative economic concept and creative Ramayana tourism has encouraged to development of creative environments in Thailand to transfer unique experiences for Ramayana tourists in Thailand;

It is sighted that Ramayana tales are widely and variously applied for cultural tourism. One of the most interesting points is to travel “follow King Rama’s paths” in meaningful sites related with local Ramakian where are believed once the real scene of the great. Besides, traditional Ramayana performances not only publicize Thai culture but also support and make affords for local artists, who are encouraged to preserve all these artistic branches.

According to Kasempholkoon (2011), the Tourism Thailand Organization (TTO) has developed creative environments in local Ramakian sites like Samo Khon Mountain, Rama’s Arrow Shrine, Sappaya Mountain by developing creative cultural and community-based activities. Local communities in Tha Hin village in Lopburi province contribute to the famous homemade chalk soil industry and people there promote their chalk soil industry by the

“belonging” of Thai Ramayana trail as; King Rama’s arrow fell in Lopburi land and then the soil there became white chalk soil. This effort can be interpreted here as a creative way to turn cultural capital into commercial profits to achieve creative economic goals through creative Ramayana tourism.

According to Kumar and Singh (2015) Hindu pilgrim tourists in India have shown high expectations for eight attributes namely attractions, accommodations, food & beverages, transportation, tourism services, attitudes of locals, security and safety and infrastructural facilities. Hindu pilgrimage tourists prefer to get experiences from sacred geography including rivers, trees, and ponds marked by shrines for particular deities, sanctified artifacts and objects, and temples; sacred specialists such as priests, religious gurus, monks and ascetics in the site and sacred performances like temple rituals (daily and seasonal), processions, festivals, feasts, religious sermons and religious conferences (Shinde, 2018). According to the above researches’ concerns, the creative environment is a vulnerable element for Hindu tourists who are the core resource of Ramayana tourism to emotionally engaged with the attraction based experiences.

The existing study done in the Sri Lankan context has identified the lack of creative environments to promote Ramayana tourism. The physical evidence of Sri Lankan Ramayana sites (including the facts and information that influencing to development of the trustworthiness of the tourist, availability of shrines, religious activities and other creative performances and contribution of local communities) is needed to the good site image (personal communication, 2022). The primary data observed through field observation proved that there is an insufficient level of creative environments in Sri Lankan Ramayana tourism sites. According to the observations; Ussangoda National Park, Kanniya hot water spring, Ramasethu of Mannar, Ravana Cave of Ella, Chariot Path, and Gurulupotha are popular significant sites in Sri Lankan Ramayana trail but there is a lack of creative environments and physical evidence has at the sites to promote

creative tourist experiences. When this scenario is compared with the case of Thailand explained by Kasempholkoon (2011), in the Sri Lankan context there are very minimal opportunities for local communities to gain economic benefits from Ramayana tourism-related sites.

C. Issues of developing creative Ramayana tourism products in Sri Lanka as a driving element of creative economic development

According to Howkins (2007), Advertising, Architecture, Art, crafts, Design, Fashion, Film, Music, performing arts, Publishing, Research & Development, Toys and games, software, Television & radio and computer games are the fifteen creative industries sectors and areas listed that can be merged with creative economic performances. Kasempholkoon (2011) has elaborated on how Thailand tourism creatively merged the above components with creative Ramayana tourism in Thailand. This study has investigated the issues of developing creative Ramayana tourism as a driving element of tourism industrial development in the Sri Lankan context. The core issues identified through primary and secondary data collection can be summarized as follows;

Inability to national level policy implementation to promote creative economic practices in tourism

As per the findings of a British Council-commissioned survey in 2018, The State of Social Enterprises in Sri Lanka, found that 13 per cent of social enterprises in Sri Lanka are also creative enterprises. The report of finding (British Council, 2020) has highlighted several areas including tourism and hospitality, Ayurveda, culinary arts, beauty culture and etc. and the government’s responsibility of clear visioning to stream line those values with tourism industry;

A more streamlined government focus on the tourism industry with a clear vision for policy development in the coming years is also essential. A strategic plan is required with capable personnel and consistent standards to cater to needs of tourists and promote the hospitality industry and give it more value.

Lack of government visioning, policy-making and planning to promote creative economic practices at national level and amalgamate with the tourism industry is a major existing issue in Sri Lanka, as per the findings through the literature survey of this study.

Lack of contribution of key stakeholders to promote creative tourism with Ramayana tourism in Sri Lanka

The majority of respondents who participated in the qualitative interviews of this study raised the lack of contribution of key stakeholders and suggested expanding the involvement of stakeholders to promote creative performances with Ramayana tourism in Sri Lanka. As the key governing bodies, the Sri Lanka Tourism Development Authority, Sri Lanka Tourism Promotion Bureau, Department of Archaeology, Central Cultural Fund, Wildlife Conservation Authority, Coastal Conservation Authority and provincial councils should have a common vision to promote Ramayana tourism in Sri Lanka with creative performances and Sri Lanka Tourism Development Authority has the major responsibility of policymaking. The involvement of local transportation providers, accommodation services, food and beverage service providers, and local community engagement with existing Ramayana sites are the suggested areas by the respondents to improve new experiences with core Ramayana tourism products in Sri Lanka. To recover this lack of contribution scenario among the stakeholders, all the stakeholders should have a common vision and mission to develop Ramayana tourism with future forecasting. With the direct contribution of the above stakeholders, it will be able to add value to Ramayana tourism products in Sri Lanka as per the explanation of Kasempholkoon's study (2011).

Insufficient recognitions and innovations on Ramayana tourism as a driving factor of economic development in Sri Lanka

According to the literature survey of this study, Sri Lanka has had a continuous growth of the Indian tourist market from 2009 to 2019. As the nearest neighbor country to Sri Lanka with direct relevancy to the Ramayana epic and the advantage of diplomatic and socio-cultural relationships Sri Lanka has plenty of

opportunities to promote Ramayana tourism among Indian tourists rather than Thailand. Further, the above-discussed finding of this study highlights the potential of high-end and other Hindu tourist markets potentials from Malaysia, South Africa, France, Germany, the United Kingdom and the United Nations of America to attract future tourists for Ramayana tourism in Sri Lanka. Even in this kind of scenario, the findings of this study also highlighted the Sri Lanka Tourism Development Authority's insufficient recognition of Ramayana tourism as a driving factor of economic development. According to the observations of this study, the Sri Lanka Tourism Development Authority is taking actions to collaboratively promote Ramayana tourism with tour operators by arranging promotional events but the observation has not recognized the contribution of the Sri Lanka Tourism Development Authority to creating long-term innovative experiences attached with Ramayana tourism products in Sri Lanka as per the highlights in the Table-I.

V RECOMMENDATIONS AND CONCLUSION

According to the above discussion grounded on this study, from 2004 to the present Sri Lanka has 19 years old experience in Ramayana tourism and Sri Lanka has directly relevant Ramayana sites with Valmiki's Ramayana epic, customer tail and a range of stakeholders to promote creative Ramayana tourism similar with the Thailand's context but the findings proved that, Sri Lanka has no so far taken sufficient level of actions to improve creative tourism experiences to achieve creative economic goals. When Sri Lanka, is compared with the Thailand context, Sri Lanka so far has not taken advantage of the concepts of creative economy and creative tourism to develop qualitative innovations in Ramayana tourism. Thus, the below recommendations can be highlighted here to adopt creative economy and creative tourism concepts for relevant innovations in Sri Lankan Ramayana tourism. The study recommends developing a national-level holistic vision of creative economy and innovative industries. Under the national

framework, the Sri Lanka Tourism Development Authority as the major Destination Management organization should develop national-level policies to promote creative tourism concepts in Sri Lanka to achieve creative economic goals. From the viewpoint of creative Ramayana tourism Sri Lanka Tourism Development Authority should recognize the range of stakeholders in Sri Lanka Ramayana tourism who can add value through innovative tourism experiences as per the highlights given in this study related to the Thailand context. These recommendations can be implemented to achieve creative economic development by implementing creative tourism performances in Sri Lankan Ramayana tourism.

REFERENCE

- "Annual Statistical Report," Sri Lanka Tourism Development Authority, Colombo, 2017.
- "Sri Lanka launches new product - Ramanya Trail," 01 April 2015. [Online]. Available: <https://www.srilanka.travel/travel-news&news=267>.
- A. Hassani and M. Bastenegar, "Components of Spirituality in Creative Tourism," *International Journal of Tourism and Spirituality*, pp. 67-90, 2016.
- A. Kasempholkoon, "'Creative Ramayana' for the Value Adding of Thai Products and Tourism: A Study of 'Creative Folklore'," Lokaratna, 2011.
- C. Stipanović and E. Rudan, "Development Concept and Strategy for Creative Tourism of the Kvarner Destination," *Tourism and Hospitality Industry 2014, CONGRESS PROCEEDINGS Trends in Tourism and Hospitality Industry*, pp. 507-517, 2014.
- C. Wight, "Quick guide to the Ramayana," 12 February 2014. [Online]. Available: <https://www.bl.uk>.
- D. Self, *The Lion encyclopaedia of world religions*, Oxford: Lion, 2010.
- Deloitte, "The Future of the Creative Economy," 2021.
- G. Richards, "Creative Tourism: New Opportunities for Destinations Worldwide?," Presentation at the World Travel Market Conference on 'Creative Tourism: All that you need to know about this growing sector', 2015.
- G. Richards, *Creative Tourism and Local Development*, Sunstone Press, 2009.
- H. R. Insuasti, N. M. Burbano, M. Y. Medranda, O. S. Rodríguez and K. P. Guerrero, "Creative Economy: A Worldwide Research in Business, Management and Accounting," *Sustainability* 2022, pp. 2-27, 2022.
- J. Howkins, *The Creative Economy: How People Make Money from Ideas*, Penguin UK, 2007.
- K. Shinde, "Governance and Management of Religious Tourism in India," *International Journal of Religious Tourism and Pilgrimage*, p. 58-71, 2018.
- M. C. Santos, A. Ferreira, C. Costa and J. António, "A Model for the Development of Innovative Tourism Products: From Service to Transformation," *Research Gate*, pp. 2-20, 2020.
- M. M. Al-Ababneh, "Creative Tourism," *Journal of Tourism & Hospitality*, 2017.
- M. Sadeghnia and H. Amiryazdani, "Creative Tourism and Its Role in the Flourishment of Religious Creativity and Spiritualism," *International Journal of Tourism and Spirituality*, pp. 9-25, 2018.
- P. I. N. Fernando and P. Sarangi, "Ramayana trail as a cultural tourism product in Sri Lanka: New paradigm for destination marketing," *Kelaniya Journal of Management*, pp. 83-98, 2017.
- R. B. Kumar and L. Singh, "The expectations and satisfaction of Hindu pilgrims in north-west India – the case of the Naina Devi shrine," *African Journal of Hospitality, Tourism and Leisure*, pp. 1-18, 2015.
- R. Levickaitė, "FOUR APPROACHES TO THE CREATIVE ECONOMY: GENERAL OVERVIEW," *Business, Management and education*, pp. 81-92, 2011.
- S. Duraiswamy, *Ramayana in Lanka*, Colombo: Chinmaya Mission of Sri Lanka, 2014.
- S. Krishnaswami, "Ramayana in Lanka," 31 December 2016. [Online]. Available: <https://callofthevedas.wordpress.com/2016/12/31/ramayana-in-lanka/>.

Empowering Middle Age (6–11) Children in Marginalized Communities: A Personality Development Project at Ashoka Primary School, Delgoda, Biyagama, Sri Lanka

R. M. T. G. U. Rathnayake

*Department of Film & Television Production Technology
University of Vocational Technology
Rathmalana, Sri Lanka
h2112fpt15b227@uovt.ac.lk*

J. D. A. Kumara

*Department of Social Sciences
General Sir John Kothalawala Defence University.
Rahmalana, Sri Lanka
ashokakumara@gmail.com*

Abstract—The research paper discusses a community-based project called "C-2022" in Sri Lanka, aimed at empowering middle-aged children aged 6–11, particularly those from marginalized communities, by fostering holistic development, emotional intelligence, social skills, and critical thinking abilities. The project, initiated at Ashoka Primary School, aims to address the unique challenges faced by these children caused by the corona-virus disease of the 2019 pandemic and the country's economic recession. The study emphasizes the importance of a student-centered approach to fostering positive values, self-expression, emotional intelligence, and critical thinking for personality development. The project involved a qualitative research design, with 185 children in grades 3, 4, and 5 engaged in recognized personal development activities. The research highlights the importance of using holistic approaches and psychological theories to improve the personality development of marginalized children through targeted interventions. It recommends improving the effectiveness of personality development projects by fulfilling basic needs, cognitive growth, social learning, and community involvement to foster empowered individuals capable of facing life's challenges confidently.

Keywords—critical thinking abilities; personality development; middle childhood; self-concept, self-esteem

I. INTRODUCTION

Middle childhood is a crucial phase in a child's life, involving the formation of social skills, self-concept, and socialization abilities. However, children from families facing economic hardships due to the COVID-19 epidemic and the country's economic recession may encounter challenges in their personality development. In marginalized communities like industrial free trade zones in Sri

Lanka, these difficulties are amplified due to limited access to resources and support systems.

Delgoda Ashoka School, located near the Biyagama Free Trade Zone, educates around 250 students, most of whom are children of Free Trade Zone employees. The recent pandemic and economic downturn have adversely affected these children's lives, leading to financial hardship and family disruptions. Social problems such as domestic violence, parental abandonment, family fragmentation, and fathers' drug addiction further compound the challenges faced by these children, putting them at a higher risk of abuse.

To address these issues, the "Community-Based Project 'C'-2022" was launched at Asoka Primary School, aiming to empower children aged 6 to 11 years, especially those from marginalized communities. The project focuses on their holistic development, emotional intelligence, social skills, and critical thinking abilities.

The researcher undertakes this research paper to conduct a comprehensive evaluation of a community-based project done by the researcher. Within, the paper carefully assesses the overall effectiveness and efficacy of the project.

The study emphasizes the importance of an inclusive and student-centered pedagogical approach that fosters positive values, self-expression, emotional intelligence, and critical thinking. Understanding the significance of personality development during middle childhood can help educators and policymakers design effective interventions and initiatives to support the overall growth and well-being of children in marginalized communities.

The Biyagama Free Trade Zone in Delgoda, Sri Lanka, has experienced significant economic hardships due to the COVID-19 pandemic and recession. This condition has led to challenges in the personality development of children aged 6–11. The family environment is characterized by limited resources, maternal or paternal abandonment, disrupted family dynamics, domestic violence, low education, and family members engaged in anti-social activities. These experiences and extreme poverty negatively impact children's overall well-being and personality development. The presence of diverse patterns of upbringing within a family holds paramount importance in shaping a child's personality development. In contrast, a child raised in an unfavorable family environment is inherently prone to developing a fragile personality (Al-Momani et al., 2022). Therefore, it is crucial to enhance the personalities of these children to help them cope and thrive in their challenging family environment.

A. Rationale

Personality development during middle childhood significantly impacts a child's social, emotional, and cognitive aspects. Early interventions focusing on positive values, emotional intelligence, and social skills can foster well-rounded personalities and increase resilience. Sri Lankan Free Trade Zone workers' children face unique challenges like abandonment, domestic violence, and orphan care, making their holistic development crucial. The personality development project aims to empower and support their holistic growth.

B. Goals, Objectives, and Scope of the Work.

The personality development project aims to empower middle-aged children at Delgoda, Ashoka, primary school by enhancing their social, emotional, and cognitive aspects. The project focuses on identifying challenges faced by Biyagama Free Trade Zone workers and designing targeted activities and interventions to address their needs. It also aims to facilitate opportunities for self-expression, creativity, and personal growth through artistic, educational, and recreational activities. The project fosters a sense of belonging and community among the children, encouraging peer support and mutual understanding. The project evaluates the impact of experimentally utilized activities on their emotional intelligence, social skills, and critical thinking abilities. The project

involved programming activities using fun and engaging approaches, such as artistic activities, role-play games, physical exercises, storytelling, public speaking, and music training. The final session included a talent show concert.

II. REVIEW OF LITERATURE

Research conducted by the Women's Center among Katunayake Free Trade Zone workers revealed that 57% of respondents experienced various diseases, including colds, fever, eye diseases, stomach ailments, diarrhea, aches, tiredness, depression, headaches, skin diseases, weight loss, backaches, chest pains, sleepiness, and breathing difficulties. Lack of sleep, long working hours, lack of free time, inadequate nutrition, poor living conditions, lack of privacy, supervisors, and irregular mealtimes are causes of diseases. The monthly wage in these free trade zones is around \$40, while in factories outside the zones, it is around \$38. Unattainable production targets and unsanitary conditions contribute to the health issues faced by workers, both inside and outside the free trade zones. Most of the students of the Asoka primary school in Delgoda, Sri Lanka, are children of these chainless enslaved people from Industrial Free Trade Zones in Sri Lanka, who earn foreign exchange for this country and suffer severe labor exploitation and other abuses (Roger McKenzie Monday, 2022).

UNESCO emphasizes the importance of holistic personality development in children, encompassing intellectual, emotional, social, and physical aspects. Key points include Early Childhood Development (ECD), Inclusive Education, Social and Emotional Learning (SEL), Child-Centered Approaches, Play-Based Learning, Cultural and Linguistic Diversity, and Physical Activity and Health. ECD is crucial for lifelong learning and personality development, while inclusive education fosters a sense of belonging and empathy. Play-based learning promotes creativity, problem-solving, and social skills. UNESCO's mission also emphasizes the importance of physical activity and a healthy lifestyle in a child's development, as it positively impacts their mental and emotional well-being (Lompscher, 1982).

A. Theoretical Framework

The development of social and personality attributes in middle-aged children (aged 6–11) is a complex process shaped by numerous factors. Various theoretical perspectives illuminate the pathways through which children undergo social development and construct their personalities. This section delves

into prominent theories and approaches that enrich our comprehension of this intricate phenomenon.

B. Sigmund Freud's Psychoanalytic Theory

Sigmund Freud's psychodynamic approach (1905) underscores the role of unconscious processes in shaping personality development. It places particular emphasis on early childhood experiences, notably the Oedipus complex and Electra complex, in the development of children in their mid-ages (Freud, 1905). This theory provides valuable insights into the interplay of the id, ego, and superego, which collectively mold behavior and emotional development.

C. Abraham Maslow's Motivational Theory

Abraham Maslow emphasized the importance of achieving specific needs, including physiological, safety, love, belongingness, esteem, and self-actualization needs. A hierarchy of needs, such as extreme deprivation and insecurity, can lead to fixation on physiological and safety needs, which can negatively impact future happiness. This fixation can result in neurotic mental health problems like anxiety or depression (Maslow, 1943).

D. Jean Piaget's Cognitive Development Theory

Piaget's Cognitive Developmental Approach highlights the cognitive processes in children's social and personality development, focusing on stages of cognitive growth that influence social interactions and self-understanding. In the concrete operational stage (ages 6-11), children develop sophisticated mental operations, logical reasoning, and an understanding of conservation and reversibility. Piaget's theory helps us understand how cognitive growth and personality development intertwine during the mid-childhood years (Bebane, 2021).

E. Behavioral Theory (B.F. et al.):

Behavioral theories, often associated with Skinner and Watson, emphasize the role of external factors and the environment in shaping personality. They believe that behavior is learned through conditioning, and thus, personality can be modified through reinforcement and punishment (Malone, 2017).

F. Social Learning Theory:

Albert Bandura's social learning theory emphasizes observational learning and modeling in shaping behavior and personality. Children learn by observing

others' behaviors, acquiring traits through imitation and reinforcement, and adopting behaviors by emulating role models (Firmansyah & Saepuloh, 2022).

G. Self-Concept Approach:

Carl Rogers' personality theory places a central emphasis on the self, specifically the concept of self-concept. Self-concept, in this context, encompasses a wide range of factors. The way an individual tends to behave in a self-actualizing manner drives personal growth, resulting in a collection of transformative experiences. These experiences, once modified and represented within one's conscious awareness, together form the essence of an individual's self-concept. This self-concept is a fundamental cornerstone of Rogers' client-centered therapy and his overall understanding of personality (İsmail & Tekke, 2015).

H. Social Interaction approach

In the theory of interaction analysis, Burn posits instruct children in perceiving the world accurately, fostering the exchange of love with others, and promoting genuine and unpretentious interactions without falsification, evasion, or deception. This guidance aims to prepare young individuals for life in the real world (Al-Momani et al., 2022).

III. METHODOLOGY

This study investigates the experiences and perceptions of middle-aged children aged 6–11, particularly from marginalized communities, at Ashoka Primary School. The research uses a participatory observation approach involving 185 children from grades 3, 4, and 5 at the school. The sample was intentionally chosen to address unique challenges due to economic hardships and complexities in their family and community environments.

The researcher actively participated in the children's activities and closely observed their behaviors, interactions, and responses. These observations provided valuable insights into the children's engagement and enthusiasm for the project activities.

Interviews were conducted with selected children based on specific family issues to understand their experiences, challenges, and transformations due to their participation in the Personality Development Project. Open-ended questions allowed children to express their thoughts and feelings.

Semi-structured interviews were conducted with the school principal, teachers, and randomly selected parents regarding the positive development of children's personalities due to the impact of the personality development project.

Data collected through observations, interviews, and focus group conversations were analyzed through thematic analysis. Themes and patterns emerging from the data were identified, allowing for a comprehensive understanding of the children's experiences and the impact of the Personality Development Project.

The implementation of the research will involve three groups of children in Grades 3, 4, and 5, with one group having two hours in the program and six hours in the community each day.

The project's timeline spanned from August 10, 2022, to January 20, 2023, comprising a total of 19 sessions. Notably, the initial session was the Welcome Session, and the concluding event featured the Kids Talent Show.

Anticipated impacts of the project encompass enhanced mental health and overall well-being, particularly beneficial for children grappling with anxiety and other mental health concerns. The project aimed to fortify socialization skills, bolster self-concept, and elevate self-confidence among the participating children.

During the project, the researcher actively participated in the Children's Day festivities, where they contributed storybooks to the children. The culmination of the project was marked by the Grand Kids Talent Show, which served as a poignant reflection of the significant outcomes achieved throughout the six-month initiative.

A. Ethical Considerations

Ethical considerations were of utmost importance in this study. Informed consent was obtained from the parents or guardians of the participating children, and the anonymity and confidentiality of the participants were strictly maintained. The research was conducted in an environment that ensured the comfort and well-being of the children.

IV. RESULT & DISCUSSION

The Personality Development Project identified several behavioral issues and symptoms of anxiety disorders among children. These included persistent crying, feeling tense and fidgety, being clingy, outbursts of being out of control, irritability, and

attention deficit hyperactivity disorder (ADHD), aggressiveness, defiance, agitation, loud and impulsive responses to questions, and worrying facial expressions. Constant crying is often an expression of emotional distress and anxiety. Several children exhibited signs of heightened anxiety levels, such as nervousness, restlessness, and fidgeting. Clinginess, particularly in social situations, indicates underlying anxiety and a need for reassurance. Outbursts of uncontrolled behavior and emotional reactions indicate emotional instability. Irritability and mood swings are common, reflecting emotional turbulence. Some children exhibited symptoms consistent with ADHD, such as impulsivity, hyperactivity, and difficulty focusing. Aggressiveness, defiance, agitation, loud and impulsive responses, and worrying facial expressions are also common.

The study reveals that students' behavioral issues and anxiety symptoms are influenced by extreme poverty, domestic violence, family disruptions, the use of corporal punishment, and public criticism. These factors can lead to emotional distress, behavioral problems, and disruptions in their emotional and psychological development. Teachers often fail to consider the emotional well-being of their students and use harsh punishments to control misbehavior.

TABLE I. WORK PLAN – SAMPLE ACTIVITIES

Activities in 19 Sessions	Impacts/Outcomes/Results
Physical Exercise & Activities	Learn social interaction and gain self-confidence. Developing physical ability allows kids to have more fun while making friends and learning team bonding.
Children Songs	It improves spatial reasoning and cognitive ability, is fun, and sparks an interest.
Dramatic activities Role-playing	Develop imagination, spark new thought processes, and give new experiences. Build self-esteem.
Public speech and debates	Overcome stage fright and feel confident when performing in front of a crowd.
Artistic Activities	Help express thoughts and creativity. Build a sense of pride and self-confidence.
Reading Storybooks	Reading storybooks Promotes brain development and sparks the imagination. Improve language and emotions. Develop cognitive ability and broaden vocabulary and life experiences.

The program emphasized a range of physical exercises and engagement to enhance social interaction, boost self-assurance, foster teamwork, and strengthen connections among children. Additionally, it incorporates exercises designed to address stage fright

and social phobias, along with interactive role-playing and dramatic activities. These endeavors assist children in cultivating empathy, refining social aptitude, honing their focus, and gaining insights into the emotions of others. The program also aids in conquering stage fright and social phobias while nurturing self-perception and self-esteem.

A. Impact of the Personality Development Program:

The Personality Development Program adopted a multifaceted approach designed to enhance the well-being and personal growth of middle-aged children. It encompassed a wide array of activities, each serving specific purposes aimed at fostering positive attributes and abilities among the participants.

B. Promoting Physical Fitness and Social Interaction

Physical exercises and activities played a central role in the program. These activities were instrumental in cultivating physical strength, enhancing social interactions, and promoting teamwork. They provided children with an opportunity to form connections with their peers while engaging in various forms of physical exercise. These activities not only boosted their self-assurance but also instilled a sense of teamwork, underscoring the importance of cooperation in their social development.

C. Addressing Stage Fright and Social Phobias:

One of the critical aspects of the program was its approach to addressing stage fright and social phobias. Through targeted exercises and activities, children were encouraged to confront their fears and anxieties related to public speaking and performing in front of an audience. This was a pivotal step in building their self-confidence and reducing the inhibitions associated with social interactions.

D. Interactive Role-playing and Dramatic Activities:

Interactive role-playing and dramatic activities were integral components of the program. They played a significant role in enabling children to understand different perspectives, develop empathy, and refine their social aptitude. These activities allowed participants to explore the emotions and experiences of others, ultimately contributing to their overall emotional intelligence and social skills.

E. Encouraging Artistic Expression:

The program strongly encouraged artistic expression as a means for children to channel their thoughts, feelings, and creativity. Artistic activities facilitated self-expression and provided a platform for children to convey their emotions. This not only enhanced their artistic abilities but also nurtured their sense of self-expression and creativity.

F. Building Peer Support and Bonding:

The Personality Development Program created a sense of community and belonging among the children. Through their participation in various activities, children developed a deeper connection with their peers, fostering mutual understanding and peer support. This communal aspect of the program was vital in enhancing the emotional well-being of the participants.

G. Developing a Positive Self-Concept:

A significant outcome of the program was the development of a more positive self-concept among the children. As they engaged in various activities and experienced personal growth, they began to perceive themselves in a more positive light. This shift in self-perception resulted in increased self-assurance and belief in their abilities.

Improving Communication Skills and Fostering Creativity:

The program also succeeded in enhancing the communication skills of the children. They became more articulate, expressive, and confident when interacting with their peers and adults. Moreover, the encouragement of creativity and imaginative thinking was a significant aspect of the program, contributing to the development of innovative problem-solving abilities.

The researcher created a welcoming environment for children to openly discuss their issues, gaining their trust and encouraging them to share their experiences. For example, an 8-year-old kid from grade three who initially displayed aggressive behaviour and was labelled as a mischievous boy in the school transformed significantly after being assigned minor responsibilities and receiving praise. This transformation was evident in their performance during the Talent Show, where he excelled in the lead

role of 'MAHADENAMUTHTHA' folk drama, showcasing leadership qualities.

Through experimental observations, researchers closely monitored various aspects of the children's experiences, including their enthusiastic involvement, responses, and feedback. Furthermore, the study highlighted the particular inclination of middle-aged children towards aesthetic activities and group performance.

The personality development program made a significant difference in the student's overall well-being, and the children exhibited a reduction in social anxiety disorder (SAD) and attention deficit hyperactivity disorder (ADHD) symptoms. It is a massive reduction of around 30-40%.

The researcher faced difficulties obtaining participation from a limited number of children in a program due to low school attendance and cultural restrictions. One child, an Islamic faith-affiliated child, rejected taking part in the stage play.

The program and research identified various themes and patterns emerging from the data collection methods. These patterns were evaluated through observations and interviews with the principal, teachers, and randomly selected parents.

TABLE 2: IDENTIFIED THEMES AND PATTERNS

Theme or Pattern	Evaluated by Observation	Evaluated by Interviewees
Increased Self-Confidence	Medium	Medium
Improved Social Interaction	High	High
Artistic Expression	Medium	Medium
Overcoming Fears	High	High
Peer Support and Bonding	High	High
Positive Self-Concept	Medium	Medium
Communication Skills	High	High
Creativity	Medium	Medium

The Personality Development Program proved to be a comprehensive initiative that significantly impacted the well-being and personal growth of middle-aged children. The findings suggest that targeted interventions can effectively address behavioral issues and anxiety symptoms among children, equipping them with vital life skills and a positive self-concept.

V. CONCLUSION

INTERNATIONAL RESEARCH SYMPOSIUM -2023 (IRS2023-UoVT) “Emerging Technologies and Skills for Resilient Industries”

The research demonstrates the significance of targeted interventions in promoting personality development among marginalized children. By examining results through multiple psychological theories, including psychoanalysis, motivation, cognitive development, psychosocial stages, behaviorism, social learning, and self-concept, the study underscores the complexity of factors influencing children's development. It emphasizes the need for comprehensive approaches that consider early experiences, basic needs, cognitive growth, behavior modification, social learning, and self-perception in shaping children's personalities.

VI. RECOMMENDATIONS

The study suggests several recommendations to improve the efficacy of personality development projects for middle-aged children in marginalized communities. These include holistic program design, basic needs fulfillment, cognitive growth alignment, positive reinforcement techniques, social learning initiatives, self-concept enhancement, and community involvement and sustainability. These interventions should address emotional resilience, cognitive growth, social skills, and self-esteem concurrently while fostering positive self-concept and self-esteem. By collaborating with parents, teachers, and local community members, these recommendations can foster empowered and resilient individuals capable of navigating life's challenges confidently.

REFERENCES

- AL-Momani, M.O. and Rababa, E.M. (May 30, 2022) *Child's personality and family upbringing methods, Science and Education*
- Bebane, S. (2021, November 28). *Jean Piaget as a pioneer of modern psychology: Critical Review*. https://www.researchgate.net/publication/356597789_Jean_Piaget_as_a_Pioneer_of_Modern_Psychology_Critical_Review
- Eisenberg N; Guthrie IK; Murphy BC; Shepard SA; Cumberland A; Carlo G; (n.d.). *Consistency and development of prosocial dispositions: A longitudinal study*. Child development. <https://pubmed.ncbi.nlm.nih.gov/10621961/>
- Damon, W. (2006, May 19). *Handbook of Child Psychology, Theoretical Models of Human Development*. Google Books. https://books.google.com/books/about/Handbook_of_Child_Psychology_Theoretical.html?id=GFzWZMvQR8kC
- Freud, S. (1905/1920). *Three Essays on the Theory of Sexuality* (A. A. Brill, Trans.). Global Grey. (Original work published 1905, e-book edition published 2021)
- High-risk studies and developmental antecedents of anxiety disorders(n.d.-a).<https://onlinelibrary.wiley.com/doi/abs/10.1002/ajmg.c.30170>

- Hirshfeld-Becker, D. R., Biederman, J., Henin, A., Faraone, S. V., Dowd, S., De Petrillo, L. A.,... & Rosenbaum, J. F. (2007). "Behavioral Inhibition in Preschool Children at Risk Is a Specific Predictor of Middle Childhood Social Anxiety: A 5-Year Follow-Up." *Journal of Developmental and Behavioral Pediatrics*, 28(3), 225-233. doi:10.1097/DBP.0b013e3180327e22
- Hopper, E. (2020, February 24). *Maslow's hierarchy of needs explained*. ThoughtCo. <https://www.thoughtco.com/maslows-hierarchy-of-needs-4582571>
- İsmail, N. A. H., & Tekke, M. (2015). Rediscovering rogers's self theory and personality - researchgate. https://www.researchgate.net/publication/286456614_Rediscovering_Rogers's_Self_Theory_and_Personality
- Kendra Cherry, Msc. (2022, December 16). *Types of behavioral disorders in children*. Verywell Mind. <https://www.verywellmind.com/behavioral-disorders-in-children-definition-symptoms-traits-causes-treatment-6889450>
- Lompscher, J. (1982). *Personality development and the pedagogical organization of pupils' activities*. Unesdoc.unesco.org. <https://unesdoc.unesco.org/ark:/48223/pf0000047941>
- Malone, J. C. (2017, December 17). *William James and B. F. Skinner: Behaviorism, reinforcement, and interest*. https://www.researchgate.net/publication/232566421_William_James_and_B_F_Skinner_Behaviorism_reinforcement_and_interest
- Maslow, A. H. (1943). A Theory of Human Motivation. *Psychological Review*, 50(4), 370-396.
- Personality development: Stability and change | Annual review of psychology.(n.d.-c).<https://www.annualreviews.org/doi/abs/10.1146/annurev.psych.55.090902.141913>
- Roger McKenzie Monday, N. 14. (2022b, November 14). *Women's Centre in Sri Lanka has protected the rights of women garment workers for over 30 years*. Morning Star. <https://morningstaronline.co.uk/article/w/women-centre-in-sri-lanka-protect-the-rights-of-women-garment-workers-for-over-30-years>

The Socio-cultural Factors Affecting the Vocational Education Stream Student to Become an Entrepreneur

Danushka Sandeepani Galagoda
Department of Education and Training
University of Vocational Technology
Sri Lanka
danusgalagoda@gmail.com

Thanuja Vidanapathirane
Department of Management Studies
University of Vocational Technology
Sri Lanka
taravidanapathirane@yahoo.com

Abstract— Entrepreneurship has captured the attention of both scholars and policymakers during the last decades. The main reason is the growing need for entrepreneurs who accelerate economic development by generating new ideas and converting them into profitable ventures. The study reveals that religion plays a significant role, with 70% of participants making decisions based on religious background when starting a business. Family support is another crucial factor, as 38% of parents express satisfaction with their child pursuing self-employment. However, the current business culture in Sri Lanka is viewed negatively by the majority, with 72% believing it favors a single person and 68% perceiving influence from senior businessmen. Despite society's overall recognition of entrepreneurship (65.3%), there remains a negative setback (42%) in supporting university students. Additionally, 53.1% perceive their living environment as conducive to entrepreneurship. These findings inform the development of a framework for analyzing socio-cultural factors influencing vocational education students' entrepreneurial engagement. Further research in this area can contribute to fostering entrepreneurship and formulating effective policies that support entrepreneurship development

Keywords— Entrepreneurial activity, Entrepreneurship, Entrepreneurial emergence, Socio-cultural environment, Cultural factors

I INTRODUCTION

The strength of the remaining higher education system is such that both the public and private sector high educational institutes are not capable of absorbing even a quarter of the annually qualified students. Sri Lanka annually produces nearly 25,000 graduates and bachelor's degrees from all high educational institutes of the country in different fields of study (CEIC Data, 2022) The problem of unemployment could have been

more severe if at least most qualified students were annually recruited to the high educational institutes. This number is being increased annually due to the increase in the annual student intake to higher education from those who are qualified for the General Certificate of Education Advanced Level (GCE A/L) Examination. However, the economy is still not capable of absorbing these graduates as employees (V Kanagasingam 2021) either through the mechanism of market forces or the direct involvement of the Government. It is observed that university students have a reluctance to take risks related to the enterprise which is a creative task. It can be observed that there is a very low attendance of University Students in Entrepreneurship. A very profound and focused intervention on entrepreneurship needs to be made by all relevant sectors in the country (MDPI, 2020). Its main objective is to identify the socio-cultural factor that affects Vocation Education students to become entrepreneurs. Recognized the reason for those factors to affect Sri Lankan Vocational Students to become entrepreneurs. Suggestions to avoid those socio-cultural factors to become entrepreneurs.

II. TYPES OF SOCIO-CULTURAL FACTORS

Within the realm of entrepreneurial development, socio-cultural factors wield a profound influence, particularly in developing nations such as Sri Lanka. As such, this study encapsulates the impact of five pivotal socio-cultural factors: **religion, family, business culture, value and attitude, and locality**. A comprehensive examination of these factors provides a holistic framework for dissecting the intricate dynamics that shape graduates' decisions

and the creation of new businesses.

A RELIGION

The role of religion in shaping economic behavior is a well- explored dimension, with seminal works by Broom and Selznick (1968) and Weber (1930) highlighting the connection between religious doctrines and entrepreneurial conduct. Religion, a ubiquitous phenomenon, influences societies across the spectrum, consequently exerting a tangible impact on economic development and entrepreneurial pursuits (Olatunji, 2010).

B FAMILY

The significance of family norms as a determinant of entrepreneurial behavior is underscored by Ajzen's theory of deliberate behavior, as cited in Kruger, Reilly, and Carsrud (2000). Empirical research conducted by Singer (1972) and Nanayakkara (1999) emphasizes the integral role of the family in nurturing positive entrepreneurial attributes and transmitting values that foster entrepreneurial initiatives.

BUSINESS CULTURE
Sri Lanka grapples with the dual challenges of high graduate unemployment and a lack of enthusiasm for entrepreneurship (Arunathilake and Jayawardena, 2010). Negative perceptions of business abound, necessitating a paradigm shift in the prevailing business culture. This shift entails transforming the perception of entrepreneurship from a mere avenue of self- employment to a dynamic force driving innovation and value creation. Education is pivotal in this transformation, propelling a renewed emphasis on entrepreneurship and catalyzing a cultural shift (Weeratunga, 2010).

C VALUE AND ATTITUDE

In the entrepreneurial sphere, attitudes assume paramount importance, shaping behaviors and actions (Robinson, Stimpson, Heufner, & Hunt 1991). Values, as enduring beliefs, offer essential insights into the motivational drivers that steer entrepreneurial pursuits. Acknowledging the role of values and attitudes is crucial for comprehending the intricate forces that guide entrepreneurial thought and action (Ajzen, 1982).

D LOCALITY (LOCATION)

The strategic location of businesses stands as a linchpin in entrepreneurship and small business development. Proximity to resources, accessibility, and local conditions exert a profound influence on entrepreneurial outcomes (Llian and Yasuo (2005). Within this context, this study elucidates the role of location as a moderator, amplifying the relationship between individual determinants, external factors, firm characteristics, and firm performance (Blackman (2003), Ogundele (2007).

III LITERATURE REVIEW

A CONCEPT OF SOCIO-CULTURAL ENVIRONMENT

The social-cultural environment, in relation to entrepreneurship, can be described as consisting of all the elements of the social system and culture of a people which positively or negatively affect and influence entrepreneurial emergence, behavior, performance, and entrepreneurship development in general. In other words, the social-cultural environment consists of all elements, conditions, and influences that shape the personality of an individual and probably affect his attitude, disposition, behavior, decisions, and activities. Such elements consist of beliefs, values, attitudes, habits, forms of behavior, and lifestyles of persons as developed from cultural, religious, educational, and social conditioning, (Bennett and Kassarian, 1972; Adeleke et.al, 2003).

B SOCIAL FACTORS AND

ENTREPRENEURIAL ACTIVITY

In the entrepreneurship community literature, three elements of network relations stand out as essential to theoretical and empirical research on the entrepreneurial process (Hoang and Antoncic, 2003; Johannisson, 1988, 1998): the nature of the content that is exchanged between actors (e.g. social capital and intangible resources, such as emotional support) (Bates, 1997; Light, 1984; Zimmer and Aldrich, 1987), the governance mechanisms in community relationships (e.g. trust between entrepreneurs and venturing partners) (Larson, 1992; Lorenzoni and Lipparini, 1999), and the network structure created by the crosscutting relationships between actors (e.g. the ability to use cohesion and structural holes to discover and boost entrepreneurial returns) (Burt, 1992; Hansen, 1995).

Embeddedness and relational networks
Understanding entrepreneurship as a social phenomenon allows us to draw on the well-developed more general kinds of literature on social capital and social networks. Given the central proposition that networks of relationships represent a valuable resource (Nahapiet and Ghoshal, 1998), many of the insights of social capital theory relative to entrepreneurial undertaking can be found in the social network literature (Casson and Della Giusta, 2007). As distinct from rational preference perspectives, the social embeddedness perspective emphasizes that, in embedded contexts, entrepreneurial agency, that is the ability to garner entrepreneurial ideas and the assets to develop them,

is shaped by implicit norms and social mores. The underlying idea is that, although entrepreneurs generally hold some of the resources necessary to create a business (e.g., ideas, knowledge, and competence to run the business), generally they also want complementary resources which they obtain through their contacts (e.g. information, economic capital, labor) to produce and deliver their goods or services (Aldrich and Zimmer, 1986; Cooper et al., 1995; Greve and Salaff, 2003; Hansen, 1995; Ribeiro- Soriano and Urbano, 2009; Teece, 1987). This view of social capital is closely associated with the emphasis positioned by Coleman (1993) on community structures as a mechanism of social control, which, in turn, is additionally linked with the predominant culture in a specific society.

Social capital is defined as the tangible and virtual sources that facilitate actors' attainment of goals and that accrue to actors through the social structure (Portes, 1999). Social networks are the relationships through which one receives possibilities to use financial and human capital - relationships in which ownership is not fully the property of an individual, but is jointly held among the contributors of a network (Burt, 1992).

C CULTURAL FACTORS & ENTREPRENEURIAL ACTIVITY

From anthropology From an anthropology perspective, attention to social and cultural factors related to the creation of a new business has provided interesting contributions to the understanding of entrepreneurship, especially through the study of social constraints (Garlick, 1971; Kennedy, 1988; Wiewel and Hunter, 1985) and collective approaches (e.g. family business, community-centered business, ethnic or organizational entrepreneurship) to business formation and growth (Benedict, 1968; Davis and Ward, 1990; Kleinberg, 1983; Parker, 1988, among others). Much of the research in entrepreneurship that considers cultural variables has followed Hofstede's (1980, 2001) seminal work showing how culture is manifested in a variety of forms, and how cultural values at individual or societal levels are influenced by national culture. In contrast to the Parsonian concept of culture as a relatively monolithic force inside a nation and Hofstadter's dimensions developed from data in the corporate setting, these students view culture as fragmented by institutional orders which may or may also not align with national culture (Busenitz et al., 2000; DiMaggio, 1997). Although ordinary research has shown cultural variables to have an influence on

entrepreneurship, cultural variables in many instances have been theorized and modeled as moderating entrepreneurial outcomes (Hayton et al., 2002). In sum, central procedures for understanding the role of social and cultural factors revolve around the concepts of networks and embeddedness" (Granovetter, 1985, 1992), and the research stream based on Hofstede's (1980, 2001) dimensional cultural framework. Accordingly, when a person creates a business in a specific cultural environment, this business displays that cultural environment, for example, characteristics such as strategic orientation and growth expectations for the business. Using Hofstede's (1980) concept of culture, researchers have in general hypothesized that entrepreneurship is facilitated by cultures that are high in individualism, low in uncertainty avoidance, low in power-distance, and excessive in masculinity (Hayton et al., 2002). The results of such cultural complexity are being explored by an eclectic group of economists and sociologists around the idea of how culture provides justifications for individuals' actions and effects in economies of worth to us all collectively (Berger, 1991; Carsrud and Johnson, 1989). These environmentally relevant patterns of behavior lead to the formation of different cultural values in special societies, some of which influence the decision to create new businesses. This suggests that greater attention must be given to the interactions among cultural dimensions and the conception of culture that approves of greater complexity in relation to other characteristics of the environment. Thus, culture, as distinct from political, social, technological, or financial contexts, has relevance for economic behavior and entrepreneurship (Shane, 1993; Shapero and Sokol, 1982).

According to this view, the main domains of life and how they affect entrepreneurial behavior are conceptualized and measured inside the context of distinct institutional orders - for example, the family, the religions, the market, the professions, the state, and the agency (Thornton, 2004; Thornton and Ocasio, 2008). The first focuses on the impact of national culture on combination measures of entrepreneurship such as national innovative output or new businesses created. One of the difficulties in examining the cultural effects in relation to entrepreneurial activity is the lack of a precise and often understood definition of culture (McGrath et al, 1992).

IV SRI LANKAN UNIVERSITY STUDENTS AND UNEMPLOYMENT

The university education system in public universities must be reoriented to meet the challenges of graduates to produce global graduates. The existing teaching and learning methods should be changed to match the necessities of the industry. The university system needs to be restructured, involved with quality and relevance, and introduce job-oriented programs to match local and international needs.

V METHODOLOGY

A RESEARCH DESIGN

The methodology adopted for this research is predominantly qualitative, employing a combination of literature review and targeted interviews with key informants across various domains. To gain a comprehensive understanding of entrepreneurial dynamics, the Focus Group Discussion (FGD) method was employed, facilitating diverse insights. Additionally, a case study approach was utilized to delve deeply into the subject matter. The data gathered from both government and non-government sources, though occasionally divergent, are consistent and reliable. Qualitative analysis takes precedence, supplemented by relevant quantitative data, contributing to an extensive exploration of variables and relationships within the context of Sri Lanka.

B POPULATION AND SAMPLE.

This study specifically focused on Vocational University Students, specifically those enrolled in NVQ level 6/7 programs. The sample consisted of 50 students hailing from two institutions: University of Vocational Technology (40 students) and University College Ratmalana (10 students). A purposeful sampling technique was applied, ensuring the inclusion of pertinent participants.

C DATA ANALYSIS.

During the data analysis phase, the collected information underwent meticulous organization and structuring. Qualitative data was amassed through techniques such as focus group discussions (FGDs) and targeted interviews with key informants. The details garnered from these qualitative sources were systematically examined and categorized, aligning with relevant topics. The analysis process aimed to uncover overarching themes and provide a comprehensive understanding of the entrepreneurial dynamics in the Sri Lankan university student population.

Table 1. Items of Part 01 in the Questionnaire

Question	Response Options
01. Gender	01. Male 02. Female 03. Prefer not to say
02. Age	01. 20-25 02. 25-30 03. 30-35

Table 2. Items in Part 02 (A - Religion) of the Questionnaire

Question	Response Options
01. What is your religion?	01. Buddhist 02. Christian/Catholic 03. Islam 04. Hindu
02. Are there any sermons on business (entrepreneurship) in your religion?	01. Yes 02. No 03. No Idea
03. If there are religious sermons about business, do you agree with the rules of the religion?	01. Yes 02. No 03. Maybe
04. Do you care about the doctrines of the religion you believe in before you start a business? (Example - Creating a New Business Opportunity for Meat)	01. Yes 02. No 03. Maybe
05. If you have a new business idea, can you expect some help from your religious members (Temple, Church, etc.) to make it work? Ex- Financial Support Providing business advice and Knowledge	01. Yes 02. No 03. Maybe

Table 3. Items in Part 02 (B - Family) of the Questionnaire

Question	Response Options
01. Are there any entrepreneurial members in your family right now?	01. Yes 02. No
02. Do you have a legacy business experience in your family background?	01. Yes 02. No

03. What would be the reaction of family members if you refused a job at an institution and planned to start your own business?	01. Very Satisfied 02. Satisfied 03. Neither Satisfied nor dissatisfied 04. Dissatisfied 05. Very Dissatisfied
04. What do your family members think about your future career?	01. I should do a Government Job 02. I should do a private sector white collar Job 03. I should do My own Business 04. I should go abroad for a job 05. They have no idea
05. If you are planning to start a business, can your family help you with capital for that business?	01. Yes 02. No 03. Maybe

Table 4. Items in Part 02 (C - Business Culture) of the Questionnaire

Question	Response Options
01. Is the current business culture in Sri Lanka suitable for new entrepreneurs?	01. Strongly disagree 02. Disagree 03. Neutral 04. Agree 05. Strongly agree
02. Do you believe that the Sri Lankan business network has been invaded by some people?	01. Yes 02. No 03. Maybe
03. Do seniors in the business culture in Sri Lanka influence newcomers?	01. Yes 02. No 03. Maybe
04. Are the successful businesses that have emerged in Sri Lanka of good quality?	01. Yes 02. No 03. Maybe
05. Does the current business culture suit the university student?	01. Yes 02. No 03. Maybe

Table 5. Items in Part 02 (D - Value and Attitude) of the Questionnaire

Question	Response Options
01. What is your opinion about society's attitudes towards a businessman?	01. Very Good 02. Good 03. Fair 04. Poor 05. Very Poor
02. Do entrepreneurs get	01. Strongly disagree

more respect from society compared to other regular employees?	02. Disagree 03. Neutral 04. Agree 05. Strongly agree
03. Are you satisfied with the value that an entrepreneur has in society?	01. Yes 02. No 03. Maybe
04. Do University students agree on the attitude of the students towards entrepreneurship?	01. Strongly disagree 02. Disagree 03. Neutral 04. Agree 05. Strongly agree

Table 6: Items in Part 02 - Locality/Location of the Questionnaire.

Question	Response Options
01. Are you live in?	01. In an urban environment 02. In a semi-urban environment 03. Village 04. Slum estate
02. Does the area in which you live influence your entrepreneurial attitudes?	01. Strongly disagree 02. Disagree 03. Neutral 04. Agree 05. Strongly agree
03. Are Your Acquaintances Focusing on Entrepreneurship?	01. Yes 02. No
04. Do you see the environment in which you live as conducive to business?	01. Yes 02. No
05. If you are just starting your own business, is the environment you live in conducive to implementing your ideas?	01. Yes 02. No 03. Maybe

VI RESULTS AND DISCUSSION

A FINDINGS

This research tried to investigate whether the students in a particular culture. I used a questionnaire that consisted of 20 questions. The questionnaire was conducted with 50 students who study at a Vocational university. The questionnaire was distributed to find out how socio-cultural factors affect their business mind. Socio-cultural factors and their types consist of five parts. Further, it was to find out the socio-cultural effect on students' minds.

B DEMOGRAPHIC DETAILS OF PARTICIPANTS

Demographic information provides data regarding research participants and is necessary for the determination of whether the individuals in a particular study are a representative sample of the target population for generalization purposes in research. Fifty students filled out questionnaires as the Part 01 category of participants in the current study. Most participants were males (68%). Regarding the participants' age, I found that 80% of participants are in the 20-25 age category. Regarding the medium of instruction that they preferred, 84% of participants are in the University of Vocational Technology and 84% of students have an idea about becoming an entrepreneur.

C RELIGION

Within the exploration of the intricate relationship between religion and entrepreneurship, this section's findings offer an intricate connection between religion and entrepreneurship. Among respondents with diverse religious backgrounds, around 81.6% acknowledged differing religious views on entrepreneurship. Roughly 70% expressed alignment between their entrepreneurial efforts and religious beliefs. A diverse range of approaches emerged, with 28% willing to separate religious opinions from business pursuits.

The influence of religious institutions on entrepreneurial aspirations was also highlighted.

D FAMILY

The impact of family dynamics on fostering an entrepreneurial mindset is discussed here. Among participants, 90% hailed from non-business families. Notably, 28.6% shared a heritage of family business involvement. Family attitudes significantly influence career paths, with various sentiments expressed regarding deviating from conventional employment. The study unveils preferences for secure employment among Sri Lankan families and showcases their intricate role in shaping entrepreneurial outlooks.

E BUSINESS CULTURE

This section delves into the influence of business culture on students' entrepreneurial orientation. Findings indicate varying perspectives on business culture compatibility for new entrepreneurs. Responses to questions about the current business climate showed 62% perceiving a positive attitude, while seasoned entrepreneurs' influence and quality perceptions were explored. The intricate dynamics of Sri Lanka's contemporary entrepreneurial landscape are illuminated.

F VALUE AND ATTITUDE

Insights into the impact of values and attitudes on university students' entrepreneurial pursuits are

discussed. Responses concerning society's views on businessmen showed diverse opinions, with 68% agreeing that entrepreneurs command more respect than regular employees. Contentment with societal esteem, university students' attitudes, and perspectives are explored, revealing the complex interplay of values and attitudes in shaping the entrepreneurial landscape.

G LOCALITY (LOCATION)

This subsection examines the impact of locality on university students' entrepreneurial viewpoints. Living environments influence entrepreneurial aspirations, with 10% urban, 80% semi-urban, and 10% rural dwellers. The interplay between living environments and attitudes is scrutinized, highlighting the role of local peers in nurturing entrepreneurial spirit. Overall, the living environment is perceived as conducive to business endeavors, showcasing the intricate connection between geographical context and entrepreneurial perspectives.

VII CONCLUSION

In conclusion, this comprehensive study delves into the interaction of varied socio-cultural factors that form university students' entrepreneurial aspirations within the context of the state. The evolving landscape of upper education and therefore the substantial gap between the number of qualified graduates and obtainable opportunities intensify the requirement for a targeted intervention in entrepreneurship. This analysis underscores the profound influence of faith, family dynamics, business culture, values and attitudes, and neighborhood on students' entrepreneurial attitudes and choices.

Religious beliefs, tangled with numerous cultural backgrounds, showcase their impact on students' entrepreneurial orientations. The study illuminates however non-secular values influence students' alignment of business

endeavors with their religion, light the quality of decision-making during this context. In addition, family dynamics emerge as a major determinant in shaping students' entrepreneurial aspirations. The influence of family attitudes, career preferences, and therefore the inheritance of business legacies contribute to the range of ways students take.

The exploration of business culture's influence reveals the nuanced relationship between the prevailing business environment and students' propensity towards entrepreneurship. Notable findings concerning the compatibility of the business

culture with new entrepreneurs, the impact of seasoned entrepreneurs, and therefore the perceived quality of offerings contribute to our understanding of how students navigate the up-to-date entrepreneurial landscape.

Values and attitudes function as a cornerstone, shaping students' perceptions of social group attitudes, respect, recognition, and fellow students' views on entrepreneurship. These insights underline the involved interaction of social values and beliefs in influencing students' entrepreneurial journeys.

The role of the neighborhood, determined by urban, semi-urban, rural, or slum environments, additionally deepens our understanding of how geographical contexts impact students' entrepreneurial orientations. The study unveils the variable degrees of influence native environments wear on students' entrepreneurial mindsets, and light the importance of those contexts in fostering associate degree entrepreneurial schemes.

Collectively, these findings emphasize the multifarious nature of entrepreneurial development, influenced by a myriad of socio-cultural factors. To bridge the gap between the growing variety of graduates and obtainable opportunities, stakeholders ought to collaboratively produce an associate degree atmosphere that encourages and supports entrepreneurship. By recognizing the involved interaction of faith, family, business culture, values, attitudes, and neighborhood, policymakers, educators, and entrepreneurs alike will work towards fostering a spirited entrepreneurial scheme in the state. This analysis sets the stage for future studies to turn deeper into these factors and their multifarious impact on students' entrepreneurial choices, paving the means for interventions that drive entrepreneurial growth and contribute to the general economic and social development of the state.

VIII RECOMONDATIONS

To reduce the negative impact of socio-cultural factors on entrepreneurial aspirations, it is recommended to investigate the business concepts within different religious philosophies to stimulate the entrepreneurial mindset of students. Efforts should also focus on encouraging parental support for entrepreneurship and creating an entrepreneurial-friendly environment within families. Additionally, addressing the negative impact of the current business culture by fostering a supportive environment for new

entrepreneurs is crucial. This can be achieved through initiatives that promote entrepreneurship as a respected career choice, highlight success stories of local entrepreneurs, and facilitate collaboration between established entrepreneurs and aspiring students. Universities should implement comprehensive entrepreneurship programs, including courses, special programs, awareness campaigns, and public spaces that foster collaboration and knowledge exchange. By implementing these recommendations, it is possible to mitigate the negative effects of socio-cultural factors and create an empowering environment for student entrepreneurs.

REFERENCES

- Akhter, R., & Sumi, F. R. (2014). Socio-cultural factors influencing entrepreneurial activities: A study on Bangladesh. *IOSR Journal of Business and Management*, 16(9), 1-10.
- Abdullahi, A. I., Zainol, F. A., Daud, W. N. W., & Yazid, S. (2017). Entrepreneurial intention revisited: Measuring the impact of socio-cultural business environment using structural equation modeling. *World Applied Sciences Journal*, 35(8), 1445-1456.
- Abdullahi, A. I., & Zainol, F. A. (2016). The impact of socio-cultural business environment on entrepreneurial intention: A conceptual approach. *International Journal of Academic Research in Business and Social Sciences*, 6(2), 80-94.
- Begley, T. M., & Tan, W. L. (2001). The socio-cultural environment for entrepreneurship: A comparison between East Asian and Anglo-Saxon countries. *Journal of international business studies*, 32, 537-553.
- Buli, B. M., & Yesuf, W. M. (2015). Determinants of entrepreneurial intentions: Technical-vocational education and training students in Ethiopia. *Education+ Training*, 57(8/9), 891-907.
- Guerrero, M., Cunningham, J. A., & Urbano, D. (2015). Economic impact of entrepreneurial universities' activities: An exploratory study of the United Kingdom. *Research Policy*, 44(3), 748-764.
- Gurel, E., Altinay, L., & Daniele, R. (2010). Tourism students' entrepreneurial intentions. *Annals of Tourism Research*, 37(3), 646-669.
- Gelard, P., & Saleh, K. E. (2011). Impact of some contextual factors on entrepreneurial intention of university students. *African Journal of Business Management*, 5(26), 10707.
- Hussain, A., & Norashidah, D. (2015). Impact of entrepreneurial education on entrepreneurial intentions of Pakistani Students. *Journal of Entrepreneurship and Business Innovation*, 2(1), 43-53.
- Kabir, S. M., Haque, A., & Sarwar, A. (2017). Factors affecting the intention to become an entrepreneur: a study from Bangladeshi business graduates perspective. *International Journal of Engineering and Information Systems*, 1(6), 10-19.
- Keat, O. Y., Selvarajah, C., & Meyer, D. (2011). Inclination towards entrepreneurship among university students: An empirical study of Malaysian university students. *International journal of business and social science*, 2(4).

- Linan, F. (2008). Skill and value perceptions: how do they affect entrepreneurial intentions? *International entrepreneurship and management journal*, 4(3), 257- 272.
- Lüthje, C., & Franke, N. (2003). The 'making' of an entrepreneur: testing a model of entrepreneurial intent among engineering students at MIT. *R&d Management*, 33(2), 135-147.
- Mehtap, S., Pellegrini, M. M., Caputo, A., & Welsh, D. H. (2017). Entrepreneurial intentions of young women in the Arab world: Socio-cultural and educational barriers. *International Journal of Entrepreneurial Behavior & Research*.
- Mehtap, S., Pellegrini, M. M., Caputo, A., & Welsh, D.H. (2017). Entrepreneurial intentions of young women in the Arab world: Socio-cultural and educational barriers. *International Journal of Entrepreneurial Behavior & Research*, 23(6), 880- 902.
- Mykolenko, O., Ippolitova, I., Doroshenko, H., & Strapchuk, S. (2022). The impact of entrepreneurship education and cultural context on entrepreneurial intentions of Ukrainian students: the mediating role of attitudes and perceived control. *Higher Education, Skills and Work-Based Learning*, 12(3), 519-536.
- Noguera, M., Alvarez, C., & Urbano, D. (2013). Socio- cultural factors and female entrepreneurship. *International Entrepreneurship and Management Journal*, 9, 183-197.
- Rosique-Blasco, M., Madrid-Guijarro, A., & García-Pérez- de-Lema, D. (2016). Entrepreneurial skills and socio- cultural factors: An empirical analysis in secondary education students. *Education+ Training*.
- Raza, S. A., Qazi, W., & Shah, N. (2018). Factors affecting the motivation and intention to become an entrepreneur among business university students. *International Journal of Knowledge and Learning*, 12(3), 221-241.
- Singh, B., Verma, P., & Rao, M. K. (2017). Influence of individual and socio-cultural factors on entrepreneurial intention. In *Entrepreneurship education* (pp. 149-169). Springer, Singapore.
- Schwarz, E. J., Wdowiak, M. A., Almer-Jarz, D. A., & Breitenecker, R. J. (2009). The effects of attitudes and perceived environment conditions on students' entrepreneurial intent: An Austrian perspective. *Education+ Training*.
- Segal, G., Borgia, D., & Schoenfeld, J. (2005). The motivation to become an entrepreneur. *International journal of Entrepreneurial Behavior & research*.
- Tong, X. F., Tong, D. Y. K., & Loy, L. C. (2011). Factors influencing entrepreneurial intention among university students. *International journal of social sciences and humanity studies*, 3(1), 487-496.
- Urbano, D., Toledano, N., & Ribeiro-Soriano, D. (2011). Socio-cultural factors and transnational entrepreneurship: A multiple case study in Spain. *International Small Business Journal*, 29(2), 119-134.

Analyzing the Adequacy of Soft Skills for Employability of TVET Diploma and Certificate Holders

I. S. Samarasekara
Regional Center
Ocean University of Sri Lanka
Galle, Sri Lanka
imalkas@ocu.ac.lk

K.A.S.I. Gajaweera
Regional Center
Ocean University of Sri Lanka
Galle, Sri Lanka
shirmani@ocu.ac.lk

Jayalal Wettasinghe
Department of Mechanical and Manufacturing Technology,
University of Vocational Technology
Ratmalana, Sri Lanka
jayalal@uovt.ac.lk

Abstract— This study was conducted to find out important soft skills for diploma and certificate holders for successful employability and to find out the gap between possession of each skill and employer expectations. Teamwork, time management, flexibility, self-management and interpersonal skills are the top five soft skills expected by the industry for TVET certificate holders while communication skills, time management, teamwork, planning and organizing and leadership skills are the top five soft skills for the TVET diploma holders. Results prove that there is a significant soft skills gap between industry expectations and possession of skills by the TVET diploma and certificate holders except for critical thinking skills for certificate holders ($p < 0.05$). Employers expect teamwork and flexibility /adaptability skills in nearly equal proportion from the TVET diploma and certificate holders for employment while other skills tested are expected at a higher level from the TVET diploma holders than certificate holders. This study may help TVET students to identify the skills they have to improve for successful employability as well as helpful to the TVET teachers for teaching. Finally, this information can be utilized for developing Curricular and NCS and also should be addressed in pedagogical training.

Keywords— employability; soft skills; TVET

I INTRODUCTION

Today, most organizations seeking sustainable advantages for their businesses are moving towards flatter hierarchies. Such organizations expect employees to have more skills not only technical skills but also good social skills, life skills and leadership skills in order to achieve high performance. According to the sources of the data of the Ministry of Skills Development and Vocational Training, which is the largest TVET courses provider in the country, the employability rate of TVET graduates is nearly 50% and therefore half of the TVET graduates do not enter the labour market as expected. Therefore, minimizing the skills gap between the graduate and the industry is a wide concern in order to achieve a high employability rate. Although technical skills are prioritized when developing National competency standards and curricula for the TVET sector there is minimal emphasis on soft skills like leadership skills and social skills. The importance of these soft skills may be varied with the National Vocational Qualification levels. Therefore, it is a current

requirement to understand the gap of non-technical skills on employability in order to develop existing National competency standards and curricula and finally ensure the employability of TVET graduates.

II LITERATURE REVIEW

A number of studies proved that assigning soft skills has a major role in employability. Soft skills are important for employment in several ways; in the job-search process, candidates with soft skills are more likely to enter the labour market and be hired, important for retaining a position, and finally, soft skills lead to success on the job [6].

Soft skills competencies are transferable from job to job, from company to company, and from one economic sector to another [3]. It is difficult to find a common definition of soft skills as it varies across countries and surveys prove difficult without common understandings or definitions of skills [6]; [2]. Soft skills are defined as the “desirable qualities for certain forms of employment that do not depend on acquired knowledge” [1]. According to [6], “Soft skills refer to a broad set of skills, competencies, behaviors, attitudes, and personal qualities that enable people to effectively navigate their environment, work well with others, perform well, and achieve their goals”. A meta-analysis, done by [6], analyzed a database of nearly 400 studies relevant to soft skills and identified five dimensions of soft skills as communication, social skills, Higher-order thinking skills (problem-solving, critical thinking, and decision-making), Self-control, and positive self-concept. [8] found in their meta-analysis that Communication skills, Teamwork, Problem-solving, Creativity, Interpersonal Skills, Leadership skills, Self-management, Flexibility/adaptability, Critical thinking, Time management, Planning and organizing, Analytical skills and Decision-making. Curricular of NVQ courses in Sri Lanka contain employability modules such as workplace communication management, problem-solving and decision making, leadership and teamwork. “Employability is a set of achievements – skills, understandings and personal attributes – that makes graduates more likely to gain employment and be successful in their chosen occupations, which benefits themselves, the workforce, the community and the economy” [10].

III METHODOLOGY

Fourteen soft skills were identified by literature review and listed in a self-administrative questionnaire to collect data. Findings of [8] and [6] in their meta-analysis and soft skills which focus on the employability modules of NVQ courses were used for this study. The sampling frame was managers and officers in the registered companies listed in the chamber of commerce in Galle, Matara and Hambantota districts and companies in the Koggala BOI Zone. Ninety-four medium and large-scale organizations were used for this study.

Participants were requested to indicate the level of importance of these skills for certificate holders and diploma holders separately using a five-point Likert-type scale ranging from Not at all important to extremely important. They were also asked to rate the usual level of possession of each skill by the graduates against a five-point Likert-type scale ranging from Dissatisfied to Extremely Satisfied. A similar questionnaire design was employed by [11] for the simultaneous collection of importance and possession of skills. The conceptual framework is depicted in Fig. 1. A total of 94 questionnaires were distributed. Data collection was done both online via Google Forms and by meeting the participants. The response rate was 60%. Fifty-six respondents sent back the answers fifty-two respondents were selected for analysis and four respondents were rejected due to insufficient information. Descriptive statistics and inferential statistics were performed to analyze the results.

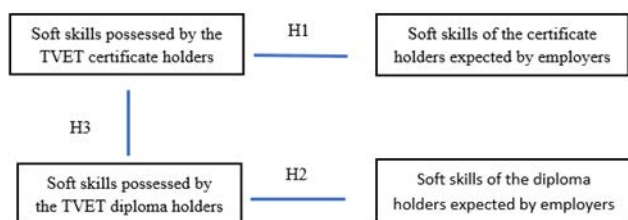


Fig.1 Conceptual framework

IV RESULTS AND DISCUSSION

Quantitative data analysis was done through paired sample t-test and independent sample t-test using SPSS version 20.

Importance and possession of soft skills in TVET certificate holders

The most important skills identified by the employers were teamwork followed by time management. The mean score reflects that communication skill is very important for TVET certificate holders. Other thirteen skills were identified as moderately important skills by the employers. According to mean values, employers were moderately satisfied regarding the level of critical thinking skills of TVET certificate holders. Employers were slightly satisfied regarding the possession of the other thirteen skills of certificate holders. Possession of all fourteen skills by the TVET certificate holders is lower than the employer's expectation (Table 1).

NVQ Level 3 qualified persons are to be worked under general supervision with significant responsibility for the quantity and quality of output while NVQ Level 4 qualified persons are to be worked under broad guidance and evaluation with complete responsibility and also with possible responsibility for the quantity and quality of the output of others and therefore Level 4 qualification provides for full craftsmanship/

workmanship [9]. In this context, craftsman-level employees should work with teams and time management, and flexibility/adaptability skills may be required to work successfully within the teams. The importance of time management, and critical thinking, was within the first five soft skills as per the results of employability research done by [5]. A pairwise comparison of the importance and possession of each skill for TVET certificate holders is shown in Table 1.

The highest mean difference between importance and possession of soft skills was self-management followed by time management while the lowest mean difference was observed in certificate holders.

The significant probability values of 13 skills namely communication, teamwork, problem-solving, creativity, interpersonal, leadership, self-management, flexibility/adaptability, time management, planning and organizing, analytical, decision-making and initiative are less than 0.05. Therefore, there is a significant gap between the possession of these skills for TVET certificate holders and the expectations of the employers. The significant value for critical thinking skills is higher than 0.05. Therefore, there is no significant difference between the possession of critical thinking skills in TVET certificate holders with the expectations of employers.

Important possession of soft skills in TVET diploma holders

According to the employer perspective, the most important skills identified by the employers were communication skills followed by time management. However, all fourteen skills were identified as very important skills. Employers are moderately satisfied with the possession of all skills except analytical and leadership skills in TVET diploma holders. They were slightly satisfied with the possession of analytical and leadership skills in TVET diploma holders.

NVQ Level 5 qualified persons are to be worked in self-directed and sometimes directive activity while Level 6 qualified persons are to be worked in managing processes with complete accountability for determining and achieving personal and/or group outcomes and they are involved in supervision and process management [9]. Communication skills and teamwork are necessary for acquiring and maintaining a job. Significant differences were observed between the importance perceived and competence attained in teamwork and leadership in hospitality industry students in Malaysia [4]. According to [12], employers in the industry said that technical graduates in Malaysia have adequate technical skills but employers are still not satisfied with the communication skills, interpersonal, critical thinking, problem-solving and entrepreneurial skills possessed by those graduates. Communication, time management, teamwork, planning and organizing skills and leadership skills are important for supervision and process management. Problem-solving and critical thinking are high-order thinking skills [6]. High-order thinking skills, as well as problem-solving and leadership skills, are also mostly required by higher management positions. The importance and possession of each skill for TVET diploma holders are in Table 1.

Possession of all fourteen skills by the TVET diploma holders was lower than the employer's expectation (Table 1). The significant probability values of all skills tested are less than 0.05 except for self-management skills. Therefore, there is a

significant gap between the possession of these skills for TVET diploma holders and the expectations of employers.

Comparison of the importance of soft skills between TVET diploma and certificate holders expected by employers.

Level comparison of the importance of soft skills was tested using the independent sample t-test and the mean scores and the significant values are listed in table 2. The mean score of the importance of each skill was higher in diploma holders than in certificate holders (Table 1). However, there was no significant difference between diploma holders and certificate holders in the importance of teamwork and the importance of flexibility/ adaptability skills as significant values were greater than 0.05. Further, significant values for the other twelve skills were lower than 0.05. Therefore, there were significant differences in the importance of these skills for employability between diploma and certificate holders.

V CONCLUSION AND RECOMMENDATION.

This study reveals that communication skills, problem-solving skills, creativity, interpersonal skills, leadership, self-management, critical thinking, time management, planning and organizing skills, analytical skills, decision-making skills and initiative are required at different levels by the employees. It is clearly understood that the job responsibilities of diploma and certificate holders are different as per the level descriptors of NVQ levels described

in [8]. Further, the results of this research clearly show that there is a skill gap between skills required by the industry and the possession of soft skills in TVET diploma and certificate holders. According to [7], technical graduates pay less emphasis on general subjects such as communication skills, information and communication technology and the English language. Therefore, it can be concluded that soft skills components in curricula do not fulfil industry requirements or teaching of soft skills or practical exposure to improve the soft skills of students are not adequate.

Soft Skills are transferable skills and improving soft skills is life lifelong process. Soft skills cannot properly be improved through regular classroom lessons. Hence, it is recommended to guide and monitor the improvement of the soft skills of students throughout the study period including extracurricular activities. Students should be given the opportunity to improve their soft skills during the on-the-job training period too. However necessary National Competency Standards and curricular revisions should be done as per the requirement. Finally, TVET teachers should be aware of the importance of soft skills for student's employability and this area should be properly included in pedagogical training.

TABLE 1. IMPORTANCE AND POSSESSION OF SOFT SKILLS

	Skill	Mean values					
		Certificate Holders			Diploma Holders		
		Importance	Possession	Sig. (2-tailed)	Importance	Possession	Sig. (2-tailed)
1	Communication skills	3.6875	2.8298	.000	4.3750	3.0833	.000
2	Time management skills	3.8750	2.8511	.000	4.2917	3.2083	.000
3	Teamwork	4.0417	2.8723	.000	4.2917	3.1667	.000
4	Planning and organizing	3.4583	2.6170	.000	4.2083	3.2083	.000
5	Leadership skills	3.5208	2.5957	.000	4.2083	2.8750	.000
6	Problem-solving	3.5000	2.7021	.000	4.2083	3.2083	.000
7	Interpersonal skills	3.7083	2.9787	.000	4.1667	3.2500	.000
8	Flexibility/ adaptability	3.7917	2.9362	.000	4.1667	3.0833	.000
9	Self-management skills	3.7083	2.8298	.000	4.1667	3.1250	.000
10	Critical thinking	3.3542	3.0213	.494	4.1250	3.0833	.000
11	Creativity	3.6250	2.7660	.000	4.0833	3.2083	.001
12	Decision making	3.5417	2.6383	.000	4.0417	3.1250	.000
13	Initiative	3.5417	2.7660	.000	4.0417	3.2917	.000
14	Analytical skills	3.2083	2.4894	.000	4.0000	2.8750	.000

TABLE 2. LEVEL COMPARISON OF THE IMPORTANT OF SOFT SKILLS

Skill	Sig. (2-tailed) between certificate and diploma holders
Importance of communication skills	.000
Importance of Teamwork	.149
Importance of Problem-solving	.002
Importance of Creativity	.029
Importance of interpersonal skills	.029
Importance of Leadership skills	.001
Importance of self-management	.032
Importance of flexibility/ adaptability	.060
Importance of critical thinking	.001
Importance of time management	.035
Importance of planning and organizing	.003
Importance of analytical skills	.001
Importance of decision-making	.027
Importance of Initiative	.019

ACKNOWLEDGEMENT

This work was financially supported by the Tertiary and Vocational Education Commission, Sri Lanka under a TVET research grant. Therefore, the authors are grateful to TVEC. We wish to thank officers in the Chambers of Commerce in Galle, Matara, and Hambantota districts and the Director of Koggala BOI Zone for supporting us with data collection. Further, our sincere gratitude goes to the third author, Dr Jayalal Wettasinghe, University of Vocational Technology for guiding and supervising us to accomplish this task.

REFERENCES

- Collins English Dictionary. (2021). HarperCollins Publishers. <https://www.collinsdictionary.com/dictionary/english/soft-skills>. Clerk Maxwell, A Treatise on Electricity and Magnetism, 3rd ed., vol. 2. Oxford: Clarendon, 1892, pp.68–73.
- Cornali, F. (2018). Training and developing soft skills in higher education. In 4th International Conference on Higher Education Advances (HEAD'18). 961-967. Editorial Universitat Politècnica de València.
- European Commission Directorate-General 5, Employment and Social Affairs. (2011). Transferability of Skills across Economic Sectors: Role and Importance for Employment at European Level. EUR-OP. <https://publications.europa.eu/en/publication-detail/-/publication/21d614b0-5da2-41e9-b71d-1cb470fa9789> R. Nicole, "Title of paper with only first word capitalized," J. Name Stand. Abbrev., in press.
- Kenayathulla, H. B., Ahmad, N. A., & Idris, A. R. (2019). Gaps between competence and importance of employability skills: evidence from Malaysia. Higher Education Evaluation and Development.
- Lim, Y.-M., Lee, T. H., Yap, C. S., & Ling, C. C. (2016). Employability skills, personal qualities, and early employment problems of entry-level auditors: Perspectives from employers.
- Lippman, L. H., Ryberg, R., Carney, R., & Moore, K. A. (2015). Workforce Connections: Key "soft skills" that foster youth workforce success: toward a consensus across fields. <https://www.childtrends.org/wp-content/uploads/2015/06/2015-24WFCSOFTSKILLS1.pdf>.
- Munishi, E. J. (2016). Factors contributing to lack of employable skills among technical and vocational education (TVET) graduates in Tanzania. Business Education Journal, 1(2).
- Osmani, M., Weerakkody, V., Hindi, N. M., Al-Esmail, R., Eldabi, T., Kapoor, K., & Irani, Z. (2015). Identifying the trends and impact of graduate attributes on employability: a literature review. Tertiary Education and Management, 21(4), 367-379.
- Tertiary and Vocational Education Commission. (2009). National Qualification Framework of Sri Lanka: Operational Manual. http://www.tvec.gov.lk/wp-content/uploads/2019/06/NVQ_Operation-Manual-2009.pdf
- Yorke, M. (2006). Employability in higher education: what it is-what it is not (1). York: Higher Education Academy.
- Ramadi, E., Ramadi, S., & Nasr, K. (2016). Engineering graduates' skill sets in the MENA region: a gap analysis of industry expectations and satisfaction. European Journal of Engineering Education, 41(1), 34-52.
- Ramlee, M. (1999). The role of vocational and technical education in the industrialization of Malaysia. In Paper for presentation at the International Vocational Education and Training Association Annual Conference. Ana Hotel, Sydney, Australia

Factors Affecting on the Small Businesses during the COVID-19 Pandemic Period with Special Reference to Mahipalagoda Grama Niladari Division

M.P.I.N Madushanka
Department of Education and Training
University of Vocational Technology
Ratmalana, Sri Lanka
iwanthanirmal@gmail.com

P.S.Y Gamage
Department of Education and Training
University of Vocational Technology
Ratmalana, Sri Lanka
padmashagl@yahoo.com

Abstract— This study is conducted to find out the Factors affecting on Small Businesses in Mahipalagoda Grama Niladari Division during the COVID-19 Period. The research questions are, how small businesses worked during the COVID-19 period in the Mahipalagoda Grama Niladari division? and what are the factors affecting during the COVID-19 period on small businesses? The objectives of the studies are, to review of the small businesses during the COVID-19 period in the Mahipalagoda Grama Niladari Division and to find out factors affecting during the COVID-19 period on small businesses. In this research, critical issues were raw - material shortage due to transportation issues, inability to use the employees optimally due to health guidelines, demand decline due to loss of income of people, delivery issues, order cancellation, etc.

Keywords— Covid-19 Period, Factors, Small Business

INTRODUCTION

The sudden outbreak of a deadly disease called COVID-19 shocked the entire world. Government of Sri Lanka decided to shut down all areas in the country on 13th March 2020 with the risk of COVID-19 pandemic. This situation challenged the business system and forced business owners. The real impact of the pandemic was felt by Sri Lanka around mid-March 2020. Thereafter with more and more infected cases being detected specially through persons arriving from abroad and the government introduced the 14-day quarantine program for all those arriving from foreign countries and all those who meet infected persons. With the increasing number of infected cases more and more quarantine centers were established, and self-quarantine system was introduced. Subsequently, curfew and lockdown of some areas was introduced as a measure to control the spread of the virus. With this situation most of the economic activities were severely affected (M.R. Roshana, Mubarak Kaldeen and A.R.F Rifna Banu 2020). Small businesses play a major role in economic activities (James Robinson, Navaneethakrishnan Kengatharan 2020). COVID-19 virus was a very new

experience for a country like Sri Lanka. The government put in place various laws to control the virus. Many businesses were affected by this action of the government. In the face of this situation many businesses reduced their production. During this virus period, small businesses in Sri Lanka were severely affected. Sales of many small businesses declined. Profits of small businesses fell as sales declined. The financial condition of many small businesses had collapsed. Small business owners reduced their production activities. Some businesses have been closed for a long time. There were also job losses for regular employees in small businesses. (M.R. Roshana, Mubarak Kaldeen and A.R.F Rifna Banu 2020) According to this situation, in this research would have to find out how the factors affect small businesses. This research studied the impact of various factors on small businesses on small businesses were studied.

OBJECTIVE

To investigate on the factors influencing during the covid-19 period on the small business owners in mahipalagoda grama niladari division

Research questions

The following questions were studied in this research:

- How small businesses worked during the COVID-19 period in the Mahipalagoda Grama Niladari division?
- What are the factors influencing during the COVID-19 period on small business owners?

Limitations of the research: The sample size limited only to the Small Business Owners in Mahipalagoda Grama Niladari Division.

The sample drawn includes both males and females. This was done by targeting all small businesses in the Grama Niladhari Division. Structured questionnaire was developed and presented to small business owners, who

obtained data from them and analyzed the data. Data was gathered on sub-factors of Business income, Business expenses, Production, Quantity of Production, Prices of raw material, Attendance of employees.

Study Location:

Administrative District of Gampaha bears the area in extent of 1387 square kilometers (139,140 hectares) and twice larger than the area of Colombo District. Gampaha District is covered 38% of total area of lands in western Province and 2.1% of area of lands in Sri Lanka. Gampaha District is one of the 25 districts of Sri Lanka, the second level administrative division of the country. It is the most populous district of Sri Lanka. There are 1386.7Sq Km land area, 1177 Grama Niladari divisions and 2.391 million of population in Gampaha District. There are major towns in Gampaha district such as Weweldeniya, Pasyala, Weliweriya, Kadawatha, and Yakkala etc. 230 Mahipalagoda Grama Niladari Division is situated in Yakkala Town. There are 5.2 Sq. Km land area and 1896 of population in Mahipalagoda Division. The incredibly famous Attanagllu Oya flows near this area.

LITERATURE REVIEW

The COVID-19 pandemic The COVID-19 outbreak (previously 2019-nCoV) was caused by the SARS-CoV-2 virus. This outbreak was triggered in December 2019 in Wuhan city in Hubei province of China. COVID-19 continues to spread across the world. (Warwick Mc Kibbin and Roshen Fernando 29 February 2020). The COVID-19 pandemic and accompanying economic crisis have opened an immediate opportunity to protect a microSME and their employees from the worst effects of the COVID-19 pandemic. The COVID-19 pandemic is affecting hundreds of thousands of people globally including business and a micro-SMEs operator. In perspective of business sustainability (Raja Suzana Raja Kasim¹, Fakhar Shahzad² and Wan Suzanna Aafanii Adeeba Wan Ibrahim³,2020) According to Sri Lankan GDP, the businesses can be categorized as three aspects. That is Agriculture sector, Industry sector and Service sector. (Central Bank Report 2018)

Small Business The Small Medium Enterprise (SME) sector has been identified as an important strategic sector in the overall policy objectives of the Government of Sri Lanka (GOSL) and it is seen as a driver of change for inclusive economic growth, regional development, employment generation and poverty reduction. SME sector is envisaged to contribute to transform lagging regions into emerging regions of prosperity. (National Policy Framework for SME Development). A small business is a business that owns and operates independently and has no power in the field (Institute of Small Business Administration of USA) Businesses with less than 25 employees are called small businesses (Department of Census and Statistics Sri Lanka 2013/2014). The term SME is used to denote micro, small, and medium enterprises. Different countries use different definitions for SMEs based on their level of development. The commonly used yardsticks are total number of employees, annual turnover,

and total investment. In the Sri Lankan context, the SME policy framework defines SMEs based on the number of employees and annual turnover. The category of Small and Medium sized Enterprises (SMEs) is made up of an enterprise which employ less than 300 employees, and which have an annual turnover not exceeding Rs.750 Mn. In this context, micro enterprises are also read with SMEs for any policy related measures. (Ministry of Industry and Commerce 2016)

Financial Factors Alexander W. Bartik (2020) could be able to certification; Small businesses employ almost fifty percent of American workers. Yet, our results underscore the financial fragility of many small businesses, and how deeply affected they are by the current crisis. In our sample, which is skewed toward retail sales, we found that 43 percent of businesses were temporarily closed, and that employment has fallen by 40 percent. This represents a shock to America's small firms that has little parallel since the 1930s. Our results suggest that many of these firms have little cash on hand, which means that they will dramatically cut expenses, take on additional debt.

Production Factors According to D.P. Gunawardana (2020), the market for handicraft products in the local market is limited and was catering to the tourism sector. This market was affected badly with the Easter Sunday attack and was recovering slowly when the COVID 19 threat came. They do not have any problem on raw materials or continuing production but marketing the products will be a big issue. It is mainly the rural folk who are engaged in this trade using mostly skills passed down from generations. (The Impact of COVID19 on the MSME Sector in Sri Lanka May 2020). Warwick McKibbin and Roshen Fernando (2020) have shown Trade has been significantly affected by the outbreak. Thus, benchmark the percentage increase in the cost of production in Chinese production sectors during the period of COVID19. AlexAnder S. KritiKoS (2020) said that Entrepreneurial activities may influence a country's economic performance by bringing new products, methods, and production processes to the market and by boosting productivity and competition more broadly.

Employee Participation Raja Suzana Raja Kasim Prior (2020) have shown to the COVID-19 outbreak, when questioned on the overall productivity of the workforce as employees work virtually, more than half of the respondents claimed somewhat concerned, 30% expressed very concerned while 10% claimed that they were not concerned. Warwick McKibbin and Roshen Fernando have shown the current recommended incubation ... 5 period for COVID-19 is 14 days, an average employee in a country would have to be absent from work for 14 days, if infected. Absence from work indicates a loss of productive capacity for 14 days out of working days for a year. The third component of the labor shock accounts for absenteeism from work due to caregiving family members who are infected. Around 70 percent of the female workers would be care givers to family members. According to Overcoming the Covid-19 Pandemic report, the Covid-19 pandemic has brought micro and small businesses to a

grinding halt; more than 50% of the businesses claiming to be non-functional after the crisis. Some of the businesses still in operation are reporting sharp declines in their revenue. Due to the downward trend in businesses or total shutdown of the enterprises, millions of workers associated with it have either lost their job or are being paid less or are on the verge of losing their jobs. (IMF report of Bangladesh,2020)] COVID-19 virus had various effects on business during the period. That were, 43 percent of businesses were temporarily closed, and that employment has fallen by 40 percent in America. Alexander W. Bartik (2020) increases in the cost of production in Chinese production sectors during the period of COVID-19 Warwick McKibbin and Roshen Fernando (2020), Absence from work indicates a loss of productive capacity for 14 days out of working days for a year. Warwick McKibbin and Roshen Fernando (2020).

METHODOLOGY

Descriptive Survey Method used to conduct this study. Because it ensures a more accurate sample to gather targeted results in which to draw conclusions and make important decisions. Since the allocated amount for the research is limited and therefore the surveys are relatively inexpensive and are useful in describing the characteristics of a population. Mainly, this research focused on Selected the sample population, Developed the questionnaire, Distributing and collecting the questionnaire for sample population, Identifying and Categorizing the data that collected through the questionnaires, analyzing the data that have been collected and categorized. Review, Analyze and interpret the findings and make suggestions. This research considered all small business owners in Gampaha district as the population. The research was conducted in the Gampaha divisional area, targeting those who run small business. 230 Mahipalagoda Grama Niadhari division is the area was selected as the accessible population. Samples were All small business owners in 230 Mahipalagoda Grama Niladari Division (55 Owners) and Five Public Officers in 230 Mahipalagoda Grama Niladari Division (Grama Niladhari Officer, Samurdhi Officer, Economic Development Officer, Public Health Inspector, Agriculture Development Officer) The data collection for this research was done in several sections. That was Questionnaire forms and Interviews. Information was collected from small business owners using a structured questionnaire. Information was also obtained from the relevant government officials in the area to further increase the veracity of the information obtained. This research was conducted based on the second wave of COVID19 in Sri Lanka.

This research is conducted under a formal supervision. The target group based on this research is 230 Mahipalagoda Grama Niladhari Division. Data were collected by providing a questionnaire to small business owners. The data obtained were analyzed using Excel computer software. A pilot survey was performed to formalize the questionnaire and structured questionnaire was developed

to obtain the data. Data was also collected from government officials to certify the data obtained. Computer software was used to analyze the collected data. The data obtained can be classified into two categories. That is Quantitative data and Qualitative data. Excel computer software was used to analyze the data. In analyzing the data, attention was paid to the factors that Mean, Mode, Median, Standard Deviation and correlation of the questions. Qualitative data was represented by suggestions. Those suggestions were filed on several major topics. The information was tabulated using above analyzing methods.

RESULTS AND DISCUSSION

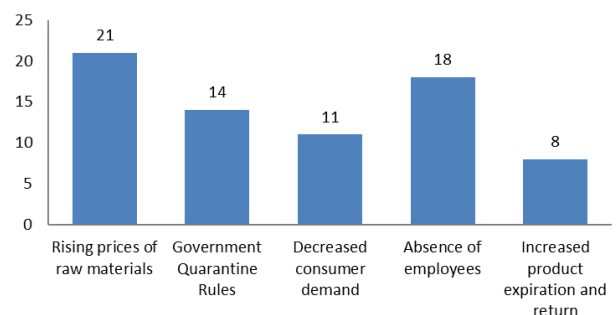


Figure 1 Factors that led to reduction of goods

The analysis of factors contributing to the reduction of goods provides crucial insights into the challenges faced by businesses. Understanding these factors is pivotal in devising strategies to address production issues. Factors such as raw material shortages, increased production costs, supply chain disruptions, or market demand fluctuations could be potential contributors to this decline. By identifying these elements, businesses can focus on mitigating these challenges, whether through diversifying suppliers, optimizing operations, or adjusting production schedules to meet market demands more effectively.

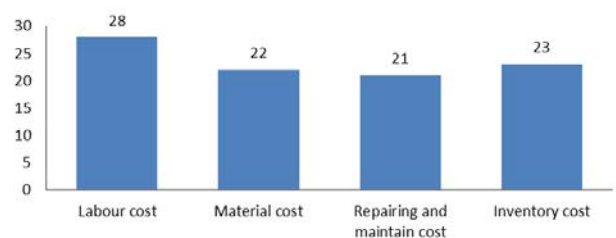


Figure 2 Change the cost of the business

The observed changes in the cost structure of businesses are indicative of the financial challenges encountered during the period under study. It could encompass various cost elements such as raw materials, labor, utilities, or operational expenses. This analysis is critical in understanding the cost dynamics and the impact on profit margins. Strategies to manage and control these escalating costs, such as renegotiating supplier contracts, optimizing resource utilization, or exploring alternative cost-effective

measures, are pivotal for sustaining business operations and ensuring profitability.

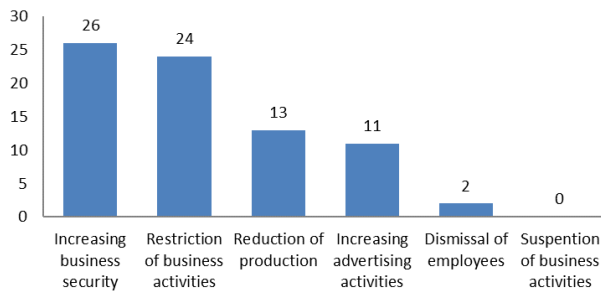


Figure 3. Major changes of the businesses

The identification of major changes implemented by businesses signifies their adaptability and resilience in response to adverse conditions. These changes might encompass shifts in business models, alterations in product lines, adoption of new technologies, or changes in operational processes. Analyzing these alterations sheds light on the agility of businesses to navigate challenges and evolve to meet evolving market demands. This information can guide other businesses facing similar challenges in devising innovative strategies to pivot and sustain operations during uncertain times.

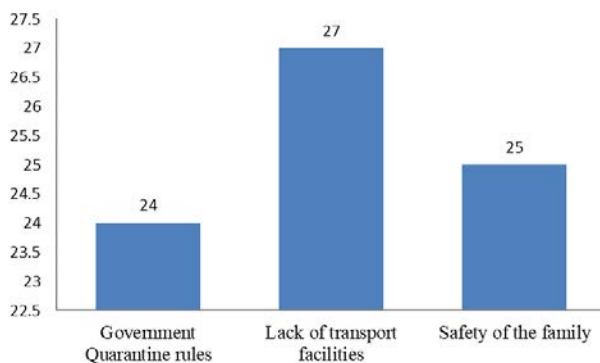


Figure 4. Factors that led to the decline in employee attendance

Understanding the factors contributing to the decline in employee attendance is crucial in addressing workforce management issues. It might include factors such as health concerns, transportation challenges, family obligations, or dissatisfaction due to work environment changes. Identifying these factors is vital in implementing measures to improve attendance, such as providing flexible work arrangements, enhancing workplace safety protocols, offering employee support programs, or addressing underlying concerns that impact employee morale and commitment.

The research findings shed light on several critical issues affecting small businesses during the COVID-19 period. One notable discovery was the financial instability experienced by most small businesses, attributed to stagnant sales despite escalating costs. The primary culprits identified were the soaring prices of raw materials and labor, leading to a decline in production.

Additionally, government regulations and inadequate transportation facilities emerged as significant obstacles, hampering worker attendance. Surprisingly, employee dismissals in these small businesses remained remarkably low during this challenging period.

Furthermore, the survey highlighted prevalent challenges among business owners, notably a lack of management knowledge and complexities in the raw material supply chain. It also revealed a common scenario where entire families depended on a single business for their livelihood.

The research substantiated Alexander's findings that revealed a 40 percent temporary closure rate among businesses and a corresponding 40 percent decrease in employment. Despite these setbacks, businesses adapted with various changes, managing to retain their workforce.

The findings echoed the financial fragility experienced by small businesses, indicating a lack of sales growth and increasing operational costs. This aligns with global observations by experts like Warwick McKibbin and Roshen Fernando, who noted cost hikes in Chinese production sectors during the pandemic.

Moreover, the research pinpointed significant hurdles faced by business owners, primarily the surge in raw material prices and workforce absence due to government regulations. Notably, diminishing consumer demand and regulatory compliance further exacerbated the decline in production. Product expiration and returns also contributed to reduced production rates.

The study validated the impact of government-mandated quarantines, with employees being absent for the recommended 14-day COVID-19 incubation period. This absence significantly affected productivity, corroborating Warwick and Roshen's analysis of labor shocks during the pandemic. Additionally, employees' reduced working hours directly correlated with decreased workplace productivity.

Moreover, caregiving responsibilities for infected family members further impacted absenteeism, particularly among female workers. This finding underscored employees' prioritization of their families' safety during the pandemic.

CONCLUSION:

In summary, the research delineated a landscape of challenges faced by small businesses during the COVID-19 period, emphasizing financial instability, operational hurdles, and workforce management difficulties. The findings not only confirmed the struggles documented by prior studies but also illuminated nuanced issues, such as family-dependent businesses and the multifaceted impacts of government regulations.

Understanding these challenges is crucial for devising targeted support mechanisms and strategies to bolster the resilience of small businesses in the face of future disruptions. Addressing knowledge gaps among business owners, streamlining supply chains, and developing

flexible work models are imperative to navigate uncertainties and fortify the sustainability of small enterprises in post-pandemic economies.

REFERENCES

- [71] AlexAnder S. KritiKoS DIW Berlin (2020), Entrepreneurs and their impact on jobs and economic growth,
- [72] University of Potsdam, and IZA, Germany
- [73] Alexander W. Bartik B. Edward L. Christopher T. (2020) How Are Small Businesses Adjusting to Covid19?
- [74] Early Evidence from A Survey
- [75] Ben L, Zhang Y.Y (2020), Impact of the COVID-19 pandemic on agricultural exports in China
- [76] Gunawardana D. (2020). The Impact of COVID19 on the MSME Sector in Sri Lanka
- [77] Firoz. F.M (2010) Entrepreneurial Orientation and Business Performance of Small and Medium Scale
- [78] Enterprises of Hambantota District Sri Lanka
- [79] McKibben. W, (2020) The Global Macroeconomic Impacts of COVID-19: Seven Scenarios
- [80] Robinson J. Kengatharan N. (2020), Exploring the effect of Covid-19 on Small and Medium Enterprises:
- [81] Early Evidence from Sri Lanka, University of Jaffna, Sri Lanka.
- [82] Roshana M.R, Kaldeen M, Rifna Banu A.R.F (2020), Impact of Covid-19 Outbreak on Sri Lankan Economy
- [83] Susana. R, Kasim. R, Shahzad. F, Ibrahim. W (2020) COVID-19 Impact on Business Sustainability: A Case of Micro- Small and Medium Enterprises in Malaysia
- [84] The International Monetary Fund (IMF) Country Report (2012) for Bangladesh
- [85] The Key indicators of Industry Trade and Service Sector Economic Census (2013/2014)

Innovative Pedagogies and developments in Language studies

Strategies Used by ESL Teachers Engaged in Emergency Remote Teaching to Overcome the Challenges in Using Activities for Developing Speaking Skills at the Secondary Level Grades of Government Schools in Sri Lanka

M.N.R Wijenayake
Department of Language Studies,
University of Vocational Technology,
Ratmalana, Sri Lanka
send2nishan@gmail.com

L.W.S Kularatne
Department of Language Studies,
University of Vocational Technology, Ratmalana, Sri Lanka
sunilkularatne6@gmail.com

Abstract— This research was conducted to identify strategies used by ESL teachers engaged in Emergency Remote Teaching (ERT) to overcome the challenges in using activities for developing speaking skills at the secondary level grades of 1C schools in the Colombo Education Zone. The study used mixed approach and survey research design. A sample of 75 teachers of English was selected and a questionnaire and semi structured Zoom interviews were used to collect data. Data was analyzed using both quantitative and qualitative techniques. It was found that conducting debates was the most challenging speaking activity for the ESL teachers and getting students to do act outs was the least challenging one. Lack of interaction of students, teachers' lack of time to teach the vocabulary and structures required for speaking activities, inhibition of students, lack of sufficient time for students to practice and get prepared for oral tasks and lack of teacher training were some of the major challenges for effective implementation of speaking activities in ERT situations. ESL teachers also used a number of effective strategies such as redesigning of the content to match ERT environment, use of grammar games, use of online polls and incorporating the videos, cartoons and power points to make speaking lessons more interesting. It was recommended to organize School Based Professional Teacher Development (SBPTD) programmes that target development of ESL teachers at secondary level.

Keywords— ERT Challenges, ERT Strategies, ESL teachers, government schools, secondary level

I. INTRODUCTION

A. The background of the study

The teaching and the administrative experiences of the researcher in the context of government schools in the Colombo Education Zone in the Western Province of Sri Lanka helped to identify the research problem investigated

in this research study. Thus, current study is related to Emergency Remote Teaching (ERT) of the English language at the secondary level grades (Grade 6 - 11) of government schools in Sri Lanka.

B. Emergency Remote Teaching in Sri Lanka

In contrast to experiences that are planned from the beginning and designed to be online, emergency remote teaching (ERT) is a temporary shift of instructional delivery to an alternate delivery mode due to crisis circumstances. Many recent research, however, use the terms “online education” or “online learning” to refer to ERT situations. As described above online education and ERT are two different types of education. Therefore, this usage cannot be considered as an accurate description of the type of education that existed in many educational institutes around the globe during the COVID19 pandemic period as well as during the crisis situation in Sri Lanka in year 2022. During both time periods Sri Lankan teachers volunteered to conduct ERT sessions from grades 1-13 from their homes according to a timetable set by their schools.

C. Rationale of the study

Although online ERT was a very useful mode of education in many government schools in Sri Lanka during the abovementioned time periods, teachers and students at all levels encountered many challenges in ERT situations from primary grades to the post-graduate level.

Wijewardene (2021) argues, a large population in Sri Lanka, comprising school-going children and university undergraduates, faced disruptions to their studies due to the pandemic's devastating effects. She further claims that the abrupt transition from the traditional face-to-face classroom methodology adopted in English teaching to undergraduates into online learning and blended learning modes created

many problems, ranging from internet connectivity issues to the inability to possess online learning devices due to economic crises.

D. The Research Problem

The researcher observed that the most significant challenges that are specific to the ESL practitioners at the secondary level stem from the lack of interaction of majority of the students as they find it difficult to communicate in English due to their poor L2 speaking skills. As a result, the ESL teachers who try to use text book activities for developing the oral skills of students during ERT sessions at secondary level are confronted with the major problem: how to develop students' oral skills through various speaking activities such as role plays, discussions, oral presentations and debates amidst their poor interaction and poor L2 skills. This is the central problem identified for the current research study.

E. Research objectives

1. To identify the challenges encountered by the ESL teachers engaged in emergency remote teaching in using activities such as role plays, discussions, oral presentations and debates for developing speaking skills at the secondary level grades of government schools in Sri Lanka.

2. To identify the strategies used by ESL teachers to face the challenges of emergency remote teaching in using activities such as role plays, discussions, oral presentations and debates for developing speaking skills at the secondary level grades of government schools in Sri Lanka.

F. Limitations of the Study

This study has two major limitations as mentioned below. Therefore, generalization of the results should be done cautiously.

- In the sampling process the purposive sampling method is to be used.
- The sample was selected from 1C type schools only. (There are four types of schools in the Colombo education zone: 1AB – 29 schools, 1C – 42 schools, Type 2 – 39 schools, Type 3 – 14 schools).

These limitations were caused by the constraints such as the accessibility to the population, expenditure, restraints of time and lack of resources.

II. REVIEW OF LITERATURE

A. Theoretical Perspectives

According Haythornthwaite et. al. (2007) online learning does mean following through a tutorial program, the kind of online learning being promoted and enacted in educational institutions, communities of practice, and online groups and communities are based on principles of collaboration, dialogue and conversation, active structuring of learning, and open sharing of resources and experiences. They further

elaborate that online learning appears under the names asynchronous learning networks. Computer-supported collaborative learning and e-learning.

B. Existing Empirical Evidence

Many recent studies, both local and foreign, have highlighted common challenges encountered by ESL teachers in teaching speaking Skills during the COVID19 pandemic. Some studies also have suggested effective strategies to overcome those challenges. However, there was a dearth of studies related to the specific challenges encountered by teachers ESL teachers engaged in ERT in using activities such as role plays, discussions, oral presentations and debates for developing speaking skills. Anugrah (2021) identified several factors that the teachers found as challenges in teaching speaking skills during the COVID19 pandemic in Indonesia. According to his discovery, the challenges related to teaching speaking via online learning were: 1.) lack of interaction, 2.) lack of knowledge about software for online learning 3.) lack of ways to apply various teaching method. In a study conducted in North Sumatra by Siregar (2021), following challenges have been identified: 1.) the students did not have smartphones or Androids, 2.) Students' laziness during online learning, 3.) poor internet connection and the value of face-to-face instruction for speaking abilities.

Since it was of paramount importance to identify the strategies to overcome challenges of ESL teachers for the current study, another three studies found in literature; Başal (2013) and Howshigan & Nadesan (2021) are significant as they have identified some strategies to overcome some of the challenges of ESL teachers in ERT situations. Başal (2013) recommends the techniques such as usage of; videos, presentation tools, Web 2.0 tools, videos from virtual classroom, authoring tools to combine texts, images, video and linking within the material using hyperlinks within the material for words, phrases, video or audio components and direct the students to explore the subject matter. Howshigan & Nadesan (2021) also have made few suggestions to improve online learning experiences.

"It is recommended that to enhance online education in general, provide electronic technology to access, free broadband packages, and increase internet speed are few ideal ways to ensure online teaching and learning effectiveness." (Başal, 2013, p.55)

According to Tiwari (2020) it is important to use digital tools and resources that teachers have been using and are comfortable with. They point out that keeping things simple would yield better results. For example, if teachers are not able to make videos, they should encourage students to make videos.

All three materials suggest practical solutions to overcome the challenges of online teachers. However, suggestions of

Basal (2013) and Tiwari (2020) are very much relevant as they give strategies for ESL practitioners.

III. METHODOLOGY

A. Research procedure

TABLE 1: SUMMARY OF THE RESEARCH PROCEDURE

Objective	Research Phase	Participants	Research Instruments	Methods of Data Analysis
Objective I & II	Phase I	65 teachers of English who conducted ERT sessions at the secondary level grades in 1C schools of Colombo Edu. Zone	Questionnaire	Quantitative
Objective I & II	Phase II	10 teachers of English who conducted ERT sessions at the secondary level grades in 1C schools of Colombo Edu.	Semi-Structured Interviews	Qualitative

The research was both quantitative and qualitative. As such mixed approach was used. Research design was survey research design. Target population of the study was 742 teachers of English in Colombo Education Zone. Accessible population was 150 teachers of English from 1C schools in the Colombo Education Zone. As such samples of 75 teachers of English who teach at secondary level of 1C schools in the Colombo Education Zone were selected using purposive sampling method. A self-administered questionnaire and semi structured Zoom Interviews were used to collect data. First, the questionnaire, which consisted of 24 questions, was administered among 65 teachers of English who conducted online English lessons for secondary level students in (1C) schools Colombo education zone. Next, another ten (10) teachers of English were interviewed.

Data were analyzed using both quantitative and qualitative techniques. As per the quantitative analysis, responses of questions 1-24 of the questionnaire were analyzed using MS Excel which finally generated tables and graphs. Responses of 10 semi structured interviews were analyzed using content analysis techniques. The method of Three Cs of Data Analysis (Codes, Categories, and Concepts) was used.

IV. RESULTS AND DISCUSSION

A. Questionnaire

From the preliminary descriptive questions (Question 1-6) it was found that 42% of the participants were actively engaged in ERT sessions during COVID19 pandemic period as well as during the period of economic crises in 2022. Then, 57% of the participants conducted ERT sessions only during COVID19 pandemic period in 2021 and 3% of the participants were engaged in ERT sessions only during economic crises in 2022. The preliminary descriptive questions also revealed that 85% of the participants used supplementary teaching materials and online resources in addition to classroom textbooks during ERT sessions.

TABLE 2 MOST CHALLENGING SPEAKING ACTIVITY FOR TEACHERS

Rank	Conducting role plays	Conducting debates	Conducting discussions	Getting students to do oral presentations	Getting students to do act outs
1	7	41	4	10	4
2	16	17	17	11	5
3	10	4	24	19	8
4	19	1	10	16	17
5	13	2	10	9	31

Question 07 of the questionnaire was designed to find the most challenging speaking activity given in the text book for ESL teachers, when they carried out ERT sessions at secondary level. Table 2 demonstrates the rank order from the most challenging to least challenging (ranked from 1 to 5) those speaking activities. It was found that conducting debates was the most challenging speaking activity and getting students to do 'act outs' was the least challenging one.

From questions 8 to 17, the participants were given (10) statements of different challenges which were supposed to be encountered by the ESL teachers engaged in ERT in using activities for developing speaking skills. The participants were requested to mark their opinion by selecting 5 - point Likert scale (from strongly agree = 5 to strongly disagree = 1). From the analysis and interpretation of responses of all 65 participants it was found that majority agreed that: (a) the students were reluctant to interact with others when they were sent to Zoom breakout rooms, (b) teachers did not have sufficient time to teach the vocabulary required for speaking activities, (c) inhibition of students was a major challenge for effective implementation of speaking activities, (d) students did not have a sufficient time to practice and get prepared for oral presentations, debates or discussions as they often got

disconnected due to signal issues, (e) secondary level students were reluctant to participate in oral tasks when compared to primary and advanced level students (f) students made a lot of grammar mistakes and teachers found it difficult to correct them.

In section three, from questions 18 - 24 the participants were requested to mention briefly the strategies that they used to overcome (six) 6 common challenges of ERT in using activities such as role plays, discussions, oral presentations and debates for developing speaking skills. Some of the strategies used to help students to get rid of their inhibition during ERT sessions were; (a) scaffolding with vocabulary input and gradually withdrawing from it, (b) creating a friendly, informal atmosphere for discussion. Using online videos and audio clips related to pronunciation, using online pronunciation dictionaries and using ELSA speak app were common strategies used to teach pronunciation, stress and intonation required for speaking activities. Some of the strategies used to teach vocabulary and grammar required for students to get engaged in speaking activities were: (a) sending PowerPoint presentations related to required vocabulary and grammar in advance, (a) using short movie clips and stories in the internet that are related to development of vocabulary and grammar. Some of the strategies used to overcome the difficulties in correcting students' grammar mistakes during speaking activities in ERT sessions were: (a) correcting mistakes of each student via WhatsApp and sending feedback personally, (b) recording Zoom sessions and discussing common mistakes.

B. Interviews

From the semi structured interviews with the 10 teachers of English, it was found that majority of the ESL practitioners face a number challenges such as lack of interaction of students during speaking tasks, inhibition of students due to lack of L2 knowledge as well as due to presence of parents and family members during ERT sessions, students' difficulties to adjust to the limited time for preparation for speaking tasks, difficulty of conducting role plays simultaneously like in face to face classes, challenges of correcting students grammar and vocabulary during speaking task, lack of resources like laptops and mobile phones, poor attendance of students, and lack of teacher training. Lack of support from the Ministry of Education (MOE) and Zonal Education Office was a major concern of all 10 participants. About 80% of them stated that they need training on handling packages such as Zoom and MS Teams as well as training on using online games and tools such as Bamboozle, Kahoot and Jamboard.

Despite those challenges about 60% of them use variety of strategies to overcome those challenges. Some of the common strategies used to overcome some of the challenges were: (a) making use of WhatsApp to send the speaking topics, grammar and vocabulary needed for speaking tasks in advance, (b) using WhatsApp to give individual feedback

and correct grammar and vocabulary related to speaking tasks (c) getting help of IT teachers, family members or parents of students to overcome teachers' lack of training (d) having short informal conversations with students on how to overcome inhibition, (e) buying data cards for students, (f) getting students to share the devices with family members or peers, (g) conducting online English lessons at convenient time for students are some of the strategies identified during the interviews. Thus, the researcher was able to achieve the two research objectives to a greater extent. However, the generalization of the results should be done cautiously as the sample of the study was limited to 75 teachers and the researcher used the purposive sampling method.

V. CONCLUSIONS AND RECOMMENDATIONS

A. Conclusions related two objectives

- With regard to the challenges encountered by the ESL teachers engaged in ERT in using activities for developing speaking skills at the secondary level grades, it can be concluded ESL practitioners have taken initiative to conduct ERT sessions in their respective schools amidst many challenges such as lack of interaction of students, inhibition of students, slow connections lack of knowledge and practice for teachers on various online tools and games such as Jamboard, Bamboozle, etc.

- With regard to strategies identified to overcome challenges of, it can be concluded that ESL practitioners have used number of effective strategies such as redesigning the content to match the ERT environment, using grammar games, online polls, Zoom break out rooms, incorporating the videos, cartoons, power points to the existing and making lessons more interesting and appealing to secondary level ESL learners.

B. Recommendations

- Recommendations for ESL Teachers

It is recommended to participate in workshops, training programmes that help ESL practitioners to acquire skills of designing online ESL content, especially on promoting speaking skills of students. It is also recommended to participate in workshops, training programmes that help ESL practitioners to acquire skills of making use of tools, games and software available online.

- Recommendations for Principals

School Principals should take steps to minimize the poor attendance of students in the online English lessons at the secondary level. It is also recommended to organize SBPTD programmes that target development of online ESL practitioners at secondary level.

- Recommendations for Zonal Education Offices, Provincial Department of Education and MOE

It is recommended to allocate funds to provide training programmes for ESL teachers to conduct online lessons.

REFERENCES

- Anugrah, P. M. (2021). Analysis of Teachers' Challenges in Teaching Speaking Through Online Learning during Covid-19 Pandemic in SMAN 2 Abiansema. *Journal of Educational Study*, 1(2), 26–36. <https://doi.org/10.36663/joes.v1i2.183>
- Başal, A. (2013). ELT Teachers as Online Material Developers. *The Online Journal of Distance Education and E-Learning*, 1(2), 8–12. <http://www.tojdel.net/?pid=showissue&volume=9&issue=3>
- Haythornthwaite, C., Andrews, R., Kazmer, M.M., Bruce, B.C., Montague, R.-A. and Preston, C. (2007). Theories and models of and for online learning. *First Monday*. doi:10.5210/fm.v12i8.1976.
- Howshigan, S., & Nadesan, T. (2021, June). Students' Perceptions of Online Learning and Teaching during COVID-19 pandemic: An Empirical Study in Selected University in Sri Lanka. *Asian Journal of Economics, Business and Accounting*, 50 –57. Available at: <https://doi.org/10.9734/ajeba/2021/v21i830411> (Accessed: December 28, 2021)
- Siregar, R. A. (2021). English Teachers' Challenges in Teaching Speaking Skill during Covid-19 Pandemic at MTsN 1 Labuhanbatu. Retrieved August 2, 2023, from <http://repository.uinsu.ac.id/15671/1/ROBIATUL%20ADAWIYAH%20SIREGAR%20SKRIPSI%282%29.pdf>
- Tiwari, M. (2020, April 20). Challenges of online teaching. <https://www.teachingenglish.org.uk>. Retrieved December 27, 2021, From <https://www.teachingenglish.org.uk/professional-development/teachers/integrating-ict/magazine/challenges-online-teaching>
- Wijewardene, L. (2021). The Impact of Covid-19 on the Teaching of English to 'Undergraduates in Sri Lanka. *Journal of Economics & Management Research*. SRC/JESMR/154. DOI: doi.org/10.47363/JESMR/2021 (2), 140.

Use of a Selected Neuro-Linguistic Programming Technique to Improve Public Speaking Skills in English among English as Second Language Learners

K.G.Dilrukshi M. Gunawardana
Department of Language Studies,
University of Vocational Technology, Sri Lanka
dilrukshigunawardana8@gmail.com

J.A.M. Buddhima Karunarathna
Department of Language Studies,
University of Vocational Technology,
Sri Lanka
buddhima@uovt.ac.lk

I INTRODUCTION

Background

The history of language education has been focused on finding more efficient methods to teach second or foreign languages. According to Richards & Rodgers (2001), despite the emergence of novel approaches, these methods have been insufficient in developing language learners' proficiency, especially in speaking. Neuro-Linguistic Programming (NLP) has been proposed as a modern approach to address this gap and enhance English language learners' abilities in various aspects (Zhang et al., 2023).

NLP is an interpersonal communication system that combines Neuro, Linguistics, and Programming (Siddiqui, 2018). It facilitates learning by linking linguistic, psychological, and pedagogical information (Moscoso, 2018). Developed in the 1970s by Dr. Grindler and Dr. Bandler, NLP helps individuals tap into their potential and strength, motivating them positively to achieve maximum results in various aspects of life (Gran, 2021).

NLP, originally known as a tool for self-motivation and personal growth, has recently gained recognition in the field of education (Carey et al., 2010). Similarly, NLP is recognized as a supportive tool that can aid educators and students in cultivating exceptional abilities, including critical thinking, academic success, emotional intelligence, self-confidence, and empathy (Begum et al., 2022). According to Silva (2017), NLP enables a person to comprehend how cognition is processed (neurologically) and how this affects behaviour and decision-making. With the use of this educational tool, students may learn about and comprehend how the brain functions, as well as how to alter their thoughts and behaviours in order to fulfill the requirements of any human activity. Jayanthi (2021) claims that it is considered a highly effective tool in many countries, and there is an increasing demand for formal NLP method training among educators. Also, helps learners make positive changes in their thinking patterns that lead to improved outcomes.

Teaching English as a foreign language has seen significant changes in recent decades, aiming to improve learning outcomes and school effectiveness (Richards & Rodgers,

Abstract— Public speaking is considered a crucial skill that is classified under the intellectual and practical skills that should be mastered by English language learners. However, many second language learners in Sri Lanka lack the motivation to speak in English. Neuro-Linguistic Programming (NLP) techniques offer a potential solution to improve speaking abilities, particularly in public speaking. One such NLP technique is "Outcome Orientation," which emphasizes setting clear goals for language learning and communication. This study aims to investigate the effectiveness of using the NLP technique of "outcome orientation" to enhance the public speaking abilities of English language learners. The study primarily focused on addressing two specific research questions. 1). How effectively can the selected NLP technique be used in teaching public speaking in English? 2). How will the learners' learning experience be in learning to do public speaking in English using the selected NLP technique? This was a classroom action research. A pre-test and post-test as well as a quasi-experimental research design was carried out, employing the mixed method of both quantitative and qualitative methods. The participants of the study were 40 students from advanced-level classes at a government school in Sri Lanka. Quantitative data were collected through pre-tests and post-tests. Qualitative data was collected through a focus group discussion. In an effort to achieve the research aims, an NLP workshop for participants was conducted prior to the post-test. A qualified English language teacher was invited to take part in the study as an external observer and tester. Paired sample t-test and thematic analysis were employed to analyze the data. The findings of the study reveal that the implementation of the NLP technique can have a significant effect on the public speaking of advanced-level students. Besides, the NLP technique can be a valuable asset in boosting students' public speaking skills.

Keywords— English language learners, motivation, Neuro Linguistic Programming (NLP), outcome orientation, public speaking

2001). However, student motivation to learn foreign languages remains a challenge. To address this issue, English language teachers worldwide are integrating NLP-based activities into their classes to improve listening, speaking, reading, and writing skills (Siddiqui, 2018).

Though English as a second language has been taught in Sri Lanka for decades, according to Gunawardana and Karunaratna (2017), English Language Teaching (ELT) in Sri Lanka is commonly viewed as unsuccessful. Despite recent efforts to address teaching and learning problems, desired outcomes have not been achieved. Moreover, many second language learners in Sri Lanka lack the motivation to speak English (Wijayatunga, 2018), and do public speaking often due to shyness and anxiety. It has been proven by many scholars, such as Ningsih (2016), Carvajal, Santiago & Salazar (2021), and Saraswat (2023). NLP techniques offer the finest solution for this matter, with Outcome Orientation being one such technique. Setting clear goals and focusing on the process are essential for overcoming public speaking barriers. NLP advocates "outcome orientation," which means being clear about your end goals, as it guides your efforts toward the desired outcome (NLP Well-Defined Outcomes, 2021). For instance, a student may aim to speak without referring to a paper. Using the SMART technique (Specific, Measurable, Achievable, Relevant, and Time-bound) is recommended (Blaine & Hornyak, 2012). Emphasizing the process over the outcome is key, and planning with the desired outcome in mind is crucial (Javadi & Asl, 2020). This study aims to explore how NLP's outcome orientation can enhance the public speaking skills of English language learners.

Research Problem

Though English as a second language has been taught in Sri Lanka for decades, the interest of ELT learners is not at the expected level (Wijayatunga, 2018). The current researcher has observed that schoolchildren were weak in oral communication, particularly in public speaking. The Pre-test (speech) given by the researcher proved that phenomenon. It seems that existing teaching methods have not adequately motivated learners to speak English in public. The necessity of a new method of language teaching is a timely need today. Hence, the current study aimed to determine how far NLP can help develop students' public speaking skills. This study also emphasizes the need to integrate NLP into our educational system to educate both teachers and students.

Research Objectives and Hypothesis

- To evaluate the effectiveness of using a selected NLP technique in teaching public speaking skills in English
- To explore the learners' learning experience in practicing public speaking skills using the selected NLP techniques

Hypothesis (Ha) - There is a significant improvement in public speaking skills in English language learners using the selected NLP technique.

Null hypothesis (Ho) - There is no significant improvement in public speaking skills in English language learners using the selected NLP technique

Ethical Considerations

To begin the study, the researcher obtained permission from the school principal to work with selected students. The participants were given a consent form, and their agreement to participate in the research activities was confirmed. The consent form provided information about the study's purpose and process (Karunaratna, 2020). Additionally, the researcher discussed the study's procedure with an English language teacher from the same section (A/L) at the school, who was invited to participate as an external observer and tester.

II LITERATURE REVIEW

An Overview of Neuro-Linguistic Programming

Silva (2017) reveals that Neuro-Linguistic Programming (NLP) has its roots in Richard Brandler in the 1970s. Silva (2017) further explains, that after studying psychology Brandler found that when someone thinks positively about a difficult event, it ceases to be worrying. Consequently, Brandler realized that how you think about something is key to how you experience it. This discovery has been termed "Modelling Human Excellence" in NLP. Bandler and Grinder created mental models based on language and behavior patterns that are applicable in various life domains, such as work, school, and interpersonal relationships (Silva, 2017). NLP comprises three components: "neuro," pertaining to the nervous system; "linguistic," involving words, images, and sounds; and "programming," which refers to the process that governs our thought patterns (Gran, 2021). From the perspective of NLP, individuals are viewed as active participants with consistent, structured connections among neurons, language, and mental processes (Gran, 2021). According to Gehlbach and Robinson (2021), NLP is a psychological discipline focused on internal cognitive processes. The primary function of NLP is to assist individuals in enhancing their self-communication and managing adverse emotions and stress (Nompo et al., 2021). Adding more to this idea Jayanthi (2021) states that NLP is thinking about thinking and it is the study of the mind and self-awareness, aimed at personal growth and achieving outstanding results in various life areas. It provides tools for self-improvement and education, serving as a self-motivation tool for reaching goals and altering behavior and mindset.

Implementation of NLP Techniques in the Field of Education

Though NLP was originally developed and used for psychological matters, it has proven that it holds potential in the field of education as well. According to Bandler (1985), a co-founder of NLP, NLP is fundamentally an educational approach that aims to empower individuals to harness their own cognitive abilities. This idea was verified by Keezhatta

and Omar, (2019) stating that NLP techniques and resources can be applied in educational settings to form perceptions of student interactions, behaviors, learning outcomes, and teaching effectiveness. A crucial skill in NLP is the ability to identify individuals' thoughts and extract relevant information to enhance the learning process for students (Jahan et al., 2022). Moreover, NLP provides a practical tool for enhancing the connection between teachers and learners, fostering collaborative learning environments (Keezhatta and Omar, 2019). When combined with traditional methods, NLP provides deeper insight into their cognitive processes during the learning process. (Zhang et al., 2023)

Use of NLP Techniques in English Language Teaching

As a self-motivation tool, NLP has been recently introduced to the education system in many countries. Hence, NLP plays a vital role in teaching English as a second language. Richards & Rodgers (2001) introduce NLP as a supplementary tool applied in the field of second or foreign-language instruction in order to assist learners in becoming excellent performers. According to Pishghadam & Shayesteh (2014), NLP is a complementary tool used by language teachers to support language learning. This idea was further elaborated by Tarnopolsky (2016) concluding that learning NLP gives teachers a chance to build positive relationships with their students. Henni (2018) explains that NLP has gained recognition as a valuable resource for enhancing language instruction effectiveness. Rayati (2021) investigates the positive effect of NLP techniques in English Language Teaching (ELT). NLP additionally aids language educators in enhancing the learning environment and conducting helpful, efficient interactions, ultimately leading to improved academic achievements (Anjomshoaa et al., 2021). Among the four language skills, speaking is an important skill for language learners to be competent with. Carvajal, Santiago, and Salazar (2021) concluded in their study that using these strategies can increase oral dexterity more effectively than using conventional or traditional procedures. Correspondingly, Kizi, (2021) did a similar research to investigate the differences between English-speaking students studying the conventional and NLP methods. The study concludes that there is a significant impact of the NLP method on developing the English-speaking skills of the students. According to Li (2018), NLP is an effective model for a valuable and productive English public speaking course. Moreover, Hallett (2020) points out, NLP can develop public speaking skills by providing techniques to build rapport with an audience, communicate better, have greater mental resilience, achieve outcomes, improve confidence, and achieve goals according to the SMART acronym.

Research Gap

According to Nunan (1991), for most people, developing speaking ability is the most crucial component of learning a second language or a foreign language. Its success is

determined by how well one can communicate in that language. Although the English language is taught from grade 1 in Sri Lankan schools, many second language learners lack the motivation to speak in English (Wijayatunga, 2018). As stated above, though it is proven that NLP helps to overcome this matter, no research paper that has been written regarding this problem in the Sri Lanka context could be found. Thus, this study primarily focuses only on how the outcome orientation technique helps to improve public speaking skills in English among Sri Lankan upper secondary students that were not studied before in the Sri Lankan context.

III METHODOLOGY

Research Design

This research was a classroom action research. A before-and-after (pre-test and post-test design) quasi-experimental research design was carried out, employing the mixed method of both quantitative and qualitative methods.

For collecting quantitative data, pre-test (speaking) and post-test (speaking) were given to the participants, before and after the treatment in order to find the answers for the first research question.

A qualitative data-collecting method involving a focus group discussion was conducted at the end of the study with the intention of achieving the second research objective,

Setting, Participants, and Sampling Procedure

The setting of the research was a government boys' school in Colombo, Sri Lanka which offers grades from 1 to 13. Grades 1 and 2 learn English as Activity Based Oral English (ABOE), while grades 3 to 11 learn English as a link language, and grades 12 and 13 learn General English.

The target population for the study was the Advanced Level (grades 12 and 13) students. Due to time constraints and the focus of grade 13 students on their upcoming G. C. E. Advanced Level examination, the accessible population was selected from the newly enrolled grade 12 students. Two classes were chosen as the sample using the purposive sampling method. Since it is a boys' school, 40 male participants (all the students of the selected two classes, 22 from one class and 18 from the other class) were selected for the study.

Methods of Data Collection

Pre-Test and Post-Test: The study utilized pre-tests and post-tests as quantitative data collection methods to assess participants' public speaking skills. Both tests were speaking assessments, and the external observer and the tester evaluated the tests to avoid bias. The speaking rubric proposed by O'Malley and Pierce which has been proven effective for secondary school students by Sari & Sembiring (2019) in their study, was used to evaluate students. The rubric assessed five components of speaking skills:

pronunciation, fluency, grammar, vocabulary, and comprehension. Participants were asked to deliver a prepared speech on any topic, with three days given for preparation. Pre-tests were conducted within a week, with 5 to 8 speeches taken each day. After the introduction of the selected NLP technique, participants delivered post-test speeches on the same topic, with a similar preparation period and assessment process.

Focus Group Discussions: Qualitative data was collected through focus group discussions with the participants after conducting the post-tests. The 40 students were clustered into 05 groups with 08 students in each group. The researcher asked questions from each group to explore their learning experience of English using NLP.

Treatment: After conducting the pre-tests, the researcher conducted a four-hour NLP workshop for the students, focusing on the "Outcome orientation" technique, one of the NLP pillars. The workshop covered theoretical and practical aspects of NLP, using a PowerPoint presentation, video clips, physical activities, writing and drawing exercises, and entertainment activities. Students learned how to set aims and goals and develop a process to achieve them. They were encouraged to focus on the process rather than the outcome and were taught correct body postures and how to overcome negative thoughts using the "pink elephant" concept when preparing and performing the speech. They were also asked to practice their speeches in front of a mirror and how to use the "self-two" strategy to overcome performance obstacles. Finally, students were given the opportunity to construct aims related to their public speaking for the upcoming post-tests.

IV RESULTS AND DISCUSSION

This study aims to find answers to the two research questions that try to determine the use of the selected NLP technique in public speaking skills in English. Tests (pre-test and post-test) and focus group discussions were conducted on the sample of the study.

Effect of the Selected NLP Technique on Public Speaking Skills in English

Results of the first objective set for the study, i.e.: "To evaluate the effectiveness of using the selected NLP technique in teaching public speaking skills in English", and answer for the first research question, i.e.: "How effectively can the selected NLP technique be used in teaching public speaking in English?" is discussed in this subsection. The pre-test and post-test evaluated the public speaking abilities of 40 students based on four criteria: pronunciation, fluency, accuracy, and vocabulary as given in O'Malley and Pierce's speaking rubric. Each criterion was weighted with a maximum score of 4, resulting in a maximum total score of 16.

According to the sample size and the assumption, a t-test was taken. The results of the paired sample t-test of the pre-test and post-test are illustrated in Table 1. According to

the results, the analysis reveals significant improvement in students' speech skills after the introduction of the "Outcome Orientation" NLP technique. The average mean value increased from 5.9 in the pre-test to 13.9 in the post-test (Table 1), indicating the effectiveness of the treatment. The p-value of the two-tailed test is 0.000 (1.9245E-28) and it is less than the Alpha value (0.05). Consequently, it rejects the null hypothesis (Ho) that there is no significant improvement in public speaking skills in English language learners using the selected NLP technique. At the same time, the hypothesis (Ha) of the study that there is a significant improvement in public speaking skills in English language learners using the selected NLP technique is accepted. The observed value of the mean difference (8.05) is statistically significant.

Therefore, according to the results of pre-test (M = 5.9 , SD = 1.9) and post-test (M = 13.9, SD = 1.4), it can be concluded that there is a statistically significant improvement in public speaking skills in English language learners using the selected NLP technique $t(39) = -29.8$, $P = 0.000$.

PAIRED SAMPLE T-TEST RESULTS

	Pre-test	Post-test
Mean	5.9	13.9
Variance	3.6	1.9
Observations	40	40
Standard Deviation	1.9	1.4
Hypothesized Mean Difference	0	
Df	39	
t Stat	-29.8	
P(T<=t) two-tail	1.9E-28	

Learning Experience of Learners in Practicing Public Speaking Skills Using the Selected NLP Techniques:

Results of the second objective set for the study, i.e.: "to explore the learners' learning experience in practicing public speaking skills using the selected NLP techniques", and answer for the second research question, i.e.: "How will the learners' learning experience be in learning English using the selected NLP technique?" is discussed in this subsection.

To achieve the second objective, the researcher conducted focus group discussions with the participants after the post-tests. The students' responses were transcribed and categorized into themes to analyze their perceptions of developing English speaking using the NLP technique.

Based on the focus group discussion data, the participants' perceptions towards developing English speaking using the NLP technique are categorized into six major themes. as; i. previous experience and preparation, ii. motivation and NLP technique iii. support and encouragement, iv. post-test experience, v. reflection and growth and experience with NLP technique, vi. future use of NLP technique.

a) *Previous Experience and Preparation:* The researcher found that 78% of the participants reported having previous experience doing public speaking in English, while 22% had not. When asked about how they prepared for those speeches, 63% of the students mentioned not following any

special method. Some students (12%) admitted to copying stories from books or the internet, while only 3% sought help from their sister and class teacher.

b) *Motivation and NLP Technique:* In the theme of motivation, it was observed that 93% of the participants indicated being motivated and following the NLP technique for post-test speech preparation, while 7% followed it but not consistently. S 30 mentioned, "I started to think in a new way that the teacher taught us, it was a good motivation for me to be prepared for the speech" Furthermore, Many students (53%) felt more confident when practicing and making speeches. Some students (17%) initially felt shame but improved gradually with practice. S 38 declared, "I felt more confident than ever before". While S 10 claimed, "First I felt shame if my family members hear me practicing an ENGLISH speech because I have done such a thing never before, but gradually I felt to do this very well". Apart from that, as stated by S 14, "I thought I would not be able to do this well since I'm very lazy, but whenever I have negative feelings, I reminded the strategies and stories taught by the teacher in the workshop. That is why I could do my speech better than the first". Students noted they struggled due to laziness but relied on NLP strategies to do better. Additionally, 13% of students expressed determination to practice well, while 5% saw it as an opportunity for recognition. Another 5% of students admitted to being inconsistent in their practice, feeling bored and lazy at times.

Support and Encouragement: The fifth question asked by the researcher was "What were the responses of your family members regarding your work/practice at home?" The majority of students mentioned positive family responses, with parents and siblings supporting and appreciating their efforts in practicing English speeches using NLP techniques. S 13 noted, "Actually my mom was very happy seeing me practicing English speech that I had done never before. It meant a lot to her. And I saw her happy tears when she was appreciating me". Some students even inspired their family members to use NLP for self-improvement. For instance, S 2 stated "It was my sister who was kidding me when I was practicing the speech in front of the mirror. She thought that I was crazy. Later on, I explained to her the techniques taught (NLP) by the teacher. She said that she also wants to follow the same techniques not only to develop her English-speaking ability but for the betterment of her future also". Apart from that, parents and siblings played a crucial role in encouraging students and providing them with opportunities to showcase their public speaking skills. It was very apparent in the response given by S 22, "My father had secretly listened to me when I was practicing the speech at home. Then he was very happy about my enthusiasm and he encouraged me to do the welcome speech at our annual family gathering".

Post-Test Experience: In response to the post-test speech, the majority of students reported improved confidence, fluency, and engagement with the audience. They mentioned using NLP techniques to overcome nervousness

and deliver their speeches more effectively. S 24 stated "Not like the 1st speech(pre-test), this time I could do the speech confidently from the beginning. And achieved my goal. I used NLP techniques to overcome nervousness, deliver my speech fluently, and engage with the audience well" while S 6 claimed "At the beginning, I felt so uncomfortable and shame, then suddenly I followed the techniques taught by the teacher, then could end up my speech according to the aim (I do the speech without stammering within 3 minutes) set by me earlier. At the same time, they were pleased to see the positive response from the audience, and some felt a sense of accomplishment in achieving their speech goals with the help of NLP techniques. "I was stuck one time when I was doing the speech, but the 'self two' technique helped me in that event to overcome my weakness and end up my speech nicely" (S 28). Additionally, S 31 declared "I felt very happy when I saw the audience staring at me silently seeing that they like the way I spoke".

Reflection and Growth and Experience with NLP Technique: The students reflected on their experience with the NLP technique and acknowledged significant improvements in their public speaking skills and confidence. "I feel I have improved a lot after following NLP techniques" (S 23). Conversely, S 36 claimed, "Thanks to NLP, now I'm confident enough to do public speeches to any audience". Also, S 27 stated, "This is such a best method we ever found to learn not only English but any other subject and work too", while S 38 expressed, "teacher's guidance and motivation mean a lot for us to make this success" These statements advocate that they credited the teacher's guidance and motivation for their success and found the NLP technique to be motivating not only for English learning but also for other subjects and tasks. They expressed gratitude for the impact of NLP on their language ability and overall growth.

Future Use of NLP Technique: All students enthusiastically expressed their commitment to using the NLP technique in the future to achieve their life goals. They firmly believed that the techniques they learned during the study would be invaluable in their personal growth and success in various areas of life.

V CONCLUSIONS AND RECOMMENDATIONS

Conclusions

This research paper examines the integration of NLP (Neuro-Linguistic Programming) in enhancing public speaking skills in English language teaching. The study focuses on the NLP technique "Outcome Orientation," as one of the pillars of NLP coaching. The conclusion of this study in accordance with two objectives is discussed in this subsection.

Based on the analysis of quantitative data, the first research objective can be concluded that the NLP technique "outcome orientation" has a notable impact on enhancing public speaking skills among English language learners. Consequently, it can be concluded that the implementation of

this NLP technique in the educational context leads to substantial improvements in students' public speaking abilities.

Based on the analysis of qualitative data investigated against the second research objective, it can be concluded as the same as the first objective, NLP techniques positively impact students' public speaking skills and language proficiency. Integrating NLP principles in language education creates a supportive environment, empowering students to communicate confidently and effectively. The use of NLP techniques fosters self-reflection, a growth mindset, and resilience. Feedback from participants showed that the NLP technique inspired confidence in preparing and delivering English speeches, and students acknowledged their progress and appreciated the teacher's support.

Recommendations

The paper recommends further research with larger sample sizes and longitudinal studies to better understand the sustained benefits of NLP interventions on students' public speaking skills and language proficiency. Integrating NLP techniques into language curriculum design is suggested based on the study's findings to enhance students' language ability and public speaking skills. To effectively implement NLP techniques in language classrooms, comprehensive professional development and training for language teachers on NLP principles and strategies are recommended. Personalized support should be provided to students who need additional help in developing their public speaking skills. Encouraging the use of multimodal instruction and incorporating multimedia resources can complement NLP techniques in the curriculum. Implementing these recommendations can cultivate articulate and self-assured communicators with essential language skills for academic and real-world success.

REFERENCES

- Anjomshoaa, H., Snagui Moharer, R., and Shirazi, M. (2021). The effectiveness of training based on neuro-linguistic programming and cognitive-behavioral approach on students' anxiety, depression, and stress. *Int. J. Pediatr.* 9, 14856–14866. doi: 10.22038/IJP.2021.57871.4539
- Bandler, R. (1985). *Using your brain for a change*. Utah: Real People Press.
- Begum, A. J., Paulraj, I. J. M., and Banu, S. H. (2022). Neuro-linguistic programming (NLP) is a promising communicative English language teaching technique. *Sch. Int. J. Linguist. Lit.* 5, 100–104. doi: 10.36348/sijll.2022.v05i03.004
- Blaine, K.L., & Hornyak, M. J. (2012). *Smart Goals: How the Application of Smart Goals Can Contribute to Achievement of Student Learning Outcomes*. Developments in Business Simulation and Experiential Learning, 29.
- Carey, J., Churches, R., Hutchinson, G., Jones, J., Foreword, P. T., & West-Burnham, J. (2010). *Neuro-linguistic programming and learning: teacher case studies on the impact of NLP in education Full report Neuro-linguistic programming and learning: teacher case studies on the impact of NLP in education 2 Welcome to CfBT Education Trust*. www.cfbt.com
- Carvajal, A. K., Santiago, A. D. S., & Salazar, M.A., (2021). Neurolinguistic programming techniques in the development of speaking skill Human and Social Science Artículo de investigación Neurolinguistic programming techniques in the development of speaking skill. 7(5), 1171–1183. <https://doi.org/10.23857/dc.v7i5.2304>
- Gehlbach, H., and Robinson, C. D. (2021). From old school to open science: the implications of new research norms for educational psychology and beyond. *Educ. Psychol.* 56, 79–89. doi: 10.1080/00461520.2021.1898961
- Gran, S. (2021). *Using NLP (Neuro-Linguistic Programming) Methods in Teaching and Learning: Case Studies on the Potential and Impact of NLP Methods on Learning and Learners* (Doctoral dissertation, Dissertation), Duisburg, Essen, Universität Duisburg-Essen 2020).
- Gunawardana, A. A., & Karunaratna, J. B. (2017, May 1). *English Language Teaching (ELT) in Sri Lanka*. English Language Teaching (ELT) in Sri Lanka. <http://repo.lib.sab.ac.lk:8080/xmlui/handle/123456789/1469>
- Hallett, C (2020, June 12), *The Men's Midlife. How NLP Will Help You Become a Better Public Speaker*. Medium. <https://medium.com/@chrishallett/107/how-nlp-will-help-you-become-a-better-public-speaker-b4be9a8a5a0>
- HENNI. (2018). *The Use of NLP Techniques in English Language Teaching*. PEOPLES' Democratic Republic of Algeria Ministry of Higher Education And Scientific Research University of Mostaganem Department of English. Retrieved June 7, 2023, from <http://ebiblio.univmosta.dz/bitstream/handle/123456789/13099/The%20Use%20of%20NLP%20Techniques%20in%20English%20Language%20Teaching%20Classes.pdf?sequence=1&isAllowed=y>
- Jahan, J., Tariq, M., and Nadeem, M. (2022). The effects of neuro-linguistic programming on a psychotherapist's communication patterns: a case study. *J. Dev. Soc. Sci.* 3, 112–147. doi: 10.47205/jdss.2022(3-II)13
- Javadi, Y., & Asl, S. A. (2020). Neuro-linguistic Programming, Teacher's Identity, and Teachers' Effectiveness. *Journal of Language Teaching and Research*, 11(3), 389. <https://doi.org/10.17507/jltr.1103.07>
- Jayanthi, G. (2021). NLP techniques for teaching gen z students: rethinking new ways of communication. www.ijert.org
- Karunaratna, J. A. M.B. (2020). Improving the Use of Language Hedges in Academic Writing through Reading Journal Articles. *Advances in Language and Literary Studies*, 11(3), 17. <https://doi.org/10.7575/aial.ac.all.v.11n.3p.17>
- Keezhatta, M. S., and Omar, A. (2019). Enhancing reading skills for Saudi secondary school students through mobile assisted language learning (MALL): an experimental study. *Int. J. English Ling.* 9, 437–447. doi: 10.5539/ijel.v9n1p437
- Kizi, M. F. S. (2021). *The Correlation of Effective Speaking Methods and Neurolinguistic Programming* Mannonova F.Sh. Email: Mannonova6112@scientifictext.ru. <https://cyberleninka.ru/article/n/the-correlation-of-effective-speaking-methods-and-neurolinguistic-programming>
- Li, X. (2018). *Integrated Teaching Model for Undergraduate English Majors' English Public Speaking Course in China*. *Creative Education*, 9, 469–478. doi: 10.4236/ce.2018.93033.
- Moscoco, M. M. (2018). *A School-based professional development proposal: Neuro-linguistic programming (NLP) techniques for ESL teachers at a private school in Antioquia* (Unpublished master's thesis). Universidad Pontificia Bolivariana
- Ningsih, M. (2016). Improving students' speaking skills using neurolinguistic programming techniques. *Revista Brasileira de Ergonomia*, 9(2), 10. <https://doi.org/10.5151/cidi2017-060>
- NLP Well Defined Outcomes. (2021, May 31). *NLP Training, NLP, NLP Coaching Academy Bangalore, Accredited Richard Bandler Programs, NLP Course, Life Coach India*. <https://nlpccoach.in/nlp-well-defined-outcomes/NLP-Foundations-The-Four-Pillars-of-NLP-JEFF-TURNER-Hypnotherapy-Life-Management>. (2018, May 23). JEFF TURNER Hypnotherapy & Life Management. <https://lifemanagement.co.uk/index.php/2018/05/23/the-four-pillars-of-nlp/>
- Nompo, R. S., Pragholaipati, A., and Thome, A. L. (2021). Effect of neuro-linguistic programming (NLP) on anxiety: a systematic literature review. *KnE Life Sci.* 1, 496–507. doi: 10.18502/cls.v6i1.8640

- Nunan, D. (1991). *Language teaching methodology: A textbook for teachers*. Prentice Hall
- Pishghadam, R., & Shayesteh, S. (2014). Neuro-linguistic Programming (NLP) for Language Teachers: Revalidation of an NLP Scale. *Theory & Practice in Language Studies*, 4(10), 2096-2104
- Rayati, M. (2021). Neuro-linguistic programming and its applicability in EFL classrooms: Perceptions of NLP-trained English teachers. *Language Teaching Research Quarterly*, 24, 44–64. <https://doi.org/10.32038/ltrq.2021.24.03>
- Richards, J. C., & Rodgers, T.S. (2001). *Approaches and Methods in Language Teaching*. New York: Cambridge University Press.
- Saraswat, D. (2023). Role of Neuro Linguistic Programming in improving listening and speaking skills. In *Educational Resurgence Journal* (Vol. 5, Issue 2). <https://coed.dypvp.edu.in/educational-resurgence-journal/>
- Siddiqui, Z. (2018). English language teaching through nlp: techniques and methods Zeba Siddiqui. In *Research Journal of English Language and Literature (RJELAL) A Peer Reviewed (Refereed) International Journal Impact Factor (Vol. 6)*. <http://www.rjelal.com>;
- Silva, D. (2017). Develops and Research Material on Education for NHEG Websites, Magazines, and Teaching Material, Book Author for NHEG.
- Tarnopolsky, O. B. (2016). NLP, suggestology and stage-acting in teaching English as a second/foreign language. *Innovative Solutions in Modern Science*, 1(1), 1-11.(2018, December 14). Relieve fear of public speaking with NLP. *NLP World*. <https://www.nlpworld.co.uk/relieve-fear-public-speaking-nlp/>
- Wijayatunga, A. (2018). English as a medium of instruction in secondary schools in Sri Lanka: challenges | *Proceedings of the International Conference on Education*. Retrieved October 9, 2022, from <https://tiikmpublishing.com/proceedings/index.php/icedu/article/view/429>
- Zhang, X., Davarpanah, N., & Izadpanah, S. (2023). The effect of neurolinguistic programming on academic achievement, emotional intelligence, and critical thinking of EFL learners. *Frontiers in Psychology*, 13. <https://doi.org/10.3389/fpsyg.2022.888797>

Assurance of Test Authenticity: Power of Table of Specification (TOS)

S.A.N. Danushka
Department of Education & Training
University of Vocational Technology
Sri Lanka
ndanushka@uovt.ac.lk

P.S.Y. Gamage
Department of Education & Training
University of Vocational Technology
Sri Lanka
padmashanthi@uovt.ac.lk

Abstract – Table of Specification (TOS), or is called as Test Blue Print contextually, is a significant theory-laden techniques to be utilized in developing valid and reliable written tests despite either in primary, secondary or tertiary level of educational assessment. And TOS provides an overall picture whether the written tests are aligned to cognitive levels suggested in Bloom's taxonomy and balance the knowledge assessments categorically among low-order and higher-order knowledge accumulation. A descriptive survey was conducted to identify whether University lecturers are willingly following the so-called knowledge assessment requirement in undergraduate level technology courses. Fifty three lecturers responded for the online survey questionnaire distributed via emails. Qualitative data was thematically analysed and quantitative data was statistically analysed via graph and percentages. Significantly the survey revealed that majority of the lecturers are unaware of TOS and they have not been using it in written test development.

Keywords - Knowledge Assessment, Table of Specification (TOS), Teacher-made tests, Test validity and reliability, Test development

I. INTRODUCTION

Testing is solemn in education as it depicts the effectiveness of the teaching-learning process, and eventually, testing makes a perpetual influence on student affairs in due course so that it should be legitimate in construction, implementation, and evaluation. As teacher-made tests have been the major source of drawing inferences about college-level student achievements, such

tests ought to be valid and reliable to get done the task. Test construction needs aligning to certain theoretical and empirical concerns targeting legitimacy; one such attempt

has been Table of Specifications (TOS) which is a two-way grid that demonstrates the interrelationships among test items and instructional objectives (Musah, Al-Hudawi, Tahir & Kamil, 2015; Gul, 2016; Osebhohiemen, 2019).

Table of Specifications has long been used in test construction (Weis, 1976; Dills, 1998; Fives & DiDonato-Barnes, 2013; DiDonato-Barnes, Fives & Krause, 2014; Musah, Al-Hudawi, Tahir & Kamil, 2015) but empirical research outcomes show that college teachers lack knowledge and skills which need for accurate development of TOS (i.e. Osebhohiemen, 2019, p. 80; Jugar, 2013, pp. 5 – 7). As it has been observed in the local university context, lecturers are not aware about the use of TOS and its applicability. Hence, it would be noteworthy inquire about the use of TOS among the local university academic staff.

LITERATURE REVIEW

The question on hand is, thus, finding out 'what does TOS do for testing?' Notar, Zuelke, Wilson, and Yunker (2004) affirmed that "the use of a table of specifications can provide teacher-made tests validity" (p. 115). Gul (2016) and Owen (2018) also held the same notion that Table of specifications improves test validity. The Table of Requirements (TOS) is a valuable educational assessment tool that describes the distribution of content across different cognitive levels and learning goals, assisting in the design of balanced and holistic assessments. It helps educators align their assessments with the intended curriculum, ensuring a fair and representative assessment of students' knowledge and skills. TOS guides the creation of tests by assigning a question rate related to each topic and cognitive level, avoiding overemphasis on some areas and ignoring others. This leads to more valid and reliable assessments, as it takes into account the diversity of the content and the perceived needs of the learning objectives.

The Table of Specification (TOS) is an important tool in educational assessment because it provides a structured framework for designing assessments that accurately reflect the program's learning goals. TOS helps educators ensure the validity, reliability, and fairness of assessments by consistently linking content to cognitive levels and learning outcomes. By assigning the distribution of questions to different topics and cognitive domains, TOS avoids bias and overemphasis on certain areas, promoting a comprehensive assessment of knowledge and skills.

TOS improves instructional planning by emphasizing the relative importance of each topic, allowing educators to allocate instructional time more effectively. It also helps students focus their academic efforts on the areas to be assessed, reducing unnecessary stress and promoting better academic results. In addition, TOS contributes to the transparency of assessment design, promoting a clear understanding of the assessment process among students, educators, and other stakeholders. This transparency helps maintain the quality and integrity of the assessment process, consistent with educational goals.

Test validity is a questionable attribute in tests it seems indiscernible on the face of a test but it is a fixed property of a test (Wolming & Wilkstrom, 2010, p. 118). Test validity means the degree to which the evaluations or judgments we make as teachers about our students can be trusted based on the quality of evidence we gathered (Wolming & Wilkstrom, 2010; Owen, 2018). Undoubtedly, test validity entrusts the quality of testing. Another form of checking the test quality is reliability which is an inseparable property of tests as it shows the amount of measurement error associated with test scores (Frisbie, 1988, p. 55). In addition, test item analysis supports eliminating misleading test items, items which can be used in later measures and items which could be having higher reliability in a test (Quaigrain & Arhin, 2017, p. 2).

A. Test validity and reliability

The highly interrelated but conceptually different properties of a test, validity and reliability, supports the test developers to understand whether test measures the intended cognitive capabilities. To assure the authenticity of a test, types of validity and types of reliability must be ensured (Alias, 2005). Face validity is crucial in ensuring that test-takers proceed and try their best on a test. A test that is other than what it claims to be measuring – absence of face validity – may discourage students from continuing with the test. Therefore, determining whether a test possesses face validity does not require the opinion of an expert. Content validity needs the opinion of an expert as it shows consistency between the syllabus content, test objectives and test contents. If the test contents cover up the test objectives and representative of the syllabus, it could be said that the test has the content validity.

Three types of classroom test reliability can be found, namely: internal consistency, inter-rater and intra-rater reliability (Black, 1999). Internal consistency refers to consistency of objectives among the items of a test (Alias, 2005). i.e. if the items of a test measure the same set of objectives related to test modes, then the internal consistency of a test is met. Inter-rater reliability refers to if the different raters give almost the same marks for same quality answers in a test (Gisev, Bell & Chen, 2013). Doubts to inter-rater reliability come when the raters give different marks for the same quality answers. Intra-rater reliability refers to marks given by the same teacher for the same answer at different occasions. If the teacher is tired of marking answers when time goes on and starts giving low marks, intra-rater reliability

issues come. Inter-rater and intra-rater reliability can be increased by a marking scheme or a marking rubric which is pre-designed and guided to mark answer scripts.

Then, how could the reliability and validity of a test be kept? Several measures can be employed in that regard. Deciding on a test objective, designing and developing a test, evaluating the test and test administration are the typical activities followed in the assessment process (Alias, 2005). Test objective can be formulated via ABCD format (Khan et al., 2012). It assists designing and developing a test. With the well-written objectives of a test, designing and developing the test is started. As many test items to be developed and covered the syllabus, test development process is critical. This task can be achieved via continuing with the Table of Specification (TOS). TOS is the best means of setting the match between syllabus and cognitive levels. Content validity of a teacher-made test can be theoretically achieved with the TOS. In the first row of the TOS associated with cognitive levels – which is the cognitive levels emphasized in Bloom's Taxonomy or SOLO Taxonomy. The first column deals with the topics and subtopics covered in the syllabus and percentage coverage of the content is shown in the second column. Further, TOS shows the number of items to be developed on each topic or objective proportionally to the time allocation. And item format (MCQs, restricted/extended response items) can also be given in the adjacent column. TOS supports determining marks for each objective/topic and overall weightage allocated (Alias, 2005). Deciding the test format, though it has been done typically looking at previous tests, needs careful attention balancing the different formats as selection type items (MCQs, True/False, matching items and filling the blank items) measure factual knowledge and supply type items (Structured essay and Open-ended items) measure depth knowledge on the content covered. Typically, test validity increases with selection type items. Conversely, essay type items take considerable time in marking the answers whereby it needs greater effort ensuring intra-rater and inter-rater reliability of a test. Test item construction can reduce the validity and reliability of a test due to many reasons like poor language usage, context of the problem, and ease of understanding. Further, ambiguous questions, questions which have different interpretations and bias questions might affect the test validity and reliability.

Test evaluation may also be a considerable attribute in student assessment. Evaluation is twofold: formative and summative. Formative assessments target small groups of students, also called in-course or continuous assessments, items are subsequently analyzed and decide the reliability. Feedback could be accommodated and revised for the test, but summative assessments come at the end and analysis is performed after the test. Feedback would be important for the next batch.

Test item analysis is done to identify the quality of test items. Two statistical techniques can be used to estimate item quality, namely Difficulty Index and Discrimination Index

(Mahjabeen et al., 2017). Difficulty index value 0.5 is said to be good for norm-referenced test (Alias, 2005)

III. STUDY QUESTIONS AND OBJECTIVES

The following research question and objectives appear to be deemed appropriate in achieving the intended study purpose.

A. Research questions

What is the level of awareness of the use of table of specification among university lecturers?

B. Objectives

1. To what extent are the University lecturers conversant with the procedures of constructing table of specification?
2. To what extent are the University lecturers using table of specifications in developing teacher-made tests

III. METHODOLOGY

As this study is to understand the existing phenomena of the study problem, a *descriptive survey research design* was employed (Salaria, 2012, p. 8) and data gathered via survey questionnaire which emailed to respondents in the University of Vocational Technology. Similar type of questionnaires has been frequently employed in survey research data collection in quite similar studies conducted in many disciplines including education (i.e. Odiagbe, 2017, p. 72; Musah, Al-Hudawi, Tahir & Kamil, 2015, p. 195). Survey questionnaire consists of ten closed-ended questions to find out the attitudes about using the TOS in teacher-made tests and it was piloted with a few academics before distribution to the sample. Piloted survey questionnaire was further revised and distributed to the sample which consist of fifty-three respondents (n=53) and invited to fill it online. Collected data was qualitatively and quantitatively analyzed to answer the two study questions.

Though it has been understood that teacher-made tests should meet psychometric properties like validity and reliability, the practice could differ from what is practised. Thus, to understand the effect of table of specifications in improving validity and reliability in teacher-made tests in any educational context, descriptive survey research (quantitative dominant) is applicable as such an attempt undoubtedly amplifies issues in the existing body of knowledge and practice.

V. DATA ANALYSIS AND INTERPRETATION

Survey respondents belong to different technology disciplines of the University. They undertake students' assessment, namely continuous and final assessments, in the respective technology areas. One of the duties of them is

developing theoretical written papers for undergraduate students in respective technology areas. As per the responses received, 23% of the lecturers are from Hotel and Tourism Management, 19% of ICT, 15% from Food Technology, 11% from English Language and rest of respondents represents Education Technology, Mechatronics, Industrial Management, Manufacturing Technology etc. Significantly, the survey found out that 69% of the lecturers have not attended any training or workshop related to student assessment and only 31% of lecturers have received training on student assessment and evaluation.

Fig.1 depicts that 67% of the lecturers are not aware of TOS. The finding is not favorable as there is a higher probability of having invalid and unreliable written assessments for undergraduate students in many fields of technology studies. Further, the final results cannot be acceptable, and the assessment related decisions are questionable due to this factor.

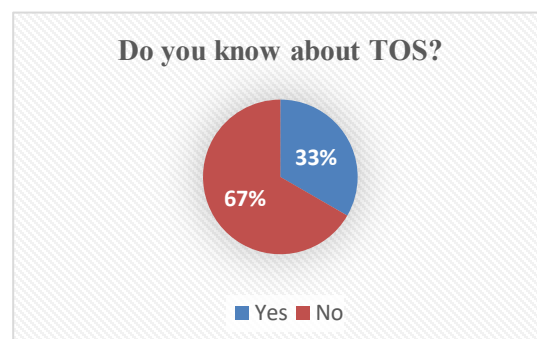


Fig. 1 Question wise responses

Table 1 shows question wise responses for the survey questions. Many lecturers are willing to know about TOS but a little attention has been paid over the issue due to unawareness of the role played by TOS in written test development and its validity and reliability. Similarly, though 38% of lecturers are aware of TOS, only 35% of lecturers are using it.

15% of lecturers know the advantages of TOS while 35% know and 50% said that they do not know it totally. These figures show that lecturers should have an exposure to TOS and its advantages. Finally, survey asked whether lectures are aware of the relationship between TOS and validity. Only 54% lecturers are having a command of practice over the use of TOS in written test development.

TABLE 1
QUESTION WISE RESPONSES

Question	Yes	Somewhat	No
4. If 'No' for question no 3, would you like to know about TOS?	81%		19%
5. Have you used TOS when you develop written test papers?	35%		65%
6. Do you know the advantages of using TOS in developing teacher-made tests?	15%	35%	50%
7. Do you know the relationship between TOS and test validity?	19%	27%	54%

Survey results are insightful and comprehensive for scholars and academics as they perform a sort of accountable duty for students and society. Test results demonstrate how well the teaching-learning process has been organized and planned to aim at the achievement of educational goals and needs of a country. If the educators are blind about implications of some theoretical concerns such as TOS specially in assessment, variation between the objectives and outcomes would be higher.

VI. CONCLUSION

The study aimed at identifying the awareness of lecturers about TOS and its benefits in test written development. Survey affirmed that the lecturers, around 68% respondents of the sample, were unaware of such a significant and essential theory-based practical application for teacher-made test development. Further, psychometric attributes of test, validity and reliability, highly rely on test development and item development. If the assessors are unaware of theoretical and practical concerns of test development certainly test validity and reliability could not be assured thereby the test authenticity would be lost.

REFERENCES

- Black, T.R., (1999), *Doing Quantitative Research in the Social Science: An Integrated Approach to Research Design, Measurement and Statistics*. London: Sage.
- DiDonato-Barnes, N., Fives, H., & Krause, E. S. (2014). Using a Table of Specifications to improve teacher-constructed traditional tests: an experimental design. *Assessment in Education: Principles, Policy & Practice*, 21(1), 90-108.
- Dills, C. R. (1998). The table of specifications: a tool for instructional design and development. *Educational Technology*, 44-51.
- Fives, H., & DiDonato-Barnes, N. (2013). Classroom test construction: The power of a table of specifications. *Practical Assessment, Research, and Evaluation*, 18(1), 3.
- Frisbie, D. A. (1988). Reliability of scores from teacher-made tests. *Educational measurement: Issues and practice*, 7(1), 25-35.
- Gisev, N., Bell, J. S., & Chen, T. F. (2013). Interrater agreement and interrater reliability: key concepts, approaches, and applications. *Research in Social and Administrative Pharmacy*, 9(3), 330-338.
- Gul, S. (2016). Integration of Table of Specification (ToS) in Academic Teaching and Evaluation.
- Jugar, R. R. (2013). An inquiry on the roles of personal test item banking (PTIB) and table of specifications (TOS) in the construction and utilization of classroom tests. *International Journal of Education and Research*, 1(12), 1-8.
- Khan, T., Hande, S., Bedi, S., Singh, T., & Kumar, V. (2012). Learning Objectives: "Perfect is the Enemy of Good!". *International Journal of User-Driven Healthcare (IJUDH)*, 2(3), 44-62.
- Mahjabeen, W., Alam, S., Hassan, U., Zafar, T., Butt, R., Konain, S., & Rizvi, M. (2017). Difficulty index, discrimination index and distractor efficiency in multiple choice questions. *Annals of PIMS-Shaheed Zulfiqar Ali Bhutto Medical University*, 13(4), 310-315.
- Musah, M. B., Al-Hudawi, S., Tahir, L. M., & Kamil, M. (2015). Validity of teacher-made assessment: A table of specification approach. *Asian Social Science*, 11(5).
- Nesamalar, C. J., & Revi, M. (2016). Assessment: Types and Methods. In *Assessment Strategies in Science* (pp. 13-28). Springer.
- Notar, C. E., Zuelke, D. C., Wilson, J. D., & Yunker, B. D. (2004). The table of specifications: Insuring accountability in teacher made tests. *Journal of Instructional Psychology*, 31(2), 115.
- Notar, C. E., Zuelke, D. C., Wilson, J. D., & Yunker, B. D. (2004). The table of specifications: Insuring accountability in teacher made tests. *Journal of Instructional Psychology*, 31(2), 115.
- Odiagbe, S. I. TABLE OF SPECIFICATION: ENSURING CONTENT VALIDITY OF TEACHER- MADE-TEST AMONG SENIOR SECONDARY SCHOOLS TEACHERS IN KWALI AREA COUNCIL. *Journal of the Nigerian Academy of Education Vol*, 13(1), 69.
- Osebhohiemen, E. (2019). Use of Table of Specification in Construction of Teacher-Made Achievement Test in Mathematics in the Primary and Secondary Schools. *The Melting Pot*, 5(2).
- Quaigrain, K., & Arhin, A. K. (2017). Using reliability and item analysis to evaluate a teacher-developed test in educational measurement and evaluation. *Cogent Education*, 4(1), 1301013.
- Salaria, N. (2012). Meaning of the term descriptive Survey research method. *International Journal of transformations in business management*, 1(6), 1-7.
- Weis, S. F. (1976, Jan./Feb.). The use of the Table of Specifications in developing educational objectives and evaluation. *Illinois Teacher of Home Economics*, 79(3), 167-169.
- Wolming, S., & Wikström, C. (2010). The concept of validity in theory and practice. *Assessment in Education: Principles, Policy & Practice*, 17(2), 117-132. DOI: 10.1080/09695941003693856

Challenges Faced in Understanding Subject Content Due to the Change of Medium of Instructions from L1 to L2: A Case Study Based on a Technical College in Sri Lanka

L. H. S. Piyumika
Department of Language Studies
University of Vocational Technology
Sri Lanka
elt19b139@uovt.ac.lk

A. A. Gunawardana
Department of Language Studies
University of Vocational Technology
Sri Lanka
anoma@uovt.ac.lk

Abstract— English Medium Education (EME) is a popular concept and is often used from primary to tertiary education. In school education, selected subjects are offered under English Medium Instructions (EMI) and at the tertiary level, most of the courses are offered under EMI. Even students who get an opportunity to select the medium of instruction at school, are not getting a chance to do the same at the tertiary level, apart from a few courses. The majority of Sri Lankan students follow the school education in Sinhala or Tamil (first language). Once they move to the tertiary level, they have to continue their study in English (second language). As a result, students are facing challenges and issues. Therefore, this study aims to find out the challenges students faced in understanding subject content due to the change of medium of instruction from first language to second language. This qualitative study was done as a case study of 15 students who are following Telecommunication Engineering (NVQ level 6) at a Technical College in Sri Lanka. A face-to-face interview was conducted to review the challenges in depth. Data were analyzed based on thematic analysis. Findings reveal that students who had exposure to EMI during school time are performing well at the tertiary level with fewer difficulties. Unlike reading, writing, and listening, students are afraid to speak in English. They face challenges in enhancing their English language while attempting to understand the subject content. Some practical solutions can be suggested to overcome challenges under EMI. EMI can be applied to the teaching-learning process from primary education onwards. Well-trained and professionally qualified English teachers should be recruited for technical colleges to enhance grammar, vocabulary, and other aspects of language.

Keywords—Bilingual Education, Challenges, English Medium Education, English Medium Instruction, Tertiary Education

I INTRODUCTION

English is considered a universal language in which all can communicate. There is no doubt that everyone is trying to learn this due to the excessive demand for English globally. It is the world's second-largest native language. (Britannica, n.d.) English is a West Germanic language of the Indo-

European language family. It originated in England and is used as a dominant language in the United States, the United

Kingdom, Canada, Australia, etc. English is used as a lingua franca all over the world. Now it is used all over the world as a global language by creating many opportunities. English is used in many fields such as business, technology, education, and health. Especially in the field of education, it has many advantages as well as disadvantages because Sri Lankans use it as the L2. In the 19th century, the Education System in Sri Lanka started conducting teaching and learning in English medium. EMI can be defined as teaching academic subjects using English. Commencing EMI was a great step in the process of education. In EMI classes, students have dual tasks. One is that students learn their academic content in English medium and the other is students get an opportunity to cultivate English language proficiency (ELP). Also, EMI is about speaking and writing in the classroom hence, students will develop listening and reading skills as well. The commencing of EMI was a huge process and it took a long time to be implemented. In history, missionary schools which were started by the Dutch and British provided education through the medium of English. Moreover, the Sri Lankan education system reflected mainly on the British model. At the beginning of the 19th century, there were two types of schools; charity and village schools and the others were grammar and public schools. However, during the latter stages of British rule, three types of schools emerged. They were English (private) schools, Anglo Vernacular schools, and Vernacular schools. Anglo-Vernacular schools or bilingual schools were established to produce officials who could work in the government sector. These schools provided instructions in the local language at the lower level and English at the higher level. Most Asian countries which were under the British Colonization started to switch their medium of instruction to English for their educational purposes. However, those colonized countries had doubts about the use of English for future purposes. They were not sure whether to continue education with the colonial language or the local language. Sri Lanka as an Asian country faced this issue. So, Sri Lanka continued English medium education from the school level to the tertiary level. This was the starting point of EMI in Sri Lankan secondary-level education. Even though most of the students studied secondary education in their first language, more students wanted to follow the

courses that were available in English medium under tertiary education. The reasons can be the validity of the course is higher when it is learned in English medium and it is easy to find jobs that are related to the field. On the other hand, most of the world-recognized courses are offered only in English to keep the recognition of the institutions. Though English medium is optional in secondary education in Sri Lanka, for some courses English medium is compulsory at the tertiary level. Once the students finish their secondary education, they enter to the tertiary-level education. Most of the students follow their secondary education under Sinhala medium and Tamil medium instructions but when they move to the tertiary level, they have to follow courses in English medium. A student who goes thirteen years of education in their first language will face several challenges when they change their medium of instruction at the tertiary level. Apart from a few courses, most of the world-recognized courses are conducted in English at the tertiary level because of the concept of globalization. The constitution of Sri Lanka has allowed being educated in English. Therefore, students who study at universities, colleges, vocational institutes, and other higher national institutes experience a different educational environment which is different from the school environment. They face difficulties such as understanding new subject content and interacting with lecturers and instructors and language issues such as spelling pronunciation and vocabulary.

Research Problem

The purpose of this study is to find out the challenges faced by students of technical colleges in understanding the subject content due to the change of medium of instruction from Sinhala at the secondary level of education to English at the tertiary level in Sri Lanka because many students follow their secondary education in Sinhala. Once they finish their secondary education, they are ready to start their education at one of the higher educational institutes. Currently, most students select technical colleges to continue their higher studies and most of the National Vocational Qualification courses are conducted only in English medium, so students have to face numerous challenges as they have to switch their medium of instruction when they start their higher education.

Research Objectives

The objectives of the research are,

1. To find out whether teaching materials and learning materials used for teaching become challenging in understanding subject content
2. To explore the language aspects that become more challenging when understanding subject content in class or at exams
3. To identify the challenges students, face when using technical terms in understanding subject content

II LITERATURE REVIEW

An overview of English Medium Education in Sri Lanka

English was introduced to Sri Lanka with the arrival of the British in 1796. It was spread in the system of Education

chronologically. English was the language of administration under the British rule. Also, it was the language of higher education and school education. The Christian missionaries started teaching English in Sri Lanka. From 1796 to 1948, English was the medium of instruction. English was considered a ladder to achieve high positions. Schoolchildren were given the privilege of having their education through Sinhala and Tamil. However, English was one of the subjects of the school curriculum and was the of instruction in the universities and other higher educational institutions (Sanmuganathan,2017). EMI can be defined as the use of the English language to teach academic subjects in countries where the first language of the majority of the population is not English. "For EMI courses, the delivery of content, whole class interaction, the learning materials, and the demonstrations and assessment of learning outcomes (such as oral presentations, assignments or tests) should be in English" (Dearden & Spain, 2021).

EMI at the School Level

Many researchers have investigated how English education works and the pros and cons of it. Mahawatta (2012) has done research that foreshadows difficulties that students face in Bilingual Education (BE). According to her, many schools all over the country conducts BE program. It is done by using EMI for selected subjects such as Mathematics, Science, and Technology including Computer Literacy and Social Science. It is expected that students will be confident in the language when they finish secondary education. In Sri Lanka, students will differ from one another based on the exposure to the language they are having. Yet, many surveys have found that students of BE in schools face several difficulties in Speaking English. The reason can be negligence of speaking in English in the classroom. Moreover, Illeperuma (2022) defines English as the language of science. When we had to shift to the English medium, we did not have any difficulties since the technical words in English used in our daily lives. But when learning science in Pali or Sanskrit, it is difficult because we never use such words in our daily lives. Some studies were carried out to discuss BE program (BEP) strengths and issues. Nanayakkara (2017) divides issues that are related to BEP into two categories. They are policy and implementation-level issues. According to his study, there is no exact policy to make circulars. As well policy is not addressing the ways to solve issues in BEP. Moreover, he states that it is important to introduce a new circular that should include what subjects and number of subjects to be taught, curriculum development, assessment, BE teacher development, and recruitment and training programs available. This will be important if respected authorities pay attention to the above factors to develop BEP. The above studies discuss a large of EMI. Many researchers have pointed out that there are many opportunities and challenges of BE at schools in Sri Lanka.

EMI at Tertiary Level

Unlike schools, English is used as a medium of instruction at the tertiary level. Higher educational institutes conduct courses in English medium. Even though this is challenging,

neither students nor lecturers can skip this process. Navaz (2016) finds out that the medium of instruction in many universities is English for Science, Engineering, and Medicine. First-language learners face many challenges when they switch their medium to second language. Many researchers have focused their attention on this. According to some of the studies, it was revealed that some of the drawbacks in the successful implementation of English medium education in the university were; the training provided for the lecturers had not improved their teaching methodology to teach the content through English and the absence of a standardized university policy towards languages and multilingualism that provided strategies for BEP. Moreover, Neranjani (2021) expresses many researchers have identified that the lack of experience of the teachers of subject matter in the development of language by balancing both language and content objectives is the one of shortages in Sri Lankan universities. Also, most instructors or lecturers are not aware of using language to teach pedagogy. It can be considered as demotivation for students because they are not able to complete their tasks due to inadequate instructions in English. Therefore, most students identify that the content they learning as a burden. Each research foreshadows the challenges students face when they are learning under English medium instructions. It depicts that both school education and tertiary education bear the above challenges and issues. Though most of the previous research had been done to investigate the challenges as a medium of instruction in English at the school level and universities, there is less research finding the challenges of EMI in technical colleges in Sri Lanka. Students at universities face many challenges due to the change of medium of instruction. Many researchers in Sri Lanka have addressed the above issues and have made recommendations. However, no research has been conducted to talk about technical education which is currently most important. Therefore, this research aims to fill the above gap by discussing the challenges of EMI for students who study at technical colleges in Sri Lanka.

III METHODOLOGY

Research Method

The study was done as a qualitative study because the researcher wanted to find out the challenges students face when they are following NVQ courses in English medium. The researcher's determination by doing this qualitative study is to find out the students' perceptions in-depth whether the teaching materials and learning materials used for teaching become challenging in understanding subject content, to explore the language aspects that become more challenging when understanding subject content in class or at exams and to identify the challenges students face when using technical terms in understanding subject content. Students who are following NVQ-level courses have to refer to materials in English. So, it is a major challenge. Doing a qualitative study will help to explore students' points of view or their ideas in depth and it helps to elicit the students' views about challenges they face when understanding the subject content under EMI.

Research Design

Under the qualitative approach, the researcher focuses on a case study. This case study was done to identify the challenges deeply. The word "case study" itself describes a study of a single case which are related primarily to people, a program, or a particular institute or organization. The case study focuses on a single entity and it has some boundaries which are clearly defined. The reason to do this study as a case study is that the challenges students face at College of Technology, Galle cannot relate with the students who are studying at every technical college. By doing this case study, the researcher can suggest for future researchers to conduct the same study as a survey to find out the challenges. This case study helps to elicit the issues of students who studied their secondary education in Sinhala or Tamil face when they switch their medium to tertiary education.

Population & sample

This case study was done at one of the technical colleges in Sri Lanka. One reason to select a technical college apart from universities and other higher educational institutes is that most of the students' option to follow a course that is relevant to the field they like to work. Technical colleges provide a wide range of courses that students can select for their interests. Also, they provide knowledge, skills, and training for every course. Among 33 colleges, the College of Technology (CoT), Galle was selected to conduct the case study because it provides different course categories and a higher number of students are currently studying in this. Also, technical colleges provide certificates and NVQ level 1-6 courses. All certificate courses and NVQ level 1-4 courses are conducted in the first language and NVQ level 5 and 6 courses are conducted only in English. Therefore. These courses are valid in foreign countries and many opportunities are available in the world of work. Another reason is this NVQ framework is very famous among the young generation nowadays. Therefore, most students prefer to follow NVQ courses and they continue up to NVQ level 7 (degree level) which is offered by the University of Vocational Technology, Ratmalana. The population was students who studied Telecommunication Engineering (NVQ level 6) at CoT, Galle. There are 33 students in the course and among them, 15 students were selected under simple random sampling. The sample was limited to 15 as the questions asked at the interview covered a wide area and the researcher aimed to find out the opinions of the students in depth. Therefore, the convenient number for the researcher was 15. Both clever and weak students were in the sample to identify the challenges.

Data Collection Procedure

The researcher used primary and secondary data to conduct the study effectively. The primary data were collected through a face-to-face interview and the secondary data were collected through previous research articles which are relevant to the study. The interview was conducted within a day. It was conducted at CoT, Galle. Three and a half hours were spent to interview 15 students. Each student was interviewed by spending 10-15 minutes. Interviewees participated in the interview actively and shared their

opinions for asked questions. Students were taken one by one. Questions were prepared to cover the three objectives. 13 questions were asked from interviewees to get a clear idea and to find out the challenges they face when they switch their medium of instruction from Sinhala or Tamil to English. Some questions were divided into sub-questions. Sub-questions helped to get the point of view of students on EMI in depth. Before interviewing with the sample, questions were piloted with 4 students who were not in the sample. All the questions were asked in English. It was difficult to get the students' views as they had to provide the answers in English too. Therefore, the questions asked at the interview were translated into Sinhala by considering the convenience of the interviewees. They gave the real ideas they had when learning under EMI. New questions were included after conducting the pilot. Those questions were based on listening to lectures and speaking in classrooms in English. Data were analyzed under the thematic analysis.

IV ANALYSIS & DISCUSSION

This chapter critically analyses the challenges and opinions of 15 participants who are studying Higher National Diploma in Telecommunication Engineering (NVQ level 6) at the College of Technology, Galle

Attitude towards EMI

After 13 years of school education, students move to follow their higher education in a university or any other higher educational institute. There is no doubt that most of the courses are conducted in L2. Students who have followed primary and secondary education in their first language face many difficulties once they start to follow the courses in L2. Therefore, they have different attitudes to EME. Since the commencement of the course, many participants have felt an interest and a fear as it was a novel experience for them. The below quotations show their feelings toward the course, P8 stated "I had an interest to follow the course as it is in English medium because this is my first time following a course in English medium. I did a self-study on grammar and read English newspapers to improve my English language"

P10 stated "I had an interest in learning a course in English medium because I had a target to learn 20 English words per day"

Certain participants stated that they felt ambitious to follow the course in English medium because it is a ladder to achieve higher positions in the job market. They directly stated that they get a chance to follow NVQ level 7 (degree) after following level 6. Therefore, it is evident that the majority have a positive attitude towards EMI. It depicts that EMI is an exciting opportunity anyone should undergo at the tertiary level.

Previous Exposure to English

The participants had the above attitudes because the individual participants had a different exposure to English. Given this theme highest number of students had followed different courses before commencing the Telecommunication Engineering (NVQ level 6). However, only 4 participants had followed courses in English such as Computer Hardware Technician (NVQ level 5), English Diploma, and Business

Management Diploma. Other 11 participants had followed courses such as Information and Communication Technology (ICT), Life skills course, and electrical course in Sinhala. It depicts that only a few participants had exposure to English before entering the CoT, Galle. The below quotation shows the comment P4 has given on his previous exposure to English

"If anyone has exposure to English, he or she will be able to manage any course in English medium"

It suggests that previous exposure to English can influence to continuation of a course in English. Most of the students study their primary and secondary education in first language. However, in tertiary education, most of the courses are conducted in English medium. P4 had learned English medium from grades 1-8 and after grade 8, he changed the medium of instruction because of the difficulties in subjects like Science and Mathematics.

P4 stated "I learnt in English medium from grade 1 to 8. However, I switched to Sinhala medium because I had difficulties in learning subjects like Science and Mathematics. I had low marks for them on term tests"

All other participants had followed their school education in their first language. All were Sinhalese. So, they had learned it in Sinhala medium. P4 who had studied in English medium at school faced fewer difficulties than the other participants who had studied in Sinhala medium. For instance, P4 claimed that,

"I have less problem while studying the course because of the EME at school time"

The above analysis shows the medium of primary and secondary education directly influences the medium of tertiary education. If anyone has a previous experience with the English medium, he or she can manage the courses which are taught in the English medium. It suggests that previous exposure to English influences tertiary education. This is a direct quote told by one of the participants at the interview.

"Language is the major thing. If anyone is confident in language, there is no matter with the subject content" (P4)

The above facts prove that the impact of the medium of instruction during primary and secondary education makes an impact on the challenges students face in understanding subject content in English medium.

Understanding of Teaching-Learning Materials in English

Most of the tertiary-level courses are offered in English medium. So, participants have to refer to teaching and learning materials in English. They help to give a better understanding of the subject content. All participants expressed that they were given teaching materials such as PowerPoint presentations and handouts. Also, they use PDF documents, library books, newspapers, and past papers as learning materials. All teaching materials are used in English medium concurrently the medium of learning materials is chosen by the learner according to their level of understanding. Therefore, participants face some difficulties while referring to them. The highest number of participants have difficulties while referring to teaching learning materials in English. Below are quotations how the challenges participants face while referring to them,

“Some words are difficult to understand because of the heavy content” (P9)

“When referring to workshop reports, usage of passive voice makes confusions in understanding some concepts” (P6)

In contrast, the least number of participants could understand them on average. They use Google Translator or a dictionary to get the meaning of difficult words. Sometimes, they asked lecturers to explain it. Therefore, they have found alternatives to understanding teaching and learning materials that are given in English medium. They familiarize difficult words by using them several times in different contexts. Below are some of the ideas of participants,

“Some words in the PowerPoint presentations are difficult to understand. Therefore, I use a dictionary to find the meaning” (P9)

“I use a Google translator when reading websites to get the information because some words are difficult to understand” (P13)

Participants get a chance to select the medium of instruction while referring to learning materials because they are used by learners to get a deep idea about the subject content. It depends on the learner’s necessity and convenience. An equal number of participants like to read books and other learning materials in Sinhala and English medium. Certain participants choose Sinhala for the following reasons.

- P9 likes to read books in Sinhala medium because of difficult words. He said that he needs to use a dictionary whenever he referring to English books.
- P12 needs to refer to books in Sinhala medium because he is not able to understand the content easily with real meaning. When he reads English books, he feels that he cannot get the same meaning compared to Sinhala books.

Similarly, some participants prefer to read books in English even when they have difficulties. Below are some quotations to reveal the reasons for choosing the above medium.

“It is easy to refer to books in English medium because everything related to the course are available in English” (P7)

“Most of the time we are using foreign resources such as articles, and websites to get a better understanding. Obviously, they are available in English. Therefore, I always want to go with English materials” (P10)

“I have a desire to learn English. English learning materials are a good opportunity for me to improve English” (P1)

Less number of participants prefer to have mixed language to understand teaching learning materials well. They choose mixed language because it is easy to understand the concepts rather than getting overall meaning in English.

“I understand the meaning of English words by looking at Sinhala words. Therefore, I prefer mixed language to read learning materials” (P11)

The majority face challenges when referring to teaching and learning materials because of the language in contrast, few participants face challenges because of the subject content. The above facts and quotes foreshadow that teaching learning materials becomes challenging in understanding subject content.

Effects of Language Aspects in Understanding Subject Content

There are four main aspects of language. They are phonology, morphology, syntax, and semantics. English is a combination of everything. All participants have issues with grammar, spelling, and vocabulary. No one was able to express that one particular aspect was difficult because everyone has issues comparatively in every aspect. They face the above difficulties both in classrooms and in exams. Most participants’ idea was that many problems occur at the exam than in the classroom. Respectively, P11, P1 and P4 states that,

“Grammar, spelling, vocabulary become challengeable at the exam. In the classrooms, we can work cooperatively when difficulties appear” (P11)

“Lack of vocabulary is the most difficult part in the classroom.” (P1)

“Grammar is used automatically but does not know the purpose. Also, when writing words, spelling is not correct always. If we write 100 words, 25 words may be wrong in spelling” (P4)

Therefore, every language aspect becomes challenging when understanding subject content in the classroom and on the exam. By considering the above factors, it is concluded that language aspects can be influenced in understanding subject content.

Challenges in Understanding Technical Terms

Each course of technical college provides knowledge, skills, and training for a particular field. Therefore, during the course, students learn technical terms. They differ from each other. Technical terms are also used in English medium. The majority expressed that technical words are difficult to understand at first glance. P8 states that he has many difficulties in understanding technical terms. Therefore, he writes down it and asks it from the lecturer at the end of the session. P11 states that first he finds the meaning and then he sees how that word is used in a sentence. Most participants agreed that they refer to a dictionary or Google translator to get the meaning of the word. The below ideas further clarify challenges in understanding technical terms.

“It is difficult to understand at first but gradually I get familiar with them” (P12)

“By drawing pictures, I remember technical terms” (P2)
Most number of participants felt that the technical terms were getting difficult because of the language. In contrast, the lowest number of participants’ opinions was that technical terms are difficult because of the subject content. However, certain students faced difficulties in understanding technical terms because of both. The below facts summarize the solutions they have found to understand technical terms

- It is easy to memorize when the technical terms are learned with pictures.
- Technical terms get familiar because of the repetition throughout the course.
- Dictionary, google translator, chat GPT helps students to find the meaning of technical words.
- The more attention should be given to the usage of technical terms in a sentence. It enables us to understand them in the context.

- Deep explanation makes it easy to understand technical terms.

V CONCLUSIONS

This study reveals that, the challenges students faced while studying Telecommunication Engineering (NVQ level 6) under EMI at the College of Technology, Galle. By analyzing the data, the researcher can draw conclusions based on the research questions. According to the analysis, it is proved that teaching learning materials have become challenging in understanding subject content because of the medium of instruction. Therefore, the medium of instruction can be influenced in understanding subject content while referring to teaching and learning materials such as PowerPoint presentations, handouts, websites, books, and other reference materials in English. As every material relevant to the course is available in English, most participants prefer referring to them in English. It suggests that though they have challenges, they need to build a sound background knowledge of English. It helps to develop the understanding of EMI in their future studies as well. Once they have finished following the course, they can start following the degree (NVQ level 7) at the University of Vocational Technology (UoVT), Ratmalana. These challenges will be a ladder to continue to the degree in English successfully. Also, analysis foreshadows that language aspects have an impact on understanding subject content. Every participant has issues with more than one aspect such as grammar, vocabulary, spelling, etc. The knowledge of language aspects is essential in understanding subject content, also it can affect speaking, listening, reading, and writing. Further, they feel fear of speaking in common places due to lack of vocabulary and they make many errors in writing due to poor grammar. Spelling can have an impact on writing in the classroom and at exams. Finally, participants face difficulties in understanding technical terms because of the medium of instruction.

Recommendations

Considering the analysis, the researcher can suggest relevant solutions to overcome challenges under EMI. Participants have switched their medium of instruction from L1 to L2 once they have started to follow the tertiary level. It is the root of where challenges occur. Reading strategies can be applied to avoid challenges while referring to reading materials in English. Participants can break up readings into chunks if it is heavy content. While referring to websites, they can use a dictionary to get the meaning. During the delivery of presentations, they can note down difficult concepts that should be clarified later. More assignments should be given to refer to materials. Then students get an opportunity to read

more and more. Instructors can apply reading circles, and peer reading in the classroom to avoid challenges in understanding teaching learning materials in English. EMI should be applied since primary education. To implement EMI, teachers should be provided with proper training programs. EME should be encouraged in rural and urban equally. It will develop participants' proficiency in English. Once they switch the medium of instruction from L1 to L2, they will be able to continue the teaching-learning process with fewer challenges. Moreover, separate sessions should be implemented to develop grammar, spelling, and vocabulary. Reading newspapers and watching films can have a positive impact on developing vocabulary. Apart from the subjects related to the course, an English period can be included per day. Well-trained and qualified English teachers should be recruited for technical colleges. Language skills such as speaking, reading, writing, and listening are equally important in EMI classrooms. Though participants manage reading writing and listening, they have issues in speaking. Therefore, speaking should be encouraged since school education. Respective authorities should pay attention to enhancing speaking skills in technical colleges. Also, current techniques like mind mapping, flashcards, and word cards will help to get a better understanding of technical terms. Workshops and field trips can be conducted to familiarize them. The researcher can recommend the above solutions to overcome challenges under EMI after a thorough study of the data analysis.

ACKNOWLEDGEMENT

I would like to express my great attitude to each person who supported me in completing the project successfully, especially the Director of the College of Technology, Galle, instructors, course coordinators, students, and the non-academic staff for giving me their fullest support for the completion of this project.

REFERENCES

- Dearden, J. (2015). English as a Medium of Instruction - a Growing Global Phenomenon. British Council.
- Illeperuma, O. (2022, November 23). The Island Online. The Death of English Medium in School.
- Nanayakkara, P. (2012). Bilingual Education Programme in Sri Lanka.
- Navaz, Abdul Majeed Mohamed. (2016). Challenges Faced by Students in English Medium Undergraduate Classes : An Experience of a Young University in Sri Lanka. Journal of Arts, Science & Commerce.
- Neranjani, S. (2021). English Medium Education and Bachelor of Education Programs in the Sri Lankan University: challenges and realities. international Journal of Research and Innovation in Social Science .
- Sanmuganathan, K. (2017). Historical Perspective of English Some Pedagogical Problems and Solutions in Teaching English in Sri Lankan Schools. International Journal of Sceintific and Rsearh Publicatons.

Strategies of Developing Speaking through Experiences of Teachers- A Narrative Inquiry

P.K.D.T.Sachithra
Department of Language Studies
University of Vocational Technology
Rathmalana, Colombo
elt19b103@uovt.ac.lk

L.H.D.L.Ranasuriya
Department of Language Studies
University of Vocational Technology
Rathmalana, Colombo
dilini.ranasuriya@uovt.ac.lk

Abstract— The English Language is taught as a compulsory subject in the curriculum of schools in Sri Lanka. Although the students have been learning English for thirteen years of schooling, the students have not reached the expected competent level in English especially, in speaking. However, many qualified and competent non-native English teachers who have obtained degrees and diplomas have been recruited in the schools and they have improved their speaking skills. They might have used many strategies to develop their speaking skills. The current study focused on exploring the strategies used by English teachers to improve their speaking skills. Eighteen English teachers from nine provinces of Sri Lankan government schools were selected as the sample. A semi-structured interview was conducted as the research tool and a narrative technique was adopted to obtain qualitative data. The data was analysed using thematic analysis. According to the analyzed data, having an English-speaking family background, engaging in activities related to English in schools, neighbours' and friends' interaction, and developing reading, listening, writing skills, and speaking skills itself were affected positively to improve speaking skills. Furthermore, reading books, listening to songs, speeches, and news, writing speeches, poems, and essays, speaking to him or herself, talking to the mirror and the pet, and use of technology were some identified strategies. It could be recommended that four skills of English should be developed to improve speaking skills and practice speaking skills as much as possible assist to in developing speaking skills. Moreover, it could be recommended to use the explored strategies to improve the speaking skills of the students in Language classrooms.

Keywords: *English teachers, speaking, develop, strategies, Language classroom*

IX. INTRODUCTION

Language of the colonial Sri Lanka was influenced mostly by the British. Colebrook Commission prioritized English education and English language was given priority other than Sinhala and Tamil in the country. According to V.J.M. Lokubandara, the real gap in Sri Lankan society is not based on religion, ethnicity money, or caste but it is based on language. It is the gap between those who know English and those who don't know English. Due to this, different varieties of Sri Lankan English have emerged and the people who are fluent in English use Standard Sri

Lankan English (SSLE) while the ones who are not familiar with English, speak nonstandard Sri Lankan English which is called not-pot English. SSLE, generally known as Sri Lankan English consists of the Sri Lankan way of pronunciation. With the introduction of English as a subject from grade 3 in 1956 and grade 1 in 1997 the gulf between these two varieties of English was reduced to some extent. But the exposure to English in the schools was limited and it is reflected in the students in the schools of Sri Lanka even in the present. Therefore, it can be identified a significant drawback in speaking among the students. Being a government English teacher for 13 years of service I observed that, there is a significant drawback in speaking English. Although English has been taught in schools as a subject, the students are not competent enough to speak English, especially in rural areas. Further, I have witnessed how the students struggle to speak when they get the opportunity to communicate in English. However, the teachers of English have improved their speaking skills and they are fluent speakers of English. Thus, the researcher will explore the strategies used by English teachers to develop their speaking skills in order to use them in the language classroom in the current study. Although many narratives were available, about developing the speaking skills of the students, less research was done on the experience of teachers in developing their speaking skills using their strategies. As there is a research gap the researcher wants to fill this gap by researching how English teachers themselves develop their speaking skills through their experience. The following research question will be looked at:

A. Research Question

What strategies did the teachers of English Language use to improve their speaking skills?

X. LITERATURE REVIEW

A. Speaking Strategies

The main objective of this research is to explore the strategies used by English teachers to develop their speaking skills in order to use in English language classrooms. Thus, it needs to understand what is meant by strategies. Nunan (1999, p.171) states that learning strategies that are used by learners are the mental and communicative procedures that help to

learn and use the language. Therefore, learners may have long retained about structure, sentence patterns, and vocabulary if they use speaking strategies to improve themselves. Similarly, Cohen (1998, p. 66), Rahmadeni, Amri, and Adnan (2013, p. 413) present that if the learners are aware of many possible strategies while learning and using the language, the learners will be able to learn the language easily. Moreover, the use of strategy motivates the learner towards learning. The study carried out by Pawlak finds that the use of speaking strategies motivates learners. (Pawlak, 2011). Further, he explains that the speaking skills of learners can be improved by the use of strategies and these speaking strategies help to overcome the difficulties that arise in the communication process. (Pawlak, 2018). Similarly, a study done by Varela (1999) with learners of English as a second language who use different speaking strategies to improve speaking finds that the ones who use speaking strategies are more successful in conveying their ideas to others. Thus, exploring the strategies used by teachers to improve their speaking skills will aid the learners of English to improve the learners' speaking skills.

As the strategies are different from one learner to the other, the learner should be able to select the appropriate speaking strategy to use to improve herself or himself according to the level of him or her. Lopez, (2011), reveals that the speaking strategies should be selected by the learners according to their language proficiency. As there are many speaking strategies, the learners can select the speaking strategies to improve their speaking skills by considering the level of the learner. The teachers of the language classrooms can assist the students in selecting the appropriate strategies. When considering more strategies, Huang and Naerssen (1987) provide some speaking strategies such as using the target language to communicate, thinking in that language, talking to oneself, or reading to get the models for speaking. Similarly, Cohen and Olshtain (1993), mention another four strategies such as planning, thinking in two or three languages, searching for target language forms in various ways, and paying attention to grammar and pronunciation after conducting some speaking activities with 15 advanced learners of English as a foreign language. Kawai (2008) explores some strategies that are used in the classroom in order to avoid breakdowns while speaking. According to him in-class discussions, practicing speaking daily basis, starting discussions with peers, and relying on stop-gap are the strategies. A study to explore the effect of strategy training on the development of oral presentation skills by Varela in 1999 found that speaking strategies improved the oral performance of the students. Further, he says that strategies such as grouping, selective attention, cooperation, self-talk, note-taking, and self-assessment improve oral presentation (Varela,1999). Many scholars have suggested many strategies that are used to improve speaking skills. Among them, Lyman (1981), suggested that activities like information gap activities, think Pair Share and Role play enhance speaking skills whereas Wragg& Brown (2001) mention group activities improve oral communication as the students have more opportunities to

ask questions than work individually. A similar idea is presented that engaging in group work and pair work enhances speaking skills as they provide opportunities to increase chances of speaking (Brown,2001, Green, 1989 & Nation,1989). There are many scholars who suggest that role play plays an important part in improving speaking. Among them, Ladouse(1995) mentions that role-play provides various communicative techniques and improves fluency, developing interaction and motivation in the classroom. Volya (2009) has presented many strategies used by the learners in his study such as speaking with friends, speaking with an English teacher, trying to find an English speaker, talking to themselves in English, taking English courses, making dialogues, listening to English music, and watching English movie. Moreover, Shumin (2002) states that producing short utterances to communicate enables adult learners to engage in small talk which is a good strategy to improve speaking skills.

XI. METHODOLOGY

This study employed a qualitative research paradigm and a narrative style to explore the strategies used by English teachers to develop their speaking skills and semi-structured interviews were used as the research tool. The Purposive Sampling technique was used to choose the sample for the study. Hence the population is English teachers in Sri Lanka consists of Eighteen English teachers employed in schools and universities. These teachers belong to nine provinces of Sri Lanka.

XII. ANALYSIS AND DISCUSSION

A. Family and School Community

Family and school community was one of the themes that emerged from the discussions.

"My mother used to tell the English words and phrases while she was doing her work in the kitchen and when I made mistakes she corrected them on the spot." (p 1)

This particular participant had exposure to the English language from her childhood because of her mother. Listening, using vocabulary, and memorizing that vocabulary might improve her fluency in speaking.

"I used to read books a lot, most of the text related to modules and love stories written by Sidney Sheldon, and Nelson DeMille". (p 3)

She further mentioned *"I chose the books that suit my interest, so I engaged in reading with pleasure."*(p 3)

Dubin and Olshtain (1997, p.97) point out some benefits of extensive reading. According to them, extensive reading provides pleasure and satisfaction as the students read on their own and it has an effect on writing and speaking skills. Thus, she might improve her speaking ability through extensive reading. Although she did not speak English at home, her strong willingness to read might help her to improve her speaking skills. Thus, it can be identified in her

story, that reading is one of the important strategies to improve speaking.

"My father had to go abroad and we had to accompany him and we stayed for 3 years there and my speaking development started after this incident." (p 2)

This particular participant had to move to a totally Englishspeaking environment and it provided excellent exposure to the English language. There she was compelled to learn and use the language.

"Once we came back, we maintained the language but we had difficulty in retaining what we learned there, therefore my parents brought out the rule we should speak in English at home." (p 2)

It was seen in her story that she had the opportunity to use the language as much as possible. Many critics have mentioned that repetition is an effective way to improve speaking. It helps to memorize the phrases, vocabulary, and structure. Thus, the use of language might assist her to develop her speaking skills.

"In the English period, we had a nice teacher who communicated in English and the Western music teacher had a good English background. So, I got the opportunity to speak English" (p 4)

When considering the school environment this particular participant got the opportunity to communicate in English during these two periods as both the teachers were good in English.

"In school, I participated in the English Day competitions, especially for recitation, dictation, and creative writing and I used to practice the poem in front of the mirror to check my pronunciation, body language, and facial expressions." (p 5)

As she got the opportunity to participate in the competitions, this particular participant was able to improve her vocabulary and pronunciation. Having sound knowledge of vocabulary and pronunciation is really helpful in improving speaking.

When the speaker lacks vocabulary, it affects the fluency of that speaker. Similarly, if the speakers are unable to produce correct pronunciation, they do not speak. Thus, both vocabulary and pronunciation are integral parts of speaking. She used to practice in front of the mirror in order to have correct pronunciation. It is a good strategy for a learner to correct the mispronouncing of the words. Based on the analysis of the gathered data, it can be inferred that being exposed to language both at home and in school is an effective strategy for enhancing speaking abilities.

B. Neighbours' and friends' interaction

Friends' and neighbours' interaction was one of the themes that emerged from the discussions.

"Burger family moved into our next door and there was a five-year-old Burger child who was going on and on talking in English. When we got together, we talked in English and talking improved because of that Burger child." (p 6)

Above is one of the statements given by one of the participants whom the researcher interviewed. She mentioned that she was able to develop her speaking skills mainly because of her neighbour. Shehadeh (2011), mentions that learning happens through face-to-face interaction and shared processes. This is also valid for language learning where interaction and sharing ideas are major components of developing language skills.

"Basically, I did not speak with my friends in English. I think there should be interaction to improve speaking." (p 5)

This statement was given by another participant and from her story, it can be understood that she did not speak in English with anyone but she practices the strategy of speaking to herself. She did it as a habit. Perhaps her strategy of talking to herself may influence her to improve her speaking ability.

"We formed a circle with our friends and we had seven members in the circle. In this circle, one friend had to read a small storybook in one day and others had to listen to it. There we could catch pronunciation, vocabulary, and some structure. It was a rotating circle that each one had to present every day." (p 7)

This particular participant and her friends understood that there was a drawback in speaking English when compared to the others in the school. Thus, they took this step to improve their speaking skills. Actually, peer interaction provides good opportunities for students to improve their language. When the environment is friendly and free, the students attempt to speak with errors and they produce utterances without any fear. This helps to develop speaking skills. *"We maintained vocabulary books and shared them among us." (p 7)*

It was seen in the stories that lack of vocabulary is one of the reasons for poor speaking ability and the above participants had used a good strategy to improve vocabulary with the assistance of friends. According to Schmitt & Carter (2000), vocabulary is a crucial part of learning a foreign language. Furthermore, August, Carlo, Dressler, and Snow (2005), state that one who has a limited vocabulary is shown less engage in oral communication with peers. A successful strategy for improving speaking skills is to maintain peer interaction. This has been identified as an effective strategy.

C. Utilizing Strategies

Nunan (1999, p.171) states that learning strategies that are used by learners are the mental and communicative procedures that help to learn and use the language. Almost all the participants used one or more strategies to improve their speaking skills. One particular participant stated, *"I talked with my pet in English as a habit then I was able to reduce my fear of talking". (p 8)*

It was seen in her story that she used the strategy of talking to her pet dog as a habit, which helped to reduce her fear of speaking in English. Thus, this particular participant uses the strategy of talking to the pet in order to overcome her anxiety to speak in English and it might help her to improve her speaking skills.

"Listening to the lectures conducted by the university, listening to native speakers of English and speakers of SSE helped to reduce anxiety and helped to improve speaking." (p 5)

In this scenario, she had anxiety but she was able to overcome it little by little by using the strategy of listening. She mainly listens to the native speakers of English as well as the speakers of SSE.

"I am a music lover and I used to listen to English music like songs by Bonny. Based on the meaning and sounds I used to sing along with the singer. Then I could improve my accent." (p 1)

She has the habit of listening to music and singing, and she was able to get familiar with the accents of the native speakers.

"I wrote everything and wrote the speeches, poems, songs, and essays and they helped me a lot to improve my speaking." (p 5)

The above statement was given by another participant. It was seen in her story that writing influences speaking. It is crucial in improving speech. There is an interrelationship between writing and speaking. The strategy of writing poems, stories, speeches and songs might help her to improve her speaking. *"The number one strategy is to speak with my sister and the other members of the family."* (p 2)

This was from another participant. When someone has the practice of using language, it builds up the self-confidence to speak in front of others. Her self-confidence might help her to improve her speaking skills. The number two strategy would be reading out loud, for example,

"If I mispronounce a word, I will take a book and read it aloud." (p 2)

This was uttered by the same participant and reading silently and reading aloud were used as strategies by many participants whom the researcher interviewed. Huang, W (2010) had done research on the effects of reading aloud on the English pronunciation of Chinese EFL learners. In that research, he found out that reading aloud significantly affects improving pronunciation.

"I had an idea to become a public speaker and I went in front of the classroom and practised." (p 1)

Because of the desire to be a public speaker, this particular participant developed her speaking ability and confidence by speaking in front of a real audience in the classroom. Thus, she got the experience of interacting with the audience. Providing opportunities to practice speaking in authentic contexts to have real-world experience can help the learners to improve their speaking abilities. (TESOL Journal, 2016). Another strategy for developing speaking skills is using real-life situations to practice, as suggested by teachers who have shared their experiences.

"I watched movies, and listened to interviews, songs, and discussions." (p 8)

Thus, this participant watched and listened to English movies, news and discussions. Watching and listening take place

simultaneously when watching the movies. Listening is a fundamental skill in developing speaking. As Goss (1982) stated, by listening to native speakers, the learners are able to listen to new vocabulary, and phrases and also can learn how these phrases and words have been used in the sentences. Similarly, it facilitates learning grammar and the usage of grammar in a proper way when producing speech. Thus, watching movies, and listening to interviews and discussions are other strategies to improve speaking skills.

D. Use of Technology

According to, Bahadorfar and Omidvar (2014), technological tools such as the internet, podcasts, video conferencing, videos, and speech recognition software are the best tools for teaching speaking.

"I followed YouTube videos such as the TEDx talk, and mind your language programs. Usually, I downloaded these videos and listened to them again and again." (p 1) According to this participant, she had the habit of following YouTube videos related to speaking.

"I mostly google for pronunciation, meanings, and synonyms and I used to watch free lessons conducted by British teachers on YouTube." (p 9)

This participant too googles unfamiliar words and their pronunciation. Although these participants belong to different age groups, they get the help of technology to develop their speaking skills. Thus, another strategy explored was the use of technology to improve speaking such as listening and watching YouTube videos and surfing the internet for unfamiliar words and their pronunciation.

V. CONCLUSION AND RECOMMENDATION

This research aimed to find out the strategies used by English teachers when improving their speaking skills to use them in the English Language classroom. The results indicate that the teachers of English have used at least one or many strategies to improve their speaking skills through the journey of developing speaking skills. They have used them consciously or unconsciously. The results depict that English-speaking family background and school environment play a significant role in developing speaking skills. It shows that English-speaking family backgrounds and the school environment provide more exposure and affect improve speaking skills positively. Similarly, communicating with neighbours and friends in English has a great impact on improving speaking. According to the results obtained, it can be understood that the teachers of English utilized strategies such as loud and silent reading, listening, writing, and practising speaking with themselves, others, the mirror, and the pet. It can be stated that improving other skills such as reading, writing, and listening assist in developing speaking skills. Other than these strategies, the results depict that peer interaction, the use of technological devices, and surfing the

internet have a successful impact on improving the speaking skills of teachers. Most English teachers have utilized the strategy of speaking to themselves, to the mirror, to a pet, or with others while the skill of writing has less impact on developing speaking skills as a strategy. Similarly, listening to videos related to speaking, native speakers, and SSLE speakers are other strategies that positively improve speaking skills among English teachers according to the analyzed results. The results showcase that the use of some strategies has a different impact on developing speaking as the use of strategies is dependable and varied from learner to learner. Especially, listening to music is not very helpful to one participant while some other participants found it assists to improve their speaking skills. As there is a generation gap among the teachers interviewed, the teachers who belong to the digital era prefer to use modern technology to enhance their speaking such as surfing the internet to find correct pronunciations of unknown words and get used to online dictionaries than use dictionaries manually. By considering the findings, the following recommendations can be mentioned. In order to develop the speaking abilities of learners in the English language classroom, teachers can employ the strategies used by the interviewed English teachers. It is recommended that individuals should improve their listening, reading, and writing skills to enhance their speaking skills, as these skills are interdependent and interdependent. Speaking with friends is also an effective strategy to improve speaking ability. Individuals may speak with themselves, pets, or a mirror to develop their speaking skills. Both loud and silent reading is important, and practising pronunciation and learning vocabulary is also beneficial for improving speaking skills. Moreover, writing speeches, poems, stories, and essays influence speaking and it is one of the effective strategies to improve speaking. Furthermore, listening to songs, conversations, and speeches by native speakers or SSLE speakers is really helpful in developing speaking skills. It can be recommended that technology-integrated strategies such as watching standard YouTube videos that are related to speaking and referring to online dictionaries and e-books improve speaking skills. Having an English-speaking family background provides more exposure to the English language and more exposure to language is an advantage for developing speaking skills. Similarly, participating English English-related activities in schools and peer interaction also positively affect improving speaking. The findings and recommendations in relation to the current study could be used to develop speaking skills among English language learners not only Sri Lankan context but other ESL learners of foreign contexts. As there is less research available related to stories of English teachers about how they develop their speaking skills in the Sri Lankan context, more research is encouraged to be conducted to enhance speaking skills.

REFERENCES

- Cohen, A. D. (1996). *SECOND LANGUAGE LEARNING AND USE STRATEGIES: CLARIFYING THE ISSUES* 1.
- Dincer, A., & Dariyemez, T. (2020). Proficient speakers of english as a foreign language: A focus-group study. *IAFOR Journal of Education*, 8(1), 83–99. <https://doi.org/10.22492/ije.8.1.05>
- Gunasekara, M. (2005). The Postcolonial Identity of Sri Lankan English.
- Huang, L. (n.d.). Asian Social Science www.ccsenet.org/ass 148 Reading loud in the Foreign Language Teaching. <http://www.esiponline.org/classroom/foundations/reading/readalouds.html>.
- Pawlak, M. (2018). Investigating the use of speaking strategies in the performance of two communicative tasks: The importance of communicative goal. *Studies in Second Language Learning and Teaching*, 8(2 Special Issue), 269–291. <https://doi.org/10.14746/ssllt.2018.8.2.5>
- Prabawa, W. P. (2016). Speaking Strategies Used By Indonesian Tertiary Students. 4(2). <https://journal.uniku.ac.id/index.php/erjee>
- Sharma, H. L., & Saarsar, P. (2018). TPS (Think-Pair-Share): An Effective Cooperative Learning Strategy for Unleashing Discussion in Classroom Interaction A Study of Goal Orientation among Secondary School Students in relation to Academic Self-Efficacy, Academic Help-Seeking Behavior and Achievement View project Flipped Classroom View project. <http://www.ijmra.us>,
- Shehadeh, A. (2011). Effects and student perceptions of collaborative writing in L2. *Journal of Second Language Writing*, 20(4), 286–305. <https://doi.org/10.1016/j.jslw.2011.05.010>
- Thi, N., & Tran, N. (n.d.). *Journal of English Language Teaching and Applied Linguistics The Relationship Between Language Learning Strategies and Gender in Learning English as a Second or Foreign Language*. <https://doi.org/10.32996/jeltal>
- Triwittayayon, T., & Sarobol, N. (n.d.). Factors Enhancing English Speaking Ability: Perspectives from Thai High School Students and Their Teachers.
- Uin, M., & Surabaya, S. A. (2020). Speaking Strategies Used By the Junior High School Students with Different Level of Speaking Ability

Effectiveness of E-Learning in Two “Type 1AB” Schools in Kandy Educational Zone

Wickramasinghe Mudiyansele Shrinika Prabodhani
Wickramasinghe

Department of Language Studies
University of Vocational Technology
Sri Lanka
elt19b239@uovt.ac.lk

Herath Mudiyansele Somaratne
Department of Language Studies
University of Vocational Technology
Sri Lanka
somehm@gmail.com

Abstract— E-learning is a learning platform that helps students with their learning by providing a variety of learning resources. E-learning is widely used globally with the support of new technologies and the latest electronic devices. This paves the way for communication for course work at any academic level for students to learn irrespective of geographical location despite barriers due to poor transportation facilities, restrictions under pandemic circumstances, and so forth. E-learning is cost-effective, time-saving, and an effective way to enhance learning skills additionally with technological knowledge. When the global education system was threatened by the COVID-19 pandemic, most countries around the world resorted to e-learning systems to avoid the deterioration of the educational process. This study mainly focuses on examining how effective e-learning is in the Sri Lankan school education context. The target population is the Grade 12 students who follow the “Technology Stream” for their A/L especially IT as one of the subjects. They were selected from two “Type 1AB” schools in the Kandy Educational Zone. The sample comprised of twelfth grade students. Thirty students from each school were selected randomly for the sample. This is an exploratory study that strived to find more information about how effective e-learning is in the context of Sri Lankan schools. The data collection was conducted using a structured questionnaire and the finalized data was taken into consideration to identify how effective the e-learning platform was among the selected group of students. The key finding of this study is that most of the students in the sample group have a preference for e-learning and they effectively learned through e-learning. This is proved by the data gathered and summarized from the responses to the questionnaire. Though the sample size was limited, a higher percentage of students used to learn e-learning effectively for their learning.

Keywords—e-learning, effective

I. INTRODUCTION

The revolution in the learning landscape has been brought about by the delivery of training and education through

networked interactivity and various technologies for knowledge collection and distribution (Fry, 2000).

This chapter starts with the signpost of the willingness toward current research trends in “E-Learning”. Among the different modes of learning that have emerged, e-learning has gained attention for its time-saving, cost-reducing, and knowledge-disseminating capabilities. By utilizing electronic devices such as computers, laptops, tablets, smart boards, and mobile phones, along with a reliable internet connection and relevant applications, e-learning facilitates the teaching-learning process, benefiting both educators and learners. E-learning activates learning in small or large groups of learners as well as individuals.

Computer literacy and time management skills are improved in students by e-learning. This study is concerned with how e-learning helps students in selected two “Type 1AB” schools in the Kandy Educational Zone. Most of the leading schools in Sri Lanka continued with e-learning with the closure of schools following COVID-19. The majority of the students in urban areas were able to continue their learning process through electronic devices. This study focuses on involving students of Grade 12 who follow the Tech stream for A/L as the target group with permission from the principals of the selected schools. It is our responsibility to make the students keep pace with the rapidly changing world dealing with the latest facilities to be on par with the international setting.

This study aimed to assess the effectiveness of e-learning among school children, with a specific focus on the inputs across e-learning platforms. To achieve this objective, the researcher randomly selected 60 students from Grade 12 Technology classes in two “Type 1 AB” schools located in the Kandy Educational Zone. It is crucial to assess how e-learning influences student learning outcomes, engagement levels, and overall educational experiences. Therefore, this study investigated the effectiveness of e-learning in two “Type 1 AB” schools in the Kandy Educational Zone, Sri Lanka, with a particular emphasis on secondary students.

Some of the benefits e-learning provides for learners include the inspiration to study more effectively in an innovative environment. E-learning is not free from

negative effects either. Poor social interaction, limited feedback from the teacher, inaccessible to others, and unavoidable cheating are among the most prominent negative effects of e-learning.

- *Research Problem*

E-learning has emerged as a transformative learning mode, offering students and teachers new opportunities for engaging and effective educational experiences. This study investigates the effectiveness of e-learning in two "Type 1 AB" schools in the Kandy Educational Zone, Sri Lanka, with a specific emphasis on secondary students. By examining the benefits, challenges, and overall impact of e-learning in this context, the research aims to contribute to understanding the role of e-learning in secondary education. The findings of this study will provide valuable insights to students, teachers, and educational policymakers, enabling them to enhance the quality and effectiveness of e-learning practices in similar settings.

- *Research Questions*

1. How do students adapt to e-learning?
2. How students do time management when involved in e-learning?
3. How do students overcome technical issues when using electronic devices?
4. What are the negative influences that could be possible with some electronic devices?

- *Research Objectives*

The objectives of the research are,

1. To identify the nature of interest learners, have towards e-learning.
2. To assess how e-learning enhances the quality of learning.
3. To identify how e-learning is helpful for their learning.
4. To distinguish the improvements identifiable after using e-learning.

II. LITERATURE REVIEW

A. Introduction

This chapter is composed of significant examples from the previous studies done with the A/L students in two "Type 1AB" schools in the Kandy zone. The main reason to conduct this research was there isn't any research conducted to discuss the effectiveness of e-learning in the Sri Lankan school context. Therefore, the researcher hoped to research to find out more about the effectiveness of e-learning in the school context. This chapter comprehensively discusses the effectiveness of e-learning in Sri Lanka.

"Impact of COVID-19 in Sri Lankan Education System" the article by Panchami Jayawardhana (2019) refers to education as "the most important weapon". With that, this

researcher hopes to get a positive entry to the present study. The effectiveness of E-Learning in schools has been a widely discussed topic recently as the COVID-19 pandemic reached Sri Lanka in 2020. This is sometimes referred to as linking electronic devices with school students to continue their education uninterrupted.

B. Similarities and Differences between Traditional Learning and E-Learning

There are similarities and differences between traditional learning and e-learning. Learning is defined by Robert Gagne as "A change in human disposition or capability that persists over some time and is not simply ascribable to processes of growth". Moving on e-learning was defined by the NCSA as "The acquisition and use of knowledge distributed and facilitated primarily by electronic means". NCSA comes with many more definitions and explanations of e-learning by mentioning how effective e-learning is not only for learners but also for others. Moving on to the comparison of these two topics the main similarity between them is that both of them are methods of learning. Usually, learning is done by rarely using electronic devices while e-learning is always done by using electronic means.

C. Globalization and E-Learning in Sri Lanka

Globalization which can be described as the increasing connectedness and interdependence of cultures and economies in the world, is recognized as one of the main causes for e-learning to spread all over the world. As e-learning is capable of educating and training learners at a distance, in a globalized society e-learning has become very important. As Sri Lanka is a third-world country, it also has connections with foreign countries. Therefore, in a globalized world, as Sri Lankans e-learning is very important to us too because it has provided us many opportunities to follow courses, diplomas, degrees, etc. which are conducted by foreign lecturers. So, we are gifted with the opportunity to learn from a distance.

D. Global E-Learning

Most of the countries started e-learning around in year 2000 with the impact of updated electronic devices introduced in the world trade market. With the COVID-19 pandemic schools and universities were closed globally and in March 2020, over 1.2 billion students in 186 countries were closed due to the COVID-19 pandemic. After that e-learning played a major role as an online learning platform. Finally, it proved online learning was working well in the year 2020 in an unexpected manner.

III. METHODOLOGY

A. Research Method

The study was done as a qualitative study because the researcher wanted to assess the effectiveness of e-learning among school students. The researcher's aim in doing this quantitative study is to find out the students' perception in depth regarding the e-learning platform. Doing a quantitative study will help to explore the extent to which the e-learning platform is effective for users.

B. Research Design

Under quantitative research, the researcher focuses on exploring information about the effectiveness of e-learning by distributing a questionnaire. This survey focuses on a double entity with several limitations which are clearly defined. The reason for doing this study is to see how effective e-learning is for the students who study the A/L Technology stream at St. Sylvester's College, Kandy, and Vidyarthi College, Kandy cannot relate with the students who study the A/L Technology stream at other schools in Sri Lanka. By doing this study, the researcher can suggest that future researchers conduct the same research to explore more about the effectiveness of e-learning in the Sri Lankan school context. This study helps to elicit how effectively these students engaged in e-learning during the COVID-19 pandemic.

C. Population & sample

The total population is grade 12 students who follow the A/L technology stream in Type 1AB government schools in Sri Lanka. The target population is grade 12 students who follow the A/L technology stream in Type 1AB schools in the Kandy Educational Zone. The accessible population is 30 students from each school and there were 60 students in this research. These students are around 17 and 18 years old and all the students are in the areas contiguous to Kandy. They all sit for their A/L examination in the technology stream and the most specific point is all 60 students follow ICT as one of their subjects.

- *Data Collection Procedure*

The researcher collected data by distributing a printed questionnaire to every student on a selected date and a scheduled period. The time selected was 2 hours from one school day. Throughout the time the researcher was available at the school to for ask any help or clarification about the questionnaire. The questionnaire consisted of 40 questions and the whole questions covered the objectives of the research. Some questions are MCQs and some are Likert scale questions.

IV. ANALYSIS AND DISCUSSION

In this analysis the researcher delves into the insightful responses gathered from the questionnaire, shedding light on valuable data and trends. The questionnaire aims to identify the effectiveness of e-learning, various online tools, the latest technologies used for learning, the preferred learning methods of students as well as the other factors that might influence their learning process. From the beginning of the survey, it was observable that the students had an idea about what e-learning is. Out of those 60 students, 51 students know how to define e-learning properly. The preference of students towards e-learning is different from each other. Some of the students like to engage in e-learning while some of the students use e-learning as they do not have any other option to continue their education. According to this survey results majority of the students prefer e-learning. The preference of students

towards e-learning is different from each other. Some of the students like to engage in e-learning while some of the students use e-learning as they do not have any other option to continue their education. It can be proved by considering the data gathered through the questionnaire distributed among the students. In school S1 19 out of 30 students prefer e-learning and 10 out of 30 students prefer e-learning to some extent. The responses received through the S2 are completely different from the responses received from S1. Seven students among 30 students would prefer e-learning while 17 of them would prefer e-learning to some extent. The majority of the students from both schools started using e-learning during COVID-19 because the schools introduced online learning. As young students, they know how to operate electronic devices properly. Though they overcome severe challenges they manage by themselves to continue their work. SMART phones and laptops are widely used for e-learning and Wi-Fi routers and mobile hotspots are the main source that provides internet for these devices. These students didn't have connection errors as they all live in and around Kandy. As these students are known as 21st-century learners they know how to deal with these devices electronically. Out of 60 students, 44 of them agreed with the statement "E-learning is most time saving, a less expensive and effective mode for learning".

Embracing challenges while learning new technologies is an effective way to expand an individual's abilities and skills. By accepting new skills, the learners can be exposed to novel experiences that offer them rewards and enjoyment. 29 Students mentioned that they always accept challenges and enjoy learning with new devices. Zoom is a popular online software extensively used by students for virtual communication, and learning and one of the most developed online software for e-learning. 57 Students upon 60 students mostly used Zoom software for their learning. It's 95% of the overall comments given by the students. In this survey majority of the students spend more than 3 hours on online learning platforms. The 13th question comes up with what the students were able to do using their digital devices. The researcher created four answers that are very familiar to the students as they are mostly engaging in studies using online platforms.

The largest amount of students can download and view online audiovisual materials and presentations using their digital devices. The effect of connection errors and the problems in devices cause some students with severe difficulties. Though they face difficulties in viewing online audiovisual materials and presentations, they try to manage by overcoming these issues. 17 students have this matter when they engage in online learning. 28.66% of the selected group have this issue. The support given by the teachers and the schools was moderately helpful for both groups of students. While the online classes were there students had to deal with other activities too. 23 Students had good time management skills while 35 students had it to some extent. When talking about the sufficient knowledge they gained through the e-learning platform 17 students mentioned they got sufficient knowledge through e-learning. There were 41 students (68.33%) who

mentioned they got sufficient knowledge to some extent through e-learning. In overall conclusion, it can be mentioned that most of the students get sufficient knowledge through e-learning platforms.

Traditional classrooms played a crucial role from the beginning of the teaching-learning process. With the development of the technology, the world became a global zone. 50% of schools prefer online classrooms because they can download and repeatedly watch and listen to the lessons while 30% mentioned they have to pay the same effort for both learning platforms. A minority of the students mentioned they were very comfortable in the traditional physical classroom. Students normally engage in several activities while they engage in their learning process. Though they had to change their physical classroom learning due to COVID-19 they had to be involved in such activities in the e-learning platform too. In this survey, the researcher tried to search for the most engaging activity they were involved in. It's seen the students mostly engaged in individual and group activities. Few of the students were involved in pair activities. E-learning often enhances one's familiarity with electronic devices. One question discussed asking if they have any improvement using electronic devices after engaging in e-learning. 19 students stated that definitely they had an improvement on the other hand 34 students were there who improved their skills to some extent. There were only 7 students who moderately developed themselves. In an overall decision, it can be stated that all the students developed their skills in using electronic devices after engaging in e-learning.

Students can overcome several technical issues during the e-learning process. First of all, they have to ensure that there is a stable internet connection and updated devices. The majority of the students use both mobile hotspots and Wi-Fi routers to overcome technical issues. That was how they managed technical issues when they were involved in e-learning. Digital approaches in e-learning have much more potential to develop greater motivation for learning. Animations, videos, PowerPoint presentations, and SMART boards are such learning approaches that make learning engaging and captivating. 73.33% from S1 and 43.33% from S2 mentioned animations and videos were the digital approach that motivated them to learn. 10 Students mentioned PPT's motivated them to learn. It was clearly shown a higher percentage of students motivated themselves in e-learning by watching animations and videos. Students have different interests when learning subjects online.

Some students do not like to study some subjects online and they like to study some subjects online. One question was there to know the subject they like to learn online out of the subjects they learn. 22 Students from S1 and 19 Students from S2 like to study "Information Technology" in the online platform. When considering the data of the two schools 68.33% of the whole population of 60 students like to learn IT on the e-learning platform. There were only 4 students who liked to study "Science for Technology"

online and 13 students mentioned they liked to study "Engineering Technology". 4 students from S2 wanted to learn "Bio-Systems Technology" in the online classroom. The average is 13.33% for BST. The majority of the students liked to learn IT on online platforms while the minority of the students liked to learn SFT in online classrooms. 42 Students stated the main advantage of e-learning is it trains more independent learners in the learning process. One survey question asked what specifically e-learning is good for. 30 students meaning 50% out of the whole population stated e-learning is specifically good for managing interactive self-study and tutorials. 20 Students mentioned e-learning was specifically good for reducing learning time. Learning digitally by staying at your own pace is more profitable, time-saving, convenient, and effective for most learners. This question reviews the experience of students with e-learning from home digitally. 32 Students learn at their own pace comfortably and for 9 students, their situational challenges are not suitable. Out of the whole population of students 53.33% population study digitally at their paces comfortably. More than 50% of the whole population does not have any uncomfortable experiences with online learning digitally. In short, a preponderance of the students have a positive experience in e-learning digitally at home.

V. CONCLUSION

Investigating the effectiveness of e-learning in a school context was a successful endeavor. The researcher was able to prove that the students acquire e-learning and get success in this platform. E-learning was favorably accepted by students as an effective tool of learning. Specially with the impact of COVID-19 e-learning played a wise role in keeping the students engaged and updated in their learning process. E-learning can be defined as an effective tool because it enhances the delivery of instructions and develops knowledge acquisition skills by providing enough resources to students for learning. Likewise, students felt a very positive attitude towards e-learning which supported their continuous learning style a successful one. In this sense, students get the chance to motivate themselves and learn independently by dealing with the latest technology instruments. Therefore, e-learning can be considered one of the best learning strategies that can be adopted for teaching and learning. It enhances students' technology skills too. In conclusion, this research can further establish the Effectiveness of E-Learning in two "Type 1AB" schools in Kandy Zone. Researchers assert that the provision of education can no longer be restricted to a single school but can be extended throughout the country through distance learning and the integration of e-learning solutions. That is why Sri Lanka provided common e-learning platforms to students who are in rural areas with fewer facilities to learn during the COVID-19 pandemic. There was so much evidence that shows the effectiveness of e-learning in the Sri Lankan education context is successful. Not only the Type 1AB schools but also all the types of schools are already experienced and experienced as well as will try to experience e-learning platforms to give the latest online experience to the students in Sri Lanka.

ACKNOWLEDGEMENT

I would like to express my great attitude to each person who supported me in completing the project successfully, especially the two principals of St. Sylvester's College, Kandy and Vidyartha College, Kandy, academic staff, students and the non-academic staff for giving me their fullest support for the completion of this project.

REFERENCES

- Abayasekara, A. (2020, June 1). "Distance Education during and after COVID-19: Long Road Ahead for Sri Lanka". Retrieved from <https://www.ips.lk/talkingeconomics/2020/07/13/distance-education-during-and-after-covid-19-long-road-ahead-for-Sri-Lanka/>
- "COVID-19 and online education in Sri Lanka: Can we do it better?". (2021, June 16). Retrieved from <https://www.ft.lk/columns/COVID-19-and-online-education-in-Sri-Lanka--Can-we-do-it-better-/4-719254>
- Nirma Subashini, Lahiru Udayanga, L.H.N De Silva, J.C Edirisinghe & M.N Nafla. (2022, July 3). Undergraduate perceptions on transitioning into E-Learning for continuation of higher education during the COVID pandemic in a developing country: a cross-sectional study from Sri Lanka. Retrieved from <https://bmcmmededuc.biomedcentral.com/articles/10.1186/s12909-022-03586-2>
- Panchami, J. (2019). "Impact of COVID-19 in the Sri Lankan education system". Retrieved from <https://www.aiesec.lk/impact-of-covid-19-in-the-sri-lanka-education-system/>

Challenges Faced During Speaking Activities A Survey Carried out among the Mechatronics Students of UoVT

S. Usenthini

*Department of Language Studies
University of Vocational Technology
Ratmalana, Colombo
elt19b125@uovt.ac.lk*

L.H.D.L. Ranasuriya

*Department of Language Studies
University of Vocational Technology
Rathmalana, Colombo
dilniranasuriya@uovt.ac.lk*

Abstract— Language plays a vital role in communication during lectures. Significantly, in a multilingual classroom that employs English as the medium of instruction in the teaching-learning process. English is used as a common language for students with different native languages. Yet, it is significantly noted that the undergraduates of UoVT have faced challenges in speaking English though they are following English medium degrees. Therefore, this study focused on discussing the challenges of speaking among UoVT mechatronics students. The main objective of the study is to identify the challenges faced by students during speaking activities. This paper is developed by administering questionnaires that consist of closed and open-ended questions among forty students of UoVT from the mechatronics department. And also conducted an interview with the 10 students from the same sample and conducted interviews with 3 lecturers. This study concluded that the undergraduates of UoVT faced challenges in speaking English such as lack of vocabulary, knowledge of grammar, feeling uncomfortable, frustrated, or worried when speaking English, not having a healthy environment to talk, shyness etc. This study was supportive of coming to the conclusion and remedial measures for these challenges such as making learner friendly environment, adding more speaking activities in the curriculum, and planning activities to enhance the learners' vocabulary, grammar, and pronunciation to develop learner's speaking ability etc.

Keywords— Challenges, Speaking, Pronunciation, Vocabulary, Grammar

I INTRODUCTION

Today English has become a part of everyday life and it is the language that connects people from different regions, cultures, religions, and nations and it plays a vital role in human life. Learning English is important and people try to learn it. According to Chaney (1998), Speaking is the “process of building and sharing meaning through the use of verbal and non-verbal symbols in a variety of contexts. Speaking is a productive skill in the oral mode. It is the skill that gives us the ability to communicate effectively and it is more complicated than it seems at first and involves just pronouncing words. One of the English language skills that must be mastered by any foreign language learner is the

ability to speak. The common issue that emerges from anybody who needs to know one's ability in a foreign language is whether he/ she is capable of speaking English or not. According to Nunan (1991),

the most important aspect of learning a second language or foreign language is mastering speaking skills. In most cases, the students are unable to speak fluently although

they can understand the English texts. When learning English as a second language (ESL), students face a lot of challenges.

When they come to the university level, they face many challenges in speaking activities. Therefore, students need a range of speaking tasks that encourage considerable independence by relying on extensive oral practice. The speaking activities are conversations, interviews, discussions, and academic presentations. Each speaking task needs to be productive purposeful, interactive, challenging, safe authentic. At the University of Vocational Technology (UoVT) mechatronics undergraduates are offered an English module titled “Communication Skills to assist them in following subject-related content which is offered in the English medium. However, as is the case in many higher educational institutions, this has not shown any favorable results. Hence, the main purpose of this survey is to identify the challenges faced by B. Tech Mechatronics students during speaking activities at the University of Vocational Technology (UoVT) in order to develop their speaking skills. Therefore the following research question will be looked at:

What are the challenges faced by mechatronics students during their speaking activities at UoVT?

II LITERATURE REVIEW

A. Definition of Speaking

According to Akbari (2015), In the 21st century, the English has become an inseparable part of the educational curriculum in most countries where English is used as a

second language or foreign language. It is considered as a global language and every part of human life is connected with it. Ur (2002) stated that among the four skills of language, speaking seems intuitively the most important and difficult skill for ESL and EFL learners. There are many definitions of the word “speaking” that have been presented by researchers in language learning. According to Brown (1994), speaking is an interactive process of constructing meaning that involves producing receiving, and processing information. Among the four skills speaking is the first and foremost skill that is needed for human beings because they spend more time interacting orally with each other. When speaking English, pronunciation, fluency, vocabulary, grammar, and comprehension are the basic components. Here, both researchers give a vivid explanation of the definition of speaking and how speaking helps the learners understand the language. Hughes (2003), stated that there are some proficiency descriptions of speaking English such as accent, grammar, vocabulary, fluency, and comprehension. When learners try to speak, they have to focus on their pronunciation, structure of grammar, accent and vocabulary. According to the above definitions speaking is not a single process. It is a collection of several factors such as pronunciation, vocabulary, grammar etc. Previous research proves that people cannot learn a language without many that people cannot learn a language without many opportunities for meaningful repetition. Oral language interactions and the opportunity to produce language in meaningful tasks provide the practice that is very important to internalize the language. Krashen (1988) examined the relationship between listening and speaking skills. He stated that when students speak, their speaking provides evidence that they have acquired the language. This idea led some teachers to jump quickly from speaking teaching to reading and writing teaching. When students learn English, speaking is significant to support their ability to apply the language.

According to the above, speaking is an important and crucial part of second language learners. Almost all the researchers have highlighted the necessity of speaking and the challenges of speaking. Also, suggestions are very important to improve the speaking ability of students. Through interesting activities, the speaking ability can be improved. From the above discussion on the literature review, it can be concluded that various learning, especially speaking challenges may occur in the way of mastering the speaking skills of second and foreign language learners. The challenges may be inhibition, lack of vocabulary, grammar, pronunciation, fear of mistakes, being unfamiliar with the socio-cultural system of communication and so many others.

B. Importance of Speaking

In the present world, communication plays a crucial part in achieving success in all fields. Language is used as a tool for communication. Speaking skill is the most important skill for acquiring foreign or second language learning. Among the four language skills, speaking is considered to be the most important skill in learning a foreign or second language. In the modern world, it has become common to

prove the candidates' talents at the time of their job interviews and many of the selections are based on the performance of the interview. The job applicants have to participate and prove themselves in debates and group discussions where the performance or oral communication skills of the candidates are primarily measured. Besides, the professionals have to give oral presentations as they have to promote the products or their companies or give training to other colleagues. Furthermore, an effective speaker can impress the audience a lot and gain their complete attention and maintain the same speed until the end of his/her speech. So the audience is fully in their speaker's speech. they sometimes forget the real world and put their complete attention on the speech. According to Ur (2000), of all the four language skills called listening, speaking, reading, and writing, speaking is the most important one that is very necessary for effective communication.

The significance of speaking is indicated by the integration of other language skills. Speaking helps learners develop their vocabulary and grammar skills and then better their writing skills. Students can express their emotions and ideas; say stories; request; talk, discuss, and show the various functions of language. Speaking is of vital importance outside the classroom. Therefore, language speakers have more opportunities to find jobs in different organizations and companies. These statements have been supported by Baker and Westrup (2003) who said that learners who speak English very well can have a greater chance of better education, finding good jobs, and getting a promotion

III METHODOLOGY

This descriptive study primarily contains a quantitative and qualitative study. This study was done to investigate the challenges faced by UoVT mechatronics students in speaking English. In this event, the views of stakeholders were analyzed through a questionnaire with the aim of investigating participants' views on the challenges they faced in speaking English. and semi-structured interviews were used as the research tool. The Purposive Sampling technique was used to choose the sample for the study. Hence the population is mechatronics students of UoVT (2019/2020, 2021/2022). Also, 10 students and 3 lecturers were selected to conduct the interview. In this study, interviews and results of the questionnaires, as well as findings from works of previous researchers, were incorporated in the content analysis section, while they will integrate into a general discussion to provide a broader perspective of the challenges faced by UoVT mechatronics students in speaking English.

IV RESULTS AND DISCUSSION

C. Perception of Speaking English

Contradictory ideas were expressed by the participants regarding the English language. According to the results obtained through According to the results obtained through interviews with both lecturers and students, the following ideas were highlighted.

Student 1 – *“I like English very much because it is very important for us to find a job”*

Similarly, the majority of students prefer English and they are aware of the importance of English. The fact that it is very important for us to find a good job highlights that there is a strong need for English. These words bring out a strong explanation of the need for English.

It is obvious that in the future, English will have a great demand in the job market. Speaking is a major skill in learning English. The students who obtained less performance in the presentation in the assignments were selected for the study. Most of the students find it difficult to speak English fluently. Majorities of students prefer speaking in their mother tongue rather than in English in the classroom.

Student 2 – “I want to speak English fluently because communicate with other nationalities”.

The above statement reveals the importance of speaking English. Therefore, speaking ability undoubtedly helps them to communicate with others all around the world. Some results got from questionnaire.

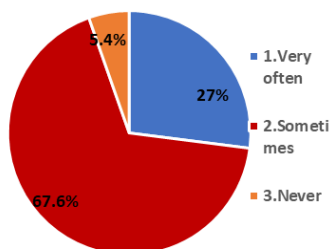


Figure 1: Frequency of getting opportunities to speak English in the classroom

With regard to Figure 1, most of the students (67.6%) stated that “sometimes” only they got a chance to speak English during the lessons while 27% of them “very often” got a chance. However, a few (6.6%) of them have not said that they “never” get a chance to speak at class. This is obviously a positive sign of a university that is taught in English. Students should be given a chance to speak in English. Yet, it will be better if they are given a chance more often than sometimes.

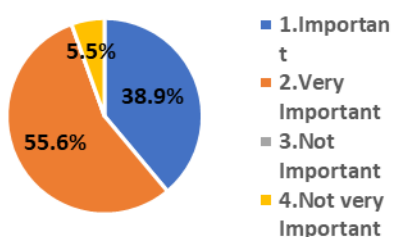


Figure 2: Students' view on knowledge of vocabulary

According to Figure 2, the Majority of the students accepted there is a vast knowledge of vocabulary is important (93.5%) while very few students (6.5%) said “no”. Therefore, it is obvious vocabulary is important for speaking ability. According to the interview also students stated that vocabulary is important to speak fluently and lack of vocabulary is one of the main barriers to speak.

Therefore, vast knowledge of vocabulary important factor to learn English.

D. Challenges Encountered by the Students

Many reasons that influence speaking challenges can be clearly seen through the research. Lack of vocabulary, shyness/fear of making mistakes, lack of opportunities, lack of practice, lack of motivation, poor pronunciation, lack of language structure, and lack of confidence are the challenges given in the interview. The results display the challenges of speaking among mechatronics students.

Here, there were some statements given by the students during interviews.

Student 1-“I find it difficult to speak in English. I don't know how to use the proper words in the proper place. Also, I don't know relevant grammar structures. So I think that it is wrong what I say.”

The above statement was said by one of the mechatronic students and it reveals the students faced some barriers when they spoke with others. One of the lecturers also stated that my students are reluctant to speak in English because they lack what they want to say clearly. This is the reason that students do not try to speak in English. As lecturers, they think that grammar is very important in speaking but at the same time, they emphasize that speaking English is also important. The students say that speaking is difficult because they tend to think about grammar and vocabulary. Thus, as per my experience, there needs to be a common way of looking at speaking English. Otherwise, they become stressed about speaking in English. Shyness is the next significant reason for speaking challenges among students. Most of the students are shy to use a language that is not familiar to them. They hesitate to speak in a language that is foreign to them. Another speaking challenge that is connected to shyness is the fear of making mistakes. Fear is a psychological factor that makes the process of learning difficult. Fear is created by bitter learning experiences or lack of confidence associated with English language learning. One of the students presented his idea regarding that, “*I fear speaking English because I think they will laugh at me when I make mistakes.*”

According to him, he does not even try to speak in English because he has a thought which is engraved in his mind that he would be mocked by others when making mistakes. This is a barrier to improving his English-speaking skills.

Student 1- “I need constant practice in speaking English because practice is an effective way of familiarizing the language.”

According to the above statement, practice can support the improvement of speaking skills. One should be confident enough in a particular language to Sri Lankan students, they should have the confidence to use it accurately and properly.

E. Suggestions Given by the Lecturers

According to the interview, Lecturers said the ‘Communication skills’ module helped the students to improve their speaking ability because most of the students came from A/L. They have done their A/L in their mother

tongue. Therefore, this is the first and foremost opportunity to learn their degree in English medium, and also the 'Communication skills' module helped the students to overcome their challenges in speaking English.

Lecturer A-*"Students should reschedule their learning styles or patterns"*.

The above statement demonstrated the inducement of self-interest, no one is gifted to speak fluently. Students have to maintain self-improvement and they can improve their speaking skills through technology sources such as YouTube, Facebook, Tedtalks online dictionaries etc.

Lecturer B – *"It will be better if role plays are there, some based on topics, and students can perform."*

Akbari (2016) also stated that learning strategies are special tools for enhancing the learning capacity of learners; adopting a special kind of learning strategy may boost the understanding of the learners. The above statement stated that adding more speaking activities to the curriculum will change students' speaking performance and give them chances to overcome their speaking barriers.

Lecture C – *"If they are not familiar with the subject matter. Combining with other modules they have to do some presentations not only in 'communication skills' lecturers but also in the other modules' lecturers also help them to improve students' speaking skills."*

They are not very familiar with the subject matter. Therefore, combining English is a tool to communicate their subject matter. One of the lecturers said "The main obstacle of speaking is lack of vocabulary that's why students hesitate to speak fluently. Sato (2003) also stated that students fail to join in the English discussion because of their vocabulary problems and fear of making mistakes resulting in their inability to speak English well.

V CONCLUSIONS AND RECOMMENDATIONS

The result of the interview significantly indicated that mechatronics undergraduates are reluctant to speak English though they are doing an English medium degree. Therefore, they tend to speak very little or not at all. As a result, the improvement of the speaking skills of students may not take place. This study investigated the factors that affect these challenges of speaking English. Additionally, the mistakes made by the undergraduates when speaking English also examined. At the same time, suggestions for developing speaking ability were stated by the participants and the lecturers.

According to findings, they constantly face numerous challenges related to English speaking such as not understanding what others say, others cannot understand what is being said to them, others want to code-switching when talking, feeling uncomfortable when speaking, feeling frustrated or worried, lack of vocabulary to talk. As a whole lack of vocabulary to talk and feeling uncomfortable when speaking is the most common issue they face.

According to the participant's comments on mistakes they made when speaking, it can be noticed that pronunciation difficulties, the accent they use when speaking, use of

grammatically incorrect sentences, or unsuitable and incorrect words, stammering while speaking and keeping long pauses while speaking are most common mistakes, they have done in speaking in English.

As reasons for these mistakes and challenges, the participants stated that lack of speaking practice, poor pronunciation and accent due influence of mother tongue, not having enough vocabulary to talk, not having good knowledge of grammar, shyness, and lack of confidence to speak, due to that, afraid of making mistakes or phobia, lack of opportunities to speak, absence of a supportive environment and lack of support from others such as family members, friends and lectures in developing their speaking ability.

The last chapter of this research report is reserved for some recommendations related to the findings and conclusion of the survey conducted. Recommendations can be given through the participant's suggestions. According to that, it is recommended that the negative attitudes of the students regarding speaking English should be changed into positive ones. In order to do that, it is compulsory to change the environment. The environment should be learner-motivated one where the learner is inspired to use English and understand its importance. Raja and Selvi (2011) highlighted that the "environment highly affects the improvement of speaking English". This was apparently revealed from the students' responses that they did not have a good environment to use English. Therefore, it is recommended to create a student-friendly environment where they are open to speaking in English freely through activity-based learning. At the same time, motivation and reinforcement should take place to add more value to this process.

Pronunciation, lack of knowledge of grammar, and lack of vocabulary are the other main obstacles to speaking English as mentioned by the participants. It is obvious that pronunciation and vocabulary are the most important aspects of English speaking. Therefore, special activities such as speeches, language games, debating, news bulleting, and role plays should be carried out to improve the pronunciation, grammar structures, and vocabulary of the students.

At the same time, it is recommended lecturers use new and interesting methodologies to teach the subject content only in English. This will help the students to build more interest in English and this will be motivation for them to speak in English. Finally, the students should be given more chances to speak only in English in class. Lecturers also gave some suggestions to improve their students' performance such as adding new teaching methodologies to the curriculum, Students should read related to the English language and also increase their self - interest otherwise they cannot overcome those challenges.

REFERENCES

- Akbari, Z. (2015). Current Challenges in teaching/learning English for EFL learners: The case of Junior High School and High School. *Procedia - Social and Behavioral Sciences*, 199, 394-401.

- Akbari, Z. (2016). Current Challenges in Teaching/ Learning English for EFL learners: The case of Junior High School and High school. *Procedia - Social and Behavioral Sciences*. English Language.
- Baker, J., & Westrup, H. (2003). *Essential Speaking Skills: A Handbook for English Language Teachers*. London: Continuum.
- Chaney,A.(1998). *Teaching Oral Communication in Gradws K-8.U.S.A.A*. Viacom Company
- Brown, H. D. (1994). *Teaching by Principles-An Interactive Approach to Language Pedagogy*. Language Pedagogy.
- Hughes, R. (2003). *Teaching and Researching Speaking*. New York: Pearson Education.
- Krashen, S. D. (1988). *Second Language Acquisition and Second* Hughes, R. (2003). *Teaching and Researching Speaking*. New York: Pearson Education.*Language Learning*. New York - Practice Hall.
- Nunan.D. (1991). *Language Teaching Methodology: A Textbook for Teachers*. Prentice Hall
- Raja, B. W. D., & Selvi, K. (2011). Causes of problems in learning English as a second language as perceived by higher secondary students. *i-manager's Journal on English Language Teaching*, 1(4), 40-45.
- Sato, K. (2003). *Improving Our Students' Speaking Skills: Using selective Error correction and Group*.
- Ur,P.(2000). *A Course in Language Teaching: Practice and Theory*. Cambridge: Cambridge University Press
- Ur, P. (2002). *A course in language teaching : Practice and theory*. Cambridge University Press

Psychological Factors Affecting Speaking in English among Lower Secondary Level ESL Learners

A.S.C.K. Kasthuriarachchi
*Department of Language Studies University of
Vocational Technology
Sri Lanka chandimakumari.4000@gmail.com*

Y.S. Manathunge
*Department of Education and Training
University of Vocational Technology
Sri Lanka
yamuna@uovt.ac.lk*

Abstract— Most Sri Lankan students face challenges when it comes to communicating effectively in English and engaging in class discussions or various conversational topics. The reasons for this are the complexity of the speaking skill and the impact of major psychological factors such as anxiety, shyness, lack of self-confidence, and lack of motivation. This research was carried out to explore the effects of main psychological factors on grade six students' second language speaking performance at Kg/Mw/Mawathagoda Rivisanda Central College. The objectives of the research are to find out the psychological problems faced by learners speaking the English language and to identify the reasons for those psychological problems. This explanatory study was carried out by the administration of a questionnaire to a sample of forty students to reveal the effect of the main factors as well as an interview conducted with five teachers of English, which are teaching these students. According to the findings, the majority of students' poor speaking abilities are caused by psychological issues including anxiety, shyness, a lack of self-confidence, and lack of motivation, which in turn cause a number of issues such as less vocabulary, shyness, and fear of making mistakes. The study made some recommendations for education, such as the necessity of creating a suitable environment for motivating students to practice speaking in class and encouraging their motivation and confidence by organizing various speaking activities. Also, for a better level and fluency, students should practice speaking English both inside and outside of the classroom. The researcher was able to verify the psychological factors affecting English among lower secondary-level English as a Second Language (ESL) learners.

Keywords- psychological factors, second language learning, self-confidence, speaking activities, speaking skill

I INTRODUCTION

Language is important because it is one of the main ways to communicate and interact with other people around us. It keeps us in contact with other people. English is an international language and has become the most important language for people in many parts

of the world. In present-day society, students cannot be ignored in learning English. As an international language, English is commonly used by all countries in the world. English is used as a second language in Sri Lanka. Speaking is an interactive activity that involves the sharing of information and, if necessary, the listener's response. It is among the four essential language skills. (Reading, writing, listening, and speaking). It implies that students can interact with others to further their ideas, hopes, and objectives. In addition, people who know a language are referred to as speakers of that language. Learning English as a second language is considered a challenging task. It is even more difficult for some undeveloped rural area students. Students in those areas face numerous challenges while learning English. Speaking English is considered one of the best tools for communication. For many language learners, expressing themselves orally might be difficult due to psychological barriers and the struggle of finding suitable words and phrases. As a result, they often face issues in effectively conveying their views and choose to remain silent.

Students cannot ignore the reality that English is the universal language for technology and worldwide trade given the significance of the English language. In this perspective, the teaching and learning of a language is seen as a contributor to the development of individual abilities. It is believed that the main psychological factors in teaching speaking are anxiety, shyness, lack of self-confidence, and lack of motivation, as well as the need to reduce students' difficulties. Therefore, reducing these obstacles and factors in the classroom allows learners to engage in discussions, particularly in oral interactions, and enhances their English speaking performance. Teaching speaking is an important aspect of language instruction because it gives students the chance to improve their oral proficiency through engaging in speaking activities, discussions, role-plays, interviews, and conversations that demonstrate their areas for improvement and the strategies used by the teachers.

English teachers must actively encourage their pupils to speak given that speaking is crucial for English learners.

II LITERATURE REVIEW

Speaking is a fundamental language skill that holds significant importance for students, enabling them to become effective communicators. It serves as a means to express oneself in various situations and convey a sequence of ideas among individuals within a community. This involves the utilization of verbal and non-verbal symbols within a specific language, context, and situation. Speaking is a multifaceted cognitive and linguistic ability. A child obtains knowledge by engaging with individuals in their immediate environment using their mother tongue. Every normal adult can speak in his native language without effort and this skill is a natural one. However, speaking in a foreign language is not instinctive and necessitates conscious effort throughout the entire process. Lindsay and Knight (2006:57) stated that speaking is a creative skill. It involves putting a message together, communicating the message, and interacting with other people. According to Fulcher (2003:23), speaking is the oral use of language to communicate with others. Making decisions is a part of speaking. Through speaking, students must decide how to interact with others and build social connections. Traditional teaching methods usually included copying the teacher and remembering or responding to movements Richards (2008:2). All of these behaviors reflect the sentence-based proficiency typical of audio-lingual and other drills- or repetition-based techniques from the 1970s. In brief, speaking allows us to express emotions and have discussions with others. It involves using words and phrases collaboratively to convey meaning. Speaking means exchanging intended meanings and correcting someone's speech to produce the preferred effect on the listener (O'Malley, 1996:59). It involves converting meaning between two or more persons, and it is always related to the context. Speaking is not only used to interact with other people but also used to get information. Moreover, language experts have proposed many definitions of speaking. Brown (2000, p.265) stated that "when someone can speak a language it means that he can carry on a conversation reasonably and competently". He further said that the successful acquisition of language is generally the ability to achieve perfect goals through collaboration with other foreign-language speakers. In speaking activities, the students usually get some problems that make it difficult to speak anything. Shy in speaking, having a lack of vocabulary, or being afraid of using sentence patterns are some reasons for that. Lack of opportunities for practice is an important contributing factor to speech failure (Thornbury, 2005:28).

Second language learning (SLL) focuses on understanding how individuals acquire a second language, often referred to as a target language, and

the associated learning process. Learning a second language involves the social role that language plays in the community. It serves as an acknowledged method of communication for individuals who speak a language other than their mother tongue. Second language learning is different from bilingual learning, where a student learns two languages simultaneously. The psychological influences of positive or negative attitudes from nearby society can be critical. That is why it needs constant and conscious strength on the part of the student to overcome various psychological interferences. In every learning situation, human psychology plays a significant role. English speaking is a language skill that is highly affected by human psychology. According to Haidara (2016) in his research on the psychological factor that affects negatively the English-speaking performance of English learners in Indonesia. This study used a descriptive qualitative research design. A theoretical review, field notes, observations, and unstructured interviews made up the research methodology. The participants were 20 students.

Authors reveal that speaking is considered one of the most important skills in learning English but many language learners find it difficult and they need much effort to produce suitable words in English (Nijat, Chandran, Atifnigar, Selvan, and Subramonie, 2019). The goal of their research is to identify psychological reasons that prevent Malaysian primary school students from speaking English fluently and to suggest possible solutions from the point of view of the students to remove these barriers. More research shows that students' anxiety levels had a negative relationship with their speaking performance (Park and Lee, 2005). Some other speaking difficulties faced by learners are inhibition, nothing to say, low participation, and mother tongue use in their speaking classes (Lukitasari, 2003). Another result of this investigation establishes that learners did not improve their speaking skills because they had not learned three components of speaking; vocabulary, grammar, and pronunciation.

Urrutia and Vega (2010) revealed that students' speaking performance was influenced by their lack of vocabulary, shyness, and fear of being insulted. It was also shown that students' collaboration, self-confidence, vocabulary knowledge, and the class environment helped them to increase their speaking skills. Furthermore, they stated that playing games would always be an important part of learning a second or foreign language. In the process of teaching English, they have emphasized the value of selecting games. Students can learn about speaking in a fun and relaxed way by playing games, which are inspiring and motivating experiences. Also, they noted that games helped students to believe in themselves, and create a good atmosphere inside the classroom. They utilized eight types of games, including caring-sharing, guessing, and storytelling games. They helped students to communicate orally

and to gain confidence in speaking. Also, during the process of implementation, students overcame their fear of making mistakes as a natural process when they were playing. As a result, there was no time limit, and the majority of students were able to express themselves and speak orally.

Ibrahim, Ali, Al-mehsin, and Alipour (2022) this research observed psychological factors affecting the language-learning process in Saudi Arabia and the impacts of flipped learning as a kind of technology-based instruction on Saudi Arabia students' motivation, anxiety, and attitude. The population was 58 students at the intermediate level from one high school in Riyadh City, Saudi Arabia, who were selected and assigned to two equal classes. The participants were chosen based on a nonrandom sampling method. One experimental group and one control group were included in this investigation. Motivation, anxiety, and attitude were the independent variables, and flipped learning was the dependent variable of this research.

Park and Lee (2005) studied the connection between second language learners' anxiety, self-confidence, and speaking performance. About one hundred and thirty-two learners in Korea participated in their study. The results of this research showed that students' anxiety levels had a negative relationship with their speaking performance. Teshome (2018) the purpose of the study was to investigate the psychological factors affecting students' academic performance among freshman psychology students at Dire Dawa University. The participants of the study were 16 first-year students. The sample of this study was taken through a purposive sampling technique. To collect data, questionnaires, and observation checklists were used. The findings of this study also revealed that there was a significant relationship between psychological factors and students' academic performance.

Yuliana (2020) investigated the relationship between psychological elements and speaking ability, as well as which psychological factors have the greatest influence on English speaking ability. This research was quantitative research with a descriptive approach and used a questionnaire as the research instrument. To select the participants, purposive sampling was used in this research; seventy-five students who had finished all of the speaking subjects became the participants in this research. This current research aims to further verify the previous findings.

III RESEARCH OBJECTIVES

This study addresses the following research objectives:

- To classify the psychological problems faced by learners speaking the English language who come from rural areas.
- To investigate the main reasons for these psychological factors.

IV METHODOLOGY

This design of the study was based on the main psychological factors affecting speaking in English among lower secondary-level ESL learners. The researcher selected grade 6 students for this study. This study uses both quantitative and qualitative approaches, owing to the fact that participants' verbal and written responses were vital in any research involving human participants. A quantitative approach was very helpful to collect information from the grade 6 students using a questionnaire. The qualitative approach followed the interview method. It was helpful to provide information about a range of ideas and experiences of the teachers regarding their students' speaking abilities.

The target population was one hundred and twenty students from grade six students in Kg/Mw/ Mawathagoda Rivisanda Central College. The sample of this study was forty students and five English teachers. Mawathagoda Rivisanda Central College is located in the Mawanella Education Zone, Kegalle district. The school is situated in the corner of Aranayaka village. Aranayaka village is a rural area in Mawanella, Kegalle district of the Sabaragamuwa Province. This school is categorized as a Type 1 AB school and operates as a government mixed school, offering education up to grade 12. The sample of forty students including twenty boys and twenty girls were selected from grades 6A, 6B, and 6C at Mawathagoda Rivisanda Central College. Also, five teachers of English who teach the above students were selected from the same school. Details of the students from these classes are as follows. Six boys and eight girls were selected from the grade 6A class, and eight boys and seven girls from the grade 6B class. Also, five boys and six girls were selected from grade 6C based on the student ratio. This sample of students was selected by using a simple random sampling technique.

In this study, for collecting data about the psychological factors affecting students' English speaking performance, two different types of questions were included in the questionnaire; close-ended questions and open-ended questions that required students to give short answers, and the sample of students could have the freedom to express anything they want relating to the questions asked. First decided on the main questionnaire. Twenty (20)

questions were arranged logically in this questionnaire. Some of them required the students to answer “yes” or “no” and some were to tick appropriate answers from the number of choices. Some questions required them to write their own opinions and justifications. The questionnaire was divided into two sections. The first section was general information. It had 5 questions to give a general overview of students’ choice to learn English. Section two is considered the main psychological factors affecting speaking. In this part, it is also divided into five categories. Those are motivation, anxiety, attitude, self-confidence, and shyness. It attempted to give the participants’ perceptions about the influence of these factors, the causes as well as the possible solutions to overcome them. This questionnaire was administered to the students in English. The forty selected students were taken to one classroom to write the answers and at that time this questionnaire was explained using both Sinhala and English languages and the students expressed their opinions in both English and Sinhala languages.

The interview was conducted with the teachers to gain further information about the main psychological factors that hinder students from speaking English. Semi-structured interview questions were used to gather details from five teachers of English to answer the research questions. They gave answers based on their opinions and experiences and mentioned various measures they use to improve their student’s speaking ability.

V RESULT AND DISCUSSION

This study aims to find out the main psychological factors that affect lower second-language learners’ speaking performance. This section is about students’ and language teachers’ opinions and views. Because they help to answer the research questions.

• *Problems Faced By Students in Speaking in English*

The results found from the student’s questionnaire, have given a deep insight into the research objectives and the topic. Speaking is considered by the students as being the most critical skill of the others. Most pupils like learning English because it is used intensely in educational settings and the curriculum. The percentage of 82% indicates that students like learning the English language as they can develop their level of speaking, improve their accent as well as understand what others say. The amount of 18% claim that they have no desire to learn English.

37% indicate that the main purpose of learning English is to go abroad. Because students also need to go to another country. So they mainly focus their attention on another country. 28% of the respondents have selected to get a job because most

of their target in learning English is for getting only a job. Because in present-day society without using English, we cannot do any kind of job. So their target is only getting a job. Furthermore, 25% of students like to learn English for further studies because their language and speaking skills will be developed. 10% indicates that learning English is for communication because the focus of language teachers is to create an environment where the students engage in classroom interaction. The participants did not respond for other purposes of learning English.

Most of them believe that their level is in general. The percentage is 45%. They think they can speak English normally. And they believe their English speaking level is at a common level. On the other hand, 28% of them believe that they are talented in English because of their ability to understand what other says.

The portions of 32% of students prefer discussion to share their knowledge and opinions because it helps them to develop their level in the language and to increase their motivation. And they can discuss with the teacher which increases their speaking ability because they can correct their language with the help of a teacher. 20% of students like the interview to increase their vocabulary and confidence. With that, they can communicate with their friends.

The majority of students agree that they are hesitant to engage since they are anxious to express their needs due to nervousness. The high percentage of 55% shows the student’s inhibition. When considering this, it seems that inhibition is the main difficulty for more than half of the students. The next students clarified that fear of making mistakes was the problem encountered by them in practice.

VI THE PSYCHOLOGICAL FACTORS AFFECTING SPEAKING

Findings reveal that most of the students are suffering from the main psychological factors such as motivation, attitude, anxiety, shyness, and lack of self-confidence. The results reveal that the students face problems that make them poor in speaking English.

RESPONSES TO THE QUESTIONNAIRE

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Motivation					
Q-6. Learning to speak English is important because you will need it for your future.	60%	18%	23%	0%	0%
Q-7. Do you agree that motivation is needed to improve your English language ability?	78%	5%	18%	0%	0%
Q-8. Your parents feel that it is very important for you to learn English.	73%	13%	15%	0%	0%
Q-9. Learning to speak English is important because other people will respect you more if you can speak English.	35%	13%	53%	0%	0%
Anxiety					
Q-11. You would get nervous if you had to speak English to a tourist.	25%	28%	43%	0%	5%
Q-12. You tremble when you know that you are going to be called into the speaking class.	15%	35%	35%	15%	0%
Q-13. You are afraid that other students will laugh at you when you speak English.	25%	33%	28%	8%	8%
Attitude					
Q-14. You tend to give up and not pay attention when you don't understand your English teacher's explanation of something.	20%	15%	20%	8%	38%
Q-15. You enjoy English speaking activities in your class	33%	13%	23%	15%	18%

more than your other subject activities.					
Self-Confidence					
Q-16. You never feel quite sure of yourself when you are speaking in English in your class.	5%	8%	48%	15%	25%
Q-17. It embarrassed you to volunteer an answer in your speaking class.	3%	8%	33%	30%	28%
Q-18. You always feel that other students speak English better than you.	18%	18%	40%	10%	15%
Shyness					
Q-19. Do you agree that shyness is the main obstacle to speaking?	0%	25%	35%	18%	23%

• *Motivation*

60% of the sample strongly agree that English speaking is important, while 78% of the students responded strongly that motivation is an important factor for speaking English. Answering the specific reasons why they are motivated, 73% responded strongly agreeing with the parents' emphasis on learning English. However, only 35% strongly agreed that English speaking is crucial for gaining respect.

• *Anxiety Equations*

Anxiety is the most influential negative affective factor, which prevents learners from successfully processing speaking English. Students get nervous when they know that they will have to speak in front of their class or speak in English in their English-speaking class and they will get that opportunity. The Percentage of 35%, of the students agreed with the statement. 33% of the respondents contend that their peers' laughter does not deter them from speaking English; instead, it serves as motivation to achieve their goals and learn from their errors, as they are all in the process of learning.

• *Attitude*

38% of students strongly disagreed with the statement of students who give up and do not pay attention when they don't understand their English teacher's explanation of something. A portion of 33% of the students showed that they strongly agreed and they prefer to do English-speaking activities and

they enjoy English-speaking activities in their class more than their other subject activities.

- *Self Confidence*

The percentages of 48% of students argue that they lack of self-confidence in speaking sessions. They have a neutral idea about that. Because they do not trust themselves. A percentage of 33% gave a neutral opinion on the statement of being embarrassed to volunteer in students' speaking classes. They are reluctant to come forward because they lack self-confidence. The students are afraid and reluctant to speak English in front of other students and think that they can speak English better than them. 40% of the respondents have a neutral opinion about this. Some students are strongly convinced that others can speak English better than them. For that reason, they are less motivated to speak in English in front of a community. Therefore, their English-speaking ability is quite low.

- *Shyness*

Most of the students 60% show strongly agree that shyness is the main obstacle because they do not have much chance to talk, they are afraid of students' laughs as well as they are afraid of teachers' judgment.

V DISCUSSION

The results found from the student's questionnaire, have given a deep insight into the research objectives and the topic. The results show that most of the ESL learners of grade 6 are in Kg/Mw/Mawathagoda Rivisanda Central College. Consider speaking as the main skill among the other micro skills. In addition, most of the students are suffering from the main psychological factors such as anxiety, shyness, lack of motivation, and lack of self-confidence. The results reveal that the students face problems that make them poor in speaking English. Among the selected sample of students, most of them showed a desire to engage in oral sessions as well as to speak English fluently inside and outside the classroom. Therefore, it is very important to learn how to speak English because it helps students to develop their level and reduce the problems that affect them to participate in the oral performance. Apart from that, the questionnaire showed that speaking is one of the common skills because it is the medium that can acquire the basic elements of language appropriately based on effective strategies and activities such as discussions, interviews, and conversations, role-plays, and storytelling provided by the teacher to improve the student's pronunciation and vocabulary. Students also pay more attention to these kinds of activities because they also want to speak in English so they should improve their speaking ability as a result of it they are actively participating in these events. Furthermore, the importance of speaking, there are some problems such as fear of making mistakes and

lack of vocabulary as obstacles to English language learners. The students feel shy and hesitant in their speaking performance because of the nature of the topic, students' laughter, lack of vocabulary, and the main psychological factors. And also students feel anxious. Anxiety is the most influential negative affective factor, which prevents learners from successfully processing speaking English. It makes the students nervous and contributes to poor oral performance. When learners have low self-confidence, it directly affects the students' anxiety levels. Therefore, it is the main responsibility of the teacher to overcome these problems by providing students with relevant materials, technology, and comfortable surroundings. Students also enjoy speaking English because of that.

According to the results obtained from the student's responses, the main reason for the student's weakness in speaking English is the negative influence of the main psychological factors. It showed shyness and anxiety affects students' willingness because they feel stressed when they are asked to answer or speak. They are very shy to speak English because they have less number of words. And also they feel nervous when speaking in English and some of them are not interested in the teacher's explanations because they cannot understand what teachers say. Apart from that, students' lack of self-confidence and lack of motivation are other main 41 factors that affect the students speaking performance. Some students never feel quite sure of their self-confidence in speaking English. They are embarrassed about speaking English. Some students are strongly convinced that others can speak English better than them. For that reason, they are less motivated to speak in English in front of a community. Therefore, their English-speaking ability is quite low.

According to the results, finally, it suggested that reducing these psychological factors helps to improve their speaking level to avoid their mistakes and increase their confidence and motivation in classroom speaking performance

VI TEACHER'S OVERVIEW

A semi-structured interview was conducted with five teachers to know about their opinions and perceptions concerning the influence of the main psychological factors on students' abilities in speaking English. The purpose of using the interview was to gain more information about the negative effect of these factors on students' progress.

- *Reasons for Students' Failures to Speak English*

English is one of the most widely spoken languages in the world, and it has become a global language for communication. However, despite the importance of English, many people struggle to speak the language fluently and confidently. When considering the

responses on the students' confidence and participation in oral expression sessions, the participants stated that the majority of the students do not have self-confidence in speaking the English language and do not participate in speaking activities due to a lack of basic language knowledge. It may be mentioned that their intake of English language is stopped from the stage of their primary education. For example, a lack of grammar and vocabulary knowledge causes some students to mix parts of speech when forming sentences, making it challenging to create meaningful ones. Among the responses of the participants, it has been mentioned that students lack vocabulary. Consequently, they limit their speaking because they are afraid of making mistakes, which leads to a loss of self-confidence.

Moreover, one of the participants added some details on similar issues. The participant stated that most of the students do not have self-confidence and only seem to have it because they fear making mistakes and mentioned some reasons for the loss of self-confidence of the students. Those reasons are lack of basic speaking skills such as greeting, requesting, exchanging ideas, and giving opinions. The next point is a lack of motivation in speaking skills. And also, less background knowledge is another reason for students' loss of self-confidence. According to the participant's view, the students do not have good background knowledge of speaking skills. As a result, their performance is also not at a satisfactory level except for very few students. Another factor is the fear of making mistakes; even though they have some ideas, they are reluctant to voice them for fear of making a mistake that would make them look foolish. When considering the views of participants, stated that the main factor is that they do not focus on speaking English because more space is given in the classroom only for writing and teaching lessons. And according to that, the teachers have also rejected this. The reason for this is that there is a lot of noise in the classroom during the speaking activities, and the school is tempted not to implement the speaking programs due to the fact that it will interfere with the teaching activities. When considering respondents it is clear that lack of motivation, lack of self-confidence, and student's poor background of language knowledge directly affect their confidence in speaking English.

- *The Motivation of the Teacher*

All the participants said that it is essential for the teachers to encourage the students and mentioned that for this encouragement, various activities should be done inside the classroom as well as outside the classroom. And also it has mentioned that various activities have been used to improve the English speaking ability of the children in this school and the main thing was that a program called English only day program is running in this school. According to the findings, giving them the opportunity to present their speaking skills in English while engaging in

teaching activities in the classroom is also a way to further encourage them. To motivate the students, all the participants suggested doing debates, speeches, and competitions. One of the main factors they mentioned is that not only in the school classroom but also outside the classroom in the school by doing various activities, students can be directed to speak English. Because it can motivate students to speak English.

- *Improving Students Speaking Abilities*

According to the responses it has been mentioned to use simplified environments that promote speaking skills. The participants said that they sometimes used pair work and group discussions. However, when the students are engaged in discussions, they tend to shift the medium of speech to their mother tongue. When the teacher moved around, they attempted to speak in English. The participant further said that sometimes used role-play and debate because they are time-consuming in a large class and rushed to complete the syllabus to cover the topics given in a term.

According to the participants, try to use pair and group discussions, role-play, debates, and storytelling but only a few students participate and most of them keep quiet because they cannot speak the language and even change the medium from the target language to their mother tongue. The participant suggested that they allow them to listen to good speakers of English and get an idea about the various dialects and various English.

VII CONCLUSION

This study was intended to reveal the psychological problems faced by students from rural areas who are studying sixth grade in Kg/Mw/ Mawathagoda Ravisanda Central College while speaking English. According to the analysis, it can be stated that students face many difficulties when they are speaking English. Speaking English fluently is essential for effective communication in today's globalized society. However, students face difficulties when they are speaking English. Psychological factors significantly affect one's ability to express themselves fluently and confidently in English. Students are afraid to speak English because they think that if they do something wrong while speaking English, some people will laugh at them. Students should improve their self-confidence because it also helps them to speak English in front of society without any fear. However, students' difficulties in the classroom are caused by their shyness, anxiety, lack of self-confidence, lack of motivation, and fear of making mistakes, which are mostly influenced by key psychological issues. All these factors show the importance of the teacher's role in determining student's weaknesses and problems in speaking English.

To identify the main reasons for these psychological factors, the analysis chapter is concerned, it can be stated that responses from five teachers were analyzed. The exam-oriented teaching process that focuses only on reading and writing skills creates students who cannot speak English and neglect speaking skills. Therefore students are not interested the speaking activities inside and outside the classroom. In this sense, teachers should provide their pupils more opportunities to express themselves by providing speaking exercises, setting appropriate situations, and encouraging easy communication among the students. The teacher may help students develop more self-confidence by using various teaching techniques to help them feel less anxious and shy. Teachers can motivate by making lessons relevant and interesting, incorporating real-world applications of the language, and highlighting the benefits of language proficiency. Furthermore, the results gained from the questionnaire and interview, it is confirmed that poor learners' speaking performance is due to anxiety, shyness, lack of self-confidence, and lack of motivation. These factors work together to significantly hinder both their linguistic growth and overall academic success. As a result, it becomes crucial for teachers to carefully consider and address the negative effects these issues have on students' academic advancement.

Finally, the researcher can achieve the objectives of this study by finding out the learners' poor English speaking ability due to anxiety, shyness, lack of motivation, and lack of self-confidence.

ACKNOWLEDGMENT

First and foremost, I would like to give my heartiest gratitude to each person who supported me to complete the project successfully. Their positive vision and motivation deeply inspired me to conduct this research and it was a great privilege. Furthermore, I wish to extend my appreciation to, the principal of Kg/Mw/ Mawathagoda Ravisanda Central College, all the teachers, and grade six students who helped me collect data for my thesis. Finally, I would like to respectfully mention my parents, and my family members for their prayers and motivation.

REFERENCES

- Brown, H. D. (2000). *Principles of language learning and teaching*. 4thEd. New York: Pearson education.
- Fauzan, Umar. (2016). Enhancing Speaking Ability of EFL Students through Debate and Peer Assessment. *EFL Journal*. 1. 49. 10.21462/eflj.v1i1.8.
- Fulcher, G. 2003. *Testing Second Language Speaking*. Malaysia: Pearson Education Limited.
- Ibrahim, K. a. A., Ali, A. a. H., Al-Mehsin, S. A., & Alipour, P. (2022). Psychological Factors Affecting Language-Learning Process in Saudi Arabia: The Effect of TechnologyBased Education on High School Students' Motivation, Anxiety, and Attitude through Flipped Learning. *Education Research International*, 2022, 1–14. <https://doi.org/10.1155/2022/8644890>
- Lindsay, C. & P. Knight. (2006) *Learning and Teaching English: A course for teachers*. OUP
- Linguistics, I. J. O. E. A., & Feo, Y. (2017). English Speaking problems of EFL learners of Mulawarman University. www.academia.edu. https://www.academia.edu/28545944/English_Speaking_Problems_of_EFL_Learners_of_Mulawarman_University
- Lukitasari, N. (2003). Student's strategies in overcoming speaking problems in speaking class. University of Muhammadiyah Malang
- Nijat, Nazifullah & Atifnigar, Hamza & Chandran, Kanageswary & Letchumi, Siva & Selvan, Tamil & Subramonie, Vijayaletchumy. (2019). Psychological Factors that Affect English Speaking Performance among Malaysian Primary School Pupils. *American International Journal of Education and Linguistics Research*. 2. 10.46545/aijeler.v2i2.117.
- O'Malley, J.M, Chamot, Anna. (1996). *Learning Strategies in Second Language Acquisition*. Cambridge: Cambridge University Press
- Park, H., & Lee, A. R. (2005). L2 Learners' Anxiety, Self-confidence, and Oral Performance. *Proceedings of the 10th Conference of Pan-Pacific Association of Applied Linguistics* (pp. 107- 208). Edinburgh University. Retrieved January, 4th, 2017 from <http://www.paaljournal.org/resources/proceedings/PAAL10/pdfs/hyesook.pdf>.
- Richards, J. C. (2008). Second Language Teacher Education today. *RELC Journal*, 39(2), 158–177. <https://doi.org/10.1177/0033688208092182>
- Teshome, Wondu. (2018). Psychological Factors Affecting Students Academic Performance Among Freshman Psychology Students in Dire Dawa University. 9. 58-65
- Thornbury S. (2005). *How to Teach Speaking*. England. Pearson Education Limited
- Youssof Haidara (2016). Psychological Factor Affecting English Speaking Performance for the English Learners in Indonesia. *Universal Journal of Educational Research*, 4(7), 1501 - 1505. DOI: 10.13189/ujer.2016.040701.
- Yuliana, 160203160 (2020). The Effect of Psychological Factors on English Speaking Performance. Skripsi thesis, UIN Ar-Raniry Banda

Implementation of School-Based Management: School Leadership Challenges and Opportunities Faced by School Principals

Raveenthiran Vivekanantharasa
Department of Secondary and Tertiary Education
Faculty of Education
The Open University of Sri Lanka
rvive@ou.ac.lk

K.T.P.C. Somarathna
Department of Language Studies
Faculty of Education
University of Vocational Technology
ktpchamika@gmail.com

Abstract - This study examined school leadership challenges and opportunities faced by school principals in the implementation of School-Based Management (SBM). The main purpose of this study is to identify the opportunities of school leadership in the implementation of SBM. This study was focused on the objective of investigating the challenges and opportunities of school leadership faced by school principals in SBM. The population of this study was the schools in Colombo District and the sample was 41 principals of the schools in Colombo Central Division of Colombo Education Zone. The study was undertaken through mixed methods and data were collected using questionnaire and focused group discussions. The collected data were statistically analyzed using the SPSS software. There are six dimensions under SBM such as school leadership, internal stakeholders, external stakeholders, school improvements, resource management, and performance accountability and school leadership are considered as an important dimension of SBM when implementing decentralization policies at school level. The findings of the study stated that more than 90% of school principals face various opportunities in school leadership though there are challenges in school leadership of the implementation of SBM. Through the findings of the study, the implication has influenced further development of SBM.

Keywords: *School-Based Management, Dimensions of SBM, School leadership, Decentralization*

I. INTRODUCTION

Globally, the concept decentralization process in educational management is described under the term "School-based Management" and it is a new and increasingly popular idea of the decentralization process in the education areas. SBM has no 'essential meaning' but needs to be understood within a particular timeframe and a particular politics. Yet a key assumption on which it is based is that consistent and significant delegation is allocated to the school level of authority to make decisions within a broader framework of government guidelines and policies (Kimber, Megan & Ehrich, Lisa C.2011).

The term SMB is defined in various ways in relation to its aims and objectives of school management. Site-based management is defined differently by various scholars, but usually includes these three components. First, there is a delegation of authority to individual schools to make decisions about the educational program of the school. This can include personal, finance and/or budget, and curriculum. Second, there is an adoption of a shared

decision-making model at the school level by a management team that should include the principal, teachers, parents, community members, and sometimes students. Third, there is facilitative leadership at the school level to ensure follow-through of decisions (Levey, et.al, 1998). Caldwell (2004) defines SBM in a system of public education as "the systematic and consistent decentralization to the school level of authority and responsibility to make decisions on significant matters related to school operations within a centrally determined framework of goals, policies, curriculum, standard and accountabilities (Abulencia, 2012).

In the successful implementation of SBM, there are six dimensions such as school leadership, internal stakeholders, external stakeholders, school improvement process, resource management, and performance accountability that connect all school related activities, such as management, teaching and learning, teachers and students' performance, and community interaction and school leadership is an important and leading dimension in the successful implementation of SBM. Therefore, this study mainly focusses on challenges and opportunities faced by school principals in school leadership.

II. RESEARCH PROBLEM

Though the initiation of SBM in Sri Lanka was started in 1987 with the 13th amendment with the aim of decentralizing power to the periphery, SBM was introduced as a pilot project in 2006 which titled as the "Programme of School Improvement" (PSI). At present, according to the ministry circular PSI is being implemented in all the government schools in Sri Lanka since 2014. In SBM, the two constituent bodies: SDC and SMC encourage the implementation of SBM with the intention of increasing efficiency and effectiveness of school education. When it happens at school level, the two constituent bodies are managed by school leadership that confronts challenge as well as opportunities.

Even though all types of schools in Sri Lanka are benefited in implementing SBM, some challenges have been arisen with school management. So, the purpose of this study is to find out the challenges and opportunities of school leadership in the implementation of SBM in Sri Lankan school context. Specially, the main intention of this study was to find out the challenges and opportunities faced by school principals when using SBM.

III. RESEARCH AIM AND OBJECTIVES

The aim of this study is to investigate the challenges and opportunities faced by school principals in the effective implementation of SBM in Sri Lankan schools. In line with school leadership dimensions of SBM, the research study focused on two objectives. The objectives are:

1. To examine the challenges and opportunities of school leadership in SBM
2. To identify the impacts of the challenges and opportunities of school leadership

IV. REVIEW OF LITERATURE

A. What is school-based management?

All over the world, the decentralization process in educational management is described under the term "SBM". SBM is a new and increasingly popular idea of the decentralization process in educational areas around the world (Valliamah and Khadijah, 2014). According to Caldwell (2005), Decentralization of authority from the central government to the school level (Indigahawala, 2014). Moreover, Caldwell, 2005; Barrera, et.al, 2009, A way to decentralize decision making power in education from the central government to the school level is known as SBM (Global Engagement and Knowledge Team, The world bank, 2015).

Caldwell (2005) defined SBM is the decentralization of authority from the central government to the school level (Osorio F.B, et al, 2009). In the words of Malen, Ogawa, and Kranz (1990), "School-based management can be viewed conceptually as a formal alteration of governance structures, as a form of decentralization that identifies the individual school as the primary unit of improvement and relies on the redistribution of decision-making authority as the primary means through which improvement might be stimulated and sustained" (Osorio F.B, et al, 2009).

SBM has many different names including site-based management, school-sited autonomy, school-sited management, school centered management, decentralized management, school-based budgeting, site-based decision making, responsible autonomy, school-lump sum budgeting, shared governance, the autonomous school concept, school-based curriculum development, and administrative decentralization (Clune and White, 1988, and Delaney. J. G, 1998).

According to the World Bank (2007) SBM has become a very popular movement over the past decade and the World Bank program emerged out of a need to define the concept more clearly, review the evidence support impact assessments in various countries and provide initial feedback to teams preparing education projects. It focuses on major issues generally faced by implementers while designing and implementing SBM programmes and gives examples from several World Bank financed projects round the world that have SBM components. In addition, it also provides more in-depth analysis of a few country case studies where the process of decentralization of authority to the local level has taken place over the past decades (Medagama. R.S, et.al, 2016).

B. Policies and Circulars on SBM in Sri Lanka

Kannangara report in 1943 is the initiative point of SBM in Sri Lanka. The first Minister of Education, Hon. C. W. W. Kannangara chaired a committee of reform in 1943 that among many other reforms prepared the foundation principles for school-based management in Sri Lanka. It is stated in the Kannangara report (1943, p.26) that:

"Very few in the country favor a perfectly state controlled system in which a Central administrative authority defines and prescribes virtually every aspect of/Is Organization, curricula, courses of study etc. The state system we discuss here is one in which control will be confined to what are called the externa of education, i.e., matters such as compulsory attendance, character of school buildings, medical inspection and health of children, size of classes, qualifications, salaries, and appointment of teachers and above all ownership of schools. We are agreed that the interna, i.e., those aspects of education for the promotion of which teachers and pupils are brought together, namely, curricula, courses of study, methods of instruction etc. should not be made subject to prescription by the state" (Yatawara, 2007).

Moreover, Report of the Education Reform Committee (1979, p. 35) states that the key role of the heads of schools should be recognized. It further states that the hierarchical structure that makes available 5-6 different administrators above the head of the school makes both the educational administration as well as school management difficult. It has suggested 'School Complexes', whereby several schools are identified as one institution for purposes of both administration and management (Yatawara, 2007).

The 1982 reforms document of the Ministry of Education has also stated that 'the prescribing of uniform curricula, textbooks and examination standards on an all-island scale has had adverse effects.' Furthermore, in 1992 the circular on School Development Society was amended to give more authority to the school. Moreover, the 1984 report on management reforms of the Ministry of Education also recommended giving substantive delegation of power directly to the school level. It strongly viewed principals as front-line managers of the Ministry of education and recommended that adequate authority should be delegated to them (Yatawara, 2007).

Moreover, according to Yatawara (2007), 1984 report on management reforms of the Ministry of Education also recommended giving substantive delegation of power directly to the school level. It strongly viewed principals as front-line managers of the Ministry of Education and recommended that adequate authority should be delegated to them and the 1984 management reforms were not systematically implemented, and responsibilities were not transferred to the principal as envisaged. Furthermore, the Ministry of Education has not followed up its policy by amending the necessary circulars, regulations etc., and in giving independence to the provinces to manage their affairs. Although education was one of the devolved subjects by the provincial council act of 1987, enacted as the 13th amendment to the constitution, the schools did not

enjoy it as it only led to more layers of administration structures above the school without any devolution of power.

C. School leadership in SBM

In the article of Leadership in the 21st Century of Martin Roll Leadership Series, leadership is defined as a trait in an individual that enables him or her to influence the behavior of others to achieve a goal or to get them to do things, they would not otherwise have the skills or motivation to do. The school principals' role is very important when the role of leadership comes to the effectiveness of SBM in schools. According to Botha 2006, the customary role of the school principal has therefore changed under SBM as decision-making is shared among stakeholders. The current position of the principal renders not only authority, but also leadership, to the incumbent. As more and more countries worldwide implement SBM, principals are empowered and given more authority over what happens in their schools. School principals in these countries increasingly find themselves with the power to make on-site decisions such as how money should be spent, where educators should be assigned, and even what should be taught in the classrooms (in countries where there is not some form of centralized curriculum development). In the implementation of SBM, the jobs and functions of the principal would change from

The study was conducted implementing mixed approach, gathering qualitative and quantitative data through the questionnaire and focused group discussion respectively.

A. Population and Sample of the study

The principals of all 41 national schools, 1AB, 1C, Type 1 and Type 2 schools of Colombo central division of Colombo Zone were selected for data collection of this study.

B. Data collections instruments

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	4	9.8	9.8	9.8
	Neutral	5	12.2	12.2	22.0
	Agree	22	53.7	53.7	75.6
	Strongly Agree	10	24.4	24.4	100.0
Total		41	100.0	100.0	

In this study, a questionnaire and focused group discussions were used for collecting primary data from principals of selected schools. The collected data were analyzed using SPSS software.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Neutral	3	7.3	7.3	7.3
	Agree	25	61.0	61.0	68.3
	Strongly Agree	13	31.7	31.7	100.0
	Total	41	100.0	100.0	

those of middle manager for the district to the leader of the school (Tanner and Stone, 1998).

Although there are other factors, the leadership role of the school principal is widely regarded as the primary factor contributing to a successful relationship between SBM and school improvement and it is therefore an essential dimension of successful SBM. The SBM literature is consistent in describing the school principal as the "key player in the decentralization and restructuring process" also touched upon this redefined leadership role of the principal when referring to principal leadership as the ability of a principal "to convince, inspire, bind and direct followers to realize common ideals". The culture of a democratic order displayed in SBM requires school principals to exercise leadership that fully promotes participation of all stakeholders (Botha, 2006).

V. METHODOLOGY

VI. FINDINGS

Data collected from questionnaire and focused group discussions clearly depicted the findings in this study. Based on the Likert scale method, a few statements were asked to identify the challenges and opportunities in school leadership faced by school principals in successful implementation of SBM. In accordance with that, the findings of the first objective of study clearly elicit the challenges and opportunities of school leadership in successful implementation of SBM.

The first statement of the questionnaire was to investigate about SBM helps to develop leadership skills. The below table and chart demonstrate the responses of the respondents. It was found that 90% of principals in the education zones have opportunities to develop leadership skills in line with the implementation of SBM. Moreover, several challenges of principals were also identified in some schools. The findings especially elicited that training and guidance for school principals were given properly. The below tables and figures clearly analyze the findings of the first objective.

TABLE I. SCHOOL- BASED MANAGEMENT HELPS TO DEVELOP LEADERSHIP SKILLS

Question statement	Responses
The challenges under principals' leadership when implementing School-Based Management	Finding the facilities of implementing the activities of SMC and SDC
	Lack of participation of school society
	Lack of students' attendance to school
	Problems in decisions making of school development
	School developmental issues
	Lack of resources
	Administrative problems
	Lack of attendance of teachers
	Students' misbehaviors (Drugs usage)

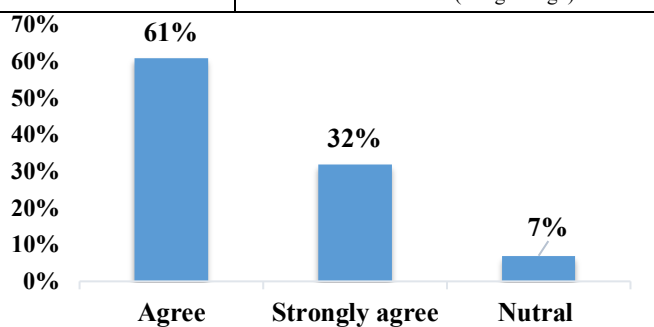


Fig. 1 SBM helps to develop leadership skills

Based on the responses of principals 61% of respondents agreed with the statement and 32% was strongly agreed while only 7% disagreed. This finding was clearly shown that from the response level of more than 90% of respondents SBM helps for opportunity to develop leadership skills of principal. This clearly explains about how SBM helps for school leadership.

TABLE II. TRAINING AND GUIDANCE IN SCHOOL LEADERSHIP TO IMPLEMENT SBM AT SCHOOL LEVEL

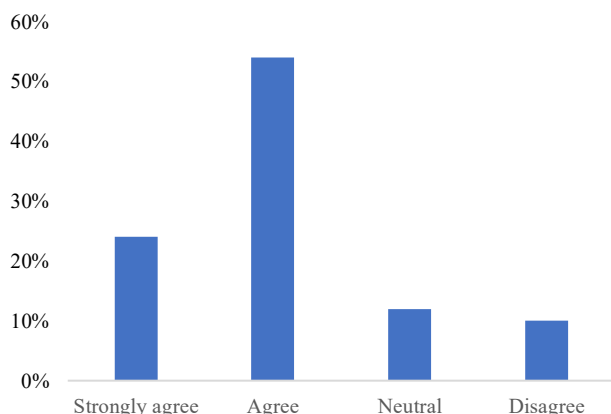


Fig.2 Training and guidance in school leadership to implement SBM at school level

As another finding of this study, principals were tested with the statements of getting training and guidance in school leadership to implement SBM at school level. Though the finding shows that proper training and guidance given to school principals were satisfactory, in some schools in backward areas were at an unsatisfactory level.

Principals were asked with open-ended question to find out the challenges of school leadership. The responses that were given by principals are listed below in the table.

TABLE III. CHALLENGES OF SCHOOL LEADERSHIP FACED BY SCHOOL PRINCIPALS

According to the second objective of this study, it was found that the impacts of challenges and opportunities of school leadership influence on effective School-Based Management in various ways. Table- III clearly illustrates the impacts of challenges in a list. Failure in implementing SMC and SDC, Lack in accessing resources, Students misbehavior, and decision-making problems are some of them. Moreover, as the impacts of opportunities in School Leadership of SBM, principals receive training and guidance to implement SBM effectively. This makes school management very successful in achieving the aims of the schools.

VII. CONCLUSION

This study clearly depicts school leadership challenges and opportunities faced by school principals in implementation of SBM. Though there are opportunities to improve school leadership in line with SBM, actions should be taken to reduce the challenges of principals. As recommendations of the study, the existing challenges could be reduced and the opportunities could be improved more to strengthen the good relationship which should be prevailed among principals and the society, for the better functioning of SDC and SMC by organizing training activities for principals.

REFERENCES

- Arthur Abulencia, (2012), School-Based Management: A Structural Reform Intervention
https://www.researchgate.net/publication/277957224_SchoolBased_Management_A_Structural_Reform_Intervention
- Barrera-Orsorio, et.al, (2009), Decentralized Decision-making in Schools: The Theory and Evidence on School-based Management Retrieved from <https://openknowledge.worldbank.org/entities/publication/5f764662-7f64-5f61-ad97-3bd1691f6bcf>
- Bandur, A.,(2008). A study of the implementation of school-based management in flores primary schools in Indonesia. (Unpublished Doctoral Thesis). The University of Newcastle, Australia.
- Barrera-Orsorio, F., Fasih, T., & Patrinos, H. A. with Sant, L. (2009). Decentralized decision-making in schools, The Theory and Evidence on School-Based Management, The World Bank
<https://unesdoc.unesco.org/ark:/48223/pf0000141025>
- Caldwell, Brian J. School-based management Retrieved from <https://unesdoc.unesco.org/ark:/48223/pf0000141025>
- Moradi, S , Beidokhti, A, A , Fathi, K., 2016, Comparative Comparison of Implementing School- Based Management in Developed Countries in the Historical Context: From Theory to Practice. International Education Studies; Vol. 9, No. 9; 2016 ISSN 1913-9020 E-ISSN 1913-9039 Published by Canadian Center of Science and Education, <https://files.eric.ed.gov/fulltext/EJ1112703.pdf>
- Washington DC. Caldwell, B. (2005). School-based management. Education Policy Series, UNESCO International Academy of Education, and International Institute for Educational Planning.

The Impediments To The Progression of Oral Competence of English As A Second Language of Grade 13 Students of The National Schools In Sri Lanka

D.M.A.N Alwis
Department of Linguistics
University of Kelaniya
Kelaniya, Sri Lanka
anunilaalwis@gmail.com

G.J.S.Wijesekara
Department of Linguistics
University of Kelaniya
Kelaniya, Sri Lanka
janakiwijesekara@gmail.com

Abstract— Ability to speak in English is considered an invincible requirement in any field to secure a respectable and comfortable place on the pyramid of social level in Sri Lanka. Every year a considerable number of novice group of students enter into the world of work after the G.C.E Advanced Level Examination. The doubt arises whether every one of them would be the best suited for the high demand of the labour market as it seems that most of them lack oral proficiency of English. Hence, the main objective of this study was to investigate the reasons that obstruct the oral competence of English of grade 13 students of the national schools of Sri Lanka. Also, addressing of the research problem of employing CLT (Communicative Language Teaching) method in a class room context of English as the second language and potential obstructions to the advancement of oral competence of students in grade 13 was done with three hypotheses postulated and research questions. A mixed-method research framework was used in this study with direct class room observations, semi-structured interviews with the teachers and students, administering a questionnaire for students, testing of grammar, vocabulary and speaking skills of students and the analysis of the text book in relation to speaking skills as main research instruments to collect data. The findings revealed that students' irregular attendance to classes, anxiety, self-esteem, lack of motivation and interest, prioritizing of main subjects, teachers' ignorance of the use of CLT, demotivation, less preparation to class and frailties of educational authorities to organize teacher trainings, workshops and maintain systematical and regular process to assess teachers and students development through observations as the main factors that impede the oral progression of students of grade 13 in national schools of Sri Lanka.

Key Words - Oral proficiency, CLT (Communicative Language Teaching), National schools, G.C.E(Advanced Level) examination.

1. INTRODUCTION

In the specific context of Sri Lanka, a linguistically diverse nation with multiple languages in use, the cultivation of spoken English proficiency has been accorded high priority

within the educational framework. Grade 13, which denotes the final stage of secondary education, assumes a crucial role in preparing students for tertiary education and the professional realm. Nevertheless, despite the emphasis placed on English language instruction, there exist obstacles that hinder the progress of spoken English proficiency among Grade 13 students attending national schools. Understanding these limitations is crucial for educational policymakers, instructors, and learners alike, as it directly affects their ability to use language effectively, their academic achievements, and their future prospects. The objective of this research is to investigate and clarify the complex limitations that impede the development of English speaking skills among students in Grade 13 of national schools in Sri Lanka. By conducting a thorough analysis of these limitations, the aim is to offer valuable insights that can inform more efficient language teaching strategies and facilitate the improvement of English speaking skills at this critical stage of education.

Aim and Objectives of the study

The main research aim of the current study, based on the central research question, was to achieve an in-depth understanding of the reasons that obstruct the oral communication of Grade 13 students of National schools in Sri Lanka. In order to achieve this main research goal, the following objectives were aspired to achieve.

1. To investigate key constraints for majority of grade 13 students in their pursuit of English oral proficiency.
2. To explore the effectiveness of the instructional practices which direct students to improve their oral proficiency in the English language in such contexts as stated above.
3. To examine the extent to which Communicative Language Teaching (CLT) is employed in grade 13 classes as a strategy for enhancing English oral proficiency.
4. To suggest remedial measures to minimize those problems and also to accelerate their learning pace.

Research Problem

It was a noticeable fact that grade 13 Advanced level students of Sri Lankan government schools find it much difficult to correspond in the English language and this in fact be largely cause to hamper their future achievements. Since Sri Lanka being a country with different ethnic groups, English language becomes the second language for majority of the students studying in Sri Lankan schools. Hence the acquisition of the English language and its oral fluency depend on multiple variables that consequently result in either the success or the failure of language acquisition. As the current study focused on the grade 13 students in Sri Lankan government schools, the development of language fluency in English within the period of English language becomes challengeable. Therefore, this study will address the problem of employing CLT (Communicative Language Teaching) method in a class room context of English as the second language and potential obstructions for the advancement of oral competence of students.

Research Questions

Research Question 1: Do majority of grade 13 students in Sri Lankan government schools show a low or limited oral proficiency in the target language?

Research Question 2: Do teachers of English in government schools use the communicative language teaching (CLT) approach in their classroom teaching?

Research Question 3: Do teachers use the mother tongue of the students so often during the lessons for class room instructions?

Research Question 4: Do teachers create a student centered or teacher centered teaching environment and do lessons which are all exam oriented?

Research Question 5: What kind of attitude and enthusiasm or interest the students exhibit towards the subject of English?

Research Question 6: How the school curriculum is designed related to the subject General English, the student's text book and the teacher's guide.

Research Hypothesis

Several hypotheses were proposed to address the research questions outlined earlier.

Hypothesis 1: Grade 13 students in Sri Lankan government schools lack sufficient English oral proficiency.

Hypothesis 2: Most Grade 13 General English teachers in schools do not use the Communicative Language Teaching (CLT) approach.

Hypothesis 3: Inadequate student participation and teacher motivation may mutually contribute to students' oral proficiency issues.

REVIEW OF LITERATURE

The purpose of this chapter is to provide the reader with a general overview of the theories, approaches and methods that have been long persisting in the field of second language (SL) teaching and learning in light to the

acquisition of second language oral competence. Various paramount scholarly ideas constructed through research done on the similar research area of this study further discuss the significant and most affective factors for the development and the encumbrance to the oral competence of the second language learners. Moreover, the affective factors that may provoke less oral competence among students are presented

singly as the external factors, learners own limitations and the pedagogical concerns to the impediment of the oral competence. The most efficacious and productive teaching approaches and methods that are potential in attracting larger

student's participation in to the lesson and tasks and activities that can be followed in the classroom are also scrutinized in this.

Oral Competence in the Second Language

It is often deemed to be the most indispensable factor among the acquisition of the second language (L2) skills is the ability to speak in a second language (L2) fluently. The conspicuousness of communicating one's aspired ideas distinctively and coherently for every requisite purpose has urged the necessity of being fluency an increasingly predominant objective for L2 learners. Lazaraton (2014.p.118) expresses that speaking becomes the transmission of all the other language skills of writing, listening and reading when language instructors like teachers take on effective teaching approaches like Communicative approach (CLT) in a very prolific and constructive way in the class room. But, "The teaching of English has traditionally been considered as teaching and making the students aware of certain aspects of the language such as grammar, vocabulary, translation etc. In this way, the students are hardly provided with adequate practice in the development of communicative skill through speaking" (Littlewood, 1981; Richards, 2006 as in Mridha et al 2020.p.2). Consequently, every L2 learners may find it difficult to enunciate their own desires, thoughts in the target second language even after many years of studying the language owing to the reasons that the language is learnt in its conventional written manifestation with a minimal use and development of oral proficiency of students.

Affective Factors relevant to the oral competence in the second language

- Self Esteem

When educating oral communication in English as the second language it is essential that the teacher has to contemplate that our emotions, or the affective domain, have a consequential effect on second language learning. One of influential factors in the affective domain is self-esteem. Brown (2000, p.142) investigated the manners of how learners' self-esteem influenced their communicative activity in the focused language and it is revealed that even though a language learner is competent enough in communicating, it does not inevitably correspond with "a high eagerness to communicate". This competence moreover is integral with attitudes, values and motivations, concerning language its features and uses and integral with

competence for, and attitudes toward, the interrelation of language with the other code of communicative conduct (Hymes 1972 as in Peterwagner 2005).

- *Anxiety*

Anxiety which considered one of predominant affective factor which has the potentiality to hinder the education process is usually admitted to be accompanied with feelings of restlessness, disappointment, self-distrust, agitation, or bother. Anxiety of language is regarded as agitation or fear transpiring when a learner is aspired to perform in the second or foreign language. It has been admitted that average anxiety can generate one's concentration on studying, whereas, extreme anxiety is potent to influence negatively on learners' achievements and advances mal performance through fear, agitation and self-distrust.

- *Motivation*

Motivation becomes one of significant factors for each and every one to acquire anything. As Cohen (2010) states that motivation which is considered as an effective procedure, is subjected to have regular conversions. As mentioned above motivation is accepted as a predominant factor for every process related to learning teachers in every classroom context have to make an extra attempt to get their students motivated and to be interested to the learning environment.

- *Influence of the mother tongue*

The use of learner's mother tongue in the class room has been presented with two contradictory perspectives of the scholars in many research. Recent trends in the field of linguistics emphasize that use of the students' mother tongue in language teaching and learning is a linguistic human right of the students (Kangas et al, 1994 as in Sanmuganathan, 2017, p.623). Therefore, the proponents of the communicative approach have given due recognition to the students' mother tongue in their teaching strategies. Translation is seen as a useful pedagogical device and therefore, a reasonable use of the mother tongue is recommended (Richards and Rodgers, 2001, p.88).

Teaching methods and approaches to develop the oral competence of the second language learners

- *Communicative competence*

Communicative competence is a combination of four different competences. To be communicatively competent, according to Hymes means that a person, apart from having grammatical competence, knows if an utterance is feasible or not, if it is appropriate or not and also if it is accepted usage (Törnqvist, 1997 as in Törnqvist, 2008, p.06). Communicative competence concerns four different ways of language acquisition as follows that ultimately directs the learner to be thrive in the oral competence of the second language.

The communicative language teaching (CLT)

Earlier, in Sri Lanka second language teaching (SLT) and foreign language teaching has generally had its prominence more than on grammatical competence than considering the improvement of students' communication skills. The major objective in relation to communicative language teaching methods is to make students to be self-assured speakers for different real-life contexts, through continuous speaking practices and peer group cooperation. CLT, as an approach than a method of teaching, surpasses the limits of rigid methods and techniques. "The theoretical position on the nature of language and on teaching and learning. CLT, aims to make communicative competence, the goal in the language teaching by providing attention that involve in any type of interaction or transaction". (Richards and Rogers, 2001, p.90)

Various aspects of the Communicative Language Teaching

- A language is learnt by the students through the application of language to communicate.
- In class activities should be designed with an intention of reaching the goals of accurate and meaningful communication.
- Being fluent is a significant aspect of communication.
- Communication requires the amalgamation of the divergent skills of the language.
- Grammatical or linguistics competence is not considered the only components for the CLT, but it necessitates all the constituents of communicative competence as well.
- Language is used in extemporize or impetuous contexts.
- As learning and teaching technique Dialogues are used since they involve communicative functions and also, they can be used spontaneously.

Three types of instructional material related to the Communicative Approach

The communicative approach involves three types of instructional material: text-based, task-based and realia (Richards and Rodgers, 2001 as in Karunaratne, n.d, p.02). According to Karunaratne (n.d) the use of textbooks in the language class room for class room activities is called Text-based teaching and the Task-based teaching requires different games, role-plays, simulations and any sort of classroom activity that fortifies target language communication in the classroom and also realia which refers to reliable teaching material such as newspapers, signs and posters in the target language.

Other approaches related to the progression of oral communication in the English Language.

- *Pupil-centered teaching approach*
This approach is based on the use of pupil – centered teaching methods rather than the practicing of teacher – centered teaching context in the class room. "A reconstruction of the traditional teacher's role is expected in a classroom functioning under the

principles of communicative teaching. Traditionally, a teacher's role was to provide correct models of language and corrective feedback (Littlewood, 1981 as in Karunaratne, n.d, p.4).

- **Oral Approach / Situational Language Teaching**
The oral approach is a method in which children to use whatever hearing they get from their surroundings. They also take help from the context to understand and use language. The target is to develop the skills in the individual so that he can communicate and function independently. This approach helps in the development of reading and writing skills (Richards and Rodgers, 2001).
- **Direct Method**
The direct method was the outcome of the reaction against the grammar translation method. It was based on the assumption that the learners of foreign and second language should directly think in English. This method is against the translation of written and oral text and focuses on telling the meanings of the words through action, demonstration or real objects. This method focuses on directly thinking, doing discussion and conversation in second language (Richards and Rodgers, 2001, p. 82).

METHODOLOGY

The current study employs 60 female students and 60 male students studying in grade 13 classes of a national boy school and a girl school in Panadura area as the sample for the questionnaire and 12 English Language teachers from both the schools and 30 students, equally 15 from each school as the sample for the interview for this research. This study employed a purposeful sampling technique which is also known as purposive and selective sampling. In order to satisfy the objectives of the study a mixed method of both combination of qualitative and quantitative research methods was used to reach the end desires of reaching the answers needed by combining the two approaches. To enhance the research, both inductive and deductive methods were employed, enabling a more thorough investigation of questions arising from the research topic. Since this study uses mixed method of the combination of both the qualitative and quantitative, the use of the inductive approach may address the research questions over the reasons behind the barriers that obstruct the oral competence of English language of grade 13 students of Sri Lankan national schools.

ANALYSIS OF DATA

Students' language proficiency at the O/L examination.

The following table represents the data collected through the students' questionnaire about the grades obtained by the students of both the schools for the English language at the G.C.E Ordinary level examination. Statistical data of the above were sorted out according to the gender of the participants and the stream of subjects followed by the students at school.

TABLE 1 -STUDENTS 'LANGUAGE PROFICIENCY AT THE O/L EXAMINATION.

	A	B	C	S	W
Boy's School (Science)	50%	26.6%	13.3%	10	-
Girl's School (Science)	53	33	6.6	6.6	-
Boy's School (Arts)	26	40	16	13	3
Girl's School (Arts)	33	10	20	26	10

According to the above table it is apparent that only 41% of students from the total number of respondents (120) have got through the English language with an "A" grade. Among them female participants from the Girls' school have exceeded the number of male students. Further the total number of all grades (A, B, C, S) obtained except failures

Future goals of students

The aspired future targets of the students after the GCE (A/L) examination was identified through the questionnaire and students from both schools irrespective of streams of subjects, wish to enroll for higher studies, to be self-employed, to be employed and to study .Among them 55 students wish to continue higher studies here in Sri Lanka which holds the maximum percentage and 15 students wish to go overseas to continue the studies.40 among the remaining respondents expect to be employed with no interest to go for higher studies after the Advanced Level examination. The other remaining 10 hope to be self-employed. It further communicates that female students have more tendency towards go for higher studies locally or in overseas as the percentage to be employed after Advanced Level examinations shows female students have lower interest than the boys.

TABLE: 2 FUTURE GOALS OF STUDENTS

Targets	Girls' School		Boys' School	
	Frequency	Percentage	Freq	Percen
To enroll for higher studies	30	50%	25	41%
To be employed	15	25%	25	41%
To be self employed	05	09%	05	9%
To study overseas	10	16%	05	9%

Exposure to the English language

TABLE 3: EXPOSURE TO THE ENGLISH LANGUAGE

Often	8%
Sometimes	8%
Never	17%
Rarely	58%
Always	88%

The above demonstrates that majority of students rarely get an opportunity to speak in the English language outside the school and among them equal number of students with the percentage of 8 have stated that the availability of opportunities are received so often, always and sometimes. The second highest percentage of students belong to the group where no opportunity is available for them to converse in English language. This analysis of the figure indicates that

most of the students come from families where English is not conversed.

Linguistic and other possible hindrances to the oral communication in English

TABLE 4: LINGUISTIC AND OTHER POSSIBLE HINDRANCES TO THE ORAL COMMUNICATION IN ENGLISH

Grammar	11%
Vocabulary	6%
Both Grammar & Vocabulary	83%

A deeper awareness to the existing situation with regard to the linguistic difficulties faced by the students. When considering the graph, it clearly manifests that a larger number of students find it difficult to use both grammar and vocabulary as a hindrance to the oral proficiency rather than encountering the difficulty individually. Between both grammar and Vocabulary, the least number of students find lack of vocabulary as a weakness of them when communicating in English. In addition to the above given answers, the following responses were made by the students (n = 30) for varied questions posed regarding the issues for

oral communication in English at the interview held with them.

Section Two- Interviews with teachers.

It was assumed that rather than surveying through questionnaires on the classroom condition and other external factors that vastly hamper the progression of the use of CLT method as an effective tool for the progression of oral communication in English, conducting interviews with teachers would be more productive and successful mean of gathering data related to teachers' experiences with regard to

the aforesaid research problem. Twelve teachers from both the schools; six from each school equally were randomly selected in order to obtain the aspired relevant data. Questions for the teachers were based on three sections: Teachers' personal and career related information, Class room context and students and School environment.

Practicing of the CLT Method in class room

Table 5 (n = 12)

Aware of the CLT method	17%
Unaware of the CLT method	83%

The concept of the use of CLT (Communicative Language Teaching) as an effective teaching method was discussed with the teachers and 10 teachers among 12 (83%) were totally unaware of the mechanism behind the method whereas 02 teachers (17%) were well aware of the CLT method. Teacher's use of Teachers' guide is apparently low as 41% teachers do not often follow the book. Question posed on the way the teachers contribute to the improving of oral communication in English was honestly responded and the (Table 4.5) represents the way teachers from both

the schools teach students in the class. Among them, it seems that priority has been given more towards the use of grammar and writing activities.

The questionnaire revealed that a significant number of students cited grammar and vocabulary as their primary language difficulties, hindering their progress in speaking skills. The importance of language exposure at school for the students who either rarely meet an opportunity or never gain an opportunity to speak in English outside the school environment was foregrounded in the questionnaire. An interview was conducted with randomly selected 15 respondents(students) from both schools could reveal that "the teacher of English has the responsibility to the pupils beyond the examination. Outside the classroom, in the institutes of high education and, ultimately, in their respective workplaces the pupils will need to use and understand English" (Maryslessor et al ,2014. p.88). Contrary to what the above scholars said, the data gathered from teachers' perspective and experiences regarding the use of CLT revealed that teachers work on much pressure due to their responsibility of practicing students to get through the GCE (A/L) Examination at least with a simple pass mark.

Hence, through their revelations it is clear that exam-oriented class room context of grade 13 in Sri Lanka hinders teachers' motivation and enthusiasm of using CLT method. As to extend up upon this, the findings of the study further conveyed that teachers most tend to follow the text book with grammar activities, grammar only, writing activities and past paper or model paper questions for grade 13 students. This finding renders two implications to the study that the teachers try their best to improve the writing skills of students as writing will only be tested at the exam or teachers are totally ignorant of the use of CLT and improving the speaking skills of students. facts that students do possess several negative attitudes towards the practice of English speaking and also the General English period due to multitude reasons as fear for peer group humiliations, ignorance of the subject, lack of self-confidence etc.

Moreover, students were questioned both at the interview and through the questionnaire about teaching and learning situation during the period of General English at school. Majority of students expressed that no assistance for the improvement for oral communication is given by the teachers and the school authority, instead teachers keep on teaching grammar and the lessons in the text book. After the interview of 13 teachers from both schools, it was found that all the teachers except 02 were not known about the CLT approach and its applicability to foster the speaking skills of the students. Teachers were also presented their difficult situations face in school when teaching English for grade 13 students extending their deeper displeasure over the irregular attendance, lack of enthusiasm, giving preference and priority for the main subjects etc. Spending four days observing 06 classes of both schools (03 from each school) in the English period was done and data was

recorded under two main domains of teachers and students' situations.

The actual situation of the teachers and the students during the English period could be recorded where the majority of teachers showed no attempt to get students involved in speaking activities and creating an environment to expose the students to English-speaking surroundings. Students also behaved in classrooms during the English period in a less enthusiastic way that evoked lots of weaknesses that hindered the gaining of language oral proficiency.

FINDINGS AND DISCUSSION

The study was supported and guided by 6 main research questions and three hypotheses as mentioned before. Interpretations of the findings of the study are also to be discussed with relevance to the research questions and hypotheses.

Speaking ability as the ability to express oneself and participate in real-time conversation/discussion in an appropriate and meaningful way is a fundamental aspect of "real-world" second language competence. Evaluating and assessing of the oral proficiency of second language learners can be done through many research instruments and activities already followed as presentations, interviews, discussions and debating.

The rubric followed indicated that students' level of oral proficiency was very low as many of them struggled hard to construct a sentence with correct grammar and tenses. Their inconsistent way of producing utterances, hesitation and frequent stammering during the speech further generated another phenomenon that most of them lacked exposure and practice in communicating in English. Hence, the first hypothesis of the research which was "Grade 13 students in Sri Lankan government schools lack sufficient English oral proficiency" was realized too.

Also, the findings of this study communicated the fact that most teachers utilized the mother tongue before and after the lesson was over. And it was revealed through the class room observation, and the teachers' interview that during the time of lesson being conducted, their use of mother tongue was at a minimum level.

Further, Dickson (1996), in his study for the National Foundation for Educational Research, entitled: Using the Target Language, states that using the "Target language (L2) promotes natural acquisition and that use of the mother tongue (L1) undermines this process by diverting attention from the object of pupils learning." Hence, exposure to the language and getting students involved in to activities that enable them to interact in the English language would be a motivational factor to improve their oral proficiency.

As to elaborate on the student textbook for A/L General English, the book is a perfect combination of creatively crafted activities that lead learners to get as much as exposure to the language while being engaged in to more group and pair activities. It was found that the amount of group and pair activities were high in number when compared to other

activities. The writers of the text book have given ample opportunities to the teachers to practice different components of CLT method such as Task Based Language Teaching, Text based Language Teaching, realia etc. which ultimately navigate learners to develop their oral proficiency in English language. Hence, the findings of the data regarding the use of CLT in the class rooms, teachers ignoring of the maximum use of group activities and getting students involved in to the

activities given in the text book etc. discuss a lot about the prevailing teaching learning system of grade 13 classes in Sri Lanka.

CONCLUSION

The main purpose of this study was to investigate the impediments to the oral progression of grade 13 students in Sri Lankan national schools as it was noticed that majority of them did not possess the required proficiency level. This study used a mixed method research design that relied mainly both on the qualitative and quantitative research approach for the sake of answering research questions, aims and addressing research hypotheses and research problem using different research instruments as interviews, questionnaires, class room observations, Testing of skills and Text book analysis. The data was collected with the above-mentioned different data collection methods which helped the researcher to triangulate the trustworthiness of the data. Though the investigation carried on with regard to the research problem of this study; the problem of employing CLT (Communicative Language Teaching) method in a class room context of English as the second language and potential obstructions for the advancement of oral competence of students in grade 13 of Sri Lankan national schools could be partly attributed to the lack of motivation, interest, of students and their irregular attendance to school, self-esteem and anxiety. This study has further emphasized the fact that the teachers' demotivated attitudes, lack of knowledge and practice, teacher centered teaching situation for the exam oriented national curriculum also have expedited the malfunction of CLT with regard to the development of oral proficiency of students in grade 13. This situation needs to be considered by the educational authorities and school administration in order to help the teachers and students to exercise and augment the practice of CLT with its different approaches to accelerate the language exposure to the students to improve their oral proficiency in English.

LIMITATIONS OF THE RESEARCH

It should be indicated that this study encountered certain limitations with regard to the process of data collection which was processed with 120 students and 12 teachers (06 from each school). The main limitation of the research could be

identified with the selection of only two leading national schools in Panadura area in the Kalutara zone. The applicability of the data gathered and generalizing the

findings to arrive to a conclusion related to the research problem are limited only to two national schools and certain mismatches with the decisions would arise when considering other provincial schools in the zone. In addition, the two schools that were under the investigation are a boy school and a girl school. Hence, the students' performances and reactions, behaviors at the time of supervision may be different and the research may have tendency to be biased due to gender differences. The selection of two grade 13 classes (one Arts class and a science class) from each two schools may also be considered a limitation due to variations in cognitive skills, competences and enthusiasm in acquiring the fluency in the language.

REFERENCES

- [1] Cohen, A.D. (2010). Focus on the language learner: Styles, strategies and motivation. In N. Schmitt (Ed.), *An introduction to applied linguistics* (2nd Ed. pp161- 178). London: Hodder Education
- [2] Creswell, J.W. (2013). *Qualitative Inquiry & Research Design: Choosing Among the Five Approaches*. Thousand Oaks, CA: SAGE Publications.
- [3] Dickson, P., (1996), Using Target: A view from the classroom, National Foundation for Educational Research. <https://www.nfer.ac.uk/media/1360/91032.pdf>, (25th January, 2022)
- [4] Karunaratne, G. R. M. (1993). English teacher effectiveness with special reference to the use of the communicative approach, *Sri Lankan Journal of educational research*, http://archive.cmb.ac.lk:8080/research/bitstream/70130/1096/1/IM%20Karunaratne_Teaching%20English.pdf, (02nd, September, 2021)
- [5] Larsen-Freeman, D. (2000). *Techniques and principles in language teaching* (2nd ed.). Oxford, UK: Oxford University Press
- [6] Littlewood, W. (2000). Do Asian students really want to listen and obey? *Elt Journal*, <http://doi.org/10.1093/elt/54.1.31>.
- [7] Maryslessor, A. O et al. (n. d). Challenges Teachers Face in the Use of the Communicative Language Teaching Approach in the Teaching Listening and Speaking Lessons in Lugrari District, Kenya. *International Journal of Science and Research (IJSR)*. www.ijer.net, (6 th , November, 2021)
- [8] Patton, M. Q., (2014), *Qualitative Research & Evaluation Methods Integrating Theory and Practice* (Fourth Edition), Thousand Oaks, Sage Publications
- [9] Richards, J. C. & Rodgers, T. S. (2001). *Approaches and Methods in Language Teaching* (2nd Edition) Cambridge: Cambridge University Press. <https://www.novaconcursos.com.br/blog/pdf/richards-jack-c.-&-rodgers.pdf>, (2 nd , December, 2021)
- [10] Törnqvist, A. (2008). Oral communication in the English language classroom: A study of the attitudes of some English teachers and 9th grade pupils Sweden towards oral communication in the English classroom. <http://www.divaportal.org/smash/get/diva2:132912/FULLTEXT01.pdf>, (1 st , January, 2022)

Applying Bloom's Digital Taxonomy for the University Education

K. M. G. N. V. Kariyawasam.
Department of Education and Training
University of Vocational Technology Ratmalana, Sri Lanka
bed18b116@uovt.ac.lk

Mr. Sudath Liyanage
Department of Education and Training University of Vocational
Technology
Ratmalana, Sri Lanka
deanfe2020@gmail.com

Abstract— The primary aim of Bloom's Digital Taxonomy is to gain knowledge on using technology and digital tools to facilitate students' learning experiences and outcomes. This research mainly focuses on connecting Bloom's Revised Taxonomy to Bloom's Digital Taxonomy features required for developing online learning activities to meet the demands of undergraduates. Bloom's Digital Taxonomy guides us through the variety of digital resources available and helps us decide on the learning experiences we want our students to have. Here we search how to apply Bloom's Digital Taxonomy to undergraduates. The activity's difficulty level will determine the most appropriate digital action concerning Bloom's Revised Taxonomy's cognitive levels. This study is mixed methods research. The questionnaire is designed in Google Form questionnaires. (About Technological Tools). The sampling method is the convenience sampling method. (Non-probability) The collected data was used for analysis through MS Excel and data was represented through line graphs, tables, Ven graphs, and bar graphs. The findings revealed that Bloom's Digital Taxonomy has intervened in the undergraduate's education, in disguise. Without proper attention or knowledge of BDT students try to learn with web tools. Besides, the results revealed that university has to apply BDT systematically so that students can easily apply digital verbs in their usual studies. Students are capable of web tools to some extent but the lack of facilities and knowledge to develop their learning through this new taxonomy. Here the research study shows a new aspect that universities should be concerned about immediately for university development and endurance.

Keywords— - Bloom's digital taxonomy, Bloom's Revised Taxonomy, Higher Order Thinking Skills, Lower Order Thinking Skills.

I. INTRODUCTION.

The research comes up with an updated version of Bloom's Revised Taxonomy, its Bloom's Digital Taxonomy. Sri Lankan Education typically followed Bloom's Revised Taxonomy, which gradually takes lower-order thinking skills (LOTS) into higher-order thinking skills (HOTS). Their students are required to demonstrate higher-order thinking and creativity and content-related basic comprehension and competencies. In (BRT) Bloom's Revised Taxonomy, students use their books and papers, and teachers use PowerPoint presentations and simple instructional materials. But with time, instead of writing articles, students focused on blogging; instead of writing letters, they started Tweeting and e-mailing. Instead of keeping bookmarks on books, students began to keep their site bookmarks and highlighters through various apps like "Delicious." Instead of drawing on books, students use Canvas and Adobe Illustrator software to design notices and posters. In the past decade, new technological verbs such as googling, tweeting, and podcasting have emerged as word forms for site communication tools. Today's learners are interested in digital learning opportunities. Here, student

activities are primarily associated with Web 2.0 technologies that enable collaboration, innovation, and individual inquiry. When considering all of this, there is a massive gap between the new generation's expected and educational outcomes. Bloom's Revised Taxonomy was Updated to Bloom's Digital Taxonomy as a solution for that gap. According to researchers in education, Educationists and governments worldwide are increasingly concerned about educating digital-age children, and practitioners have devised novel ways to combine these digital technologies with Bloom's Revised Taxonomy's structure, resulting in the creation of Bloom's Digital Taxonomy.

Bloom's Digital Taxonomy is about using these digital tools to complete recalling, understanding, applying, analyzing, evaluating, and creating. The task is not just to provide technology infrastructure but also to provide mentoring and advice on using digital resources to interact with teachers and peers anywhere and at any time. Bloom's digital taxonomy (BDT) has given a framework, systematic guidance, knowledge, and related digital tools in academic and non-academic settings for teachers, instructors, and students.

A. Background to the study.

With the arrival of the COVID-19 pandemic, Sri Lanka's Whole Education underwent Online Distance Learning (ODL). At the same time, University Education also changed to distance learning sometimes. The need for digital Taxonomy is highly noticed in this situation. It also showed the importance of technology in the teaching and learning process.

The ultimate learning experience for learners is created by integrating technology into the classroom and engaging pupils in higher-order thinking. Bloom's Taxonomy combined with digital resources produces an innovative learning environment where students are actively involved in their work. Usually, traditional face-to-face learning uses Bloom's Revised Taxonomy for Teaching Practices, student-centered methods, andragogy and pedagogies, and intrinsic and extrinsic learning methods in the teaching-learning process. The approach plays a huge role in filling the gap and making lifelong learners. I thought about applying Bloom's Digital Taxonomy for online learning to help the current situation continue the effective digital education process.

The way today's pupils learn and absorb information has fundamentally changed. These pupils are the first in their generation to have grown up with modern technology, particularly educational technology. "In addition, these new generations of students have been heavily influenced by incorporating information technology (IT) into their lives. Therefore, the best question is how do we educate these more recent generations? How can we teach the Millennial Generation (Gen Z), specifically?

B. Research objectives.

- To identify a list of Technological Tools that educators and undergraduates could use to help apply Bloom's Digital taxonomy action verbs from lower-order thinking to higher-order thinking.
- To identify the most appropriate technological tools for university education.
- To determine the digital literacy of students on the above-listed technological tools.
- To explore how undergraduates implement these technological tools for UOVT education.

C. Limitations.

The results cannot be generalized to a more significant population of all universities except Vocational Technological universities all around the country.

Digital poverty: Some students have less or inferior access to devices to engage with digital approaches to learning. In addition, they may not have access to an internet connection with limited or no bandwidth, which could degrade the quality of their digital learning experience and the research study.

II. LITERATURE REVIEW.

A. Bloom's Revised Taxonomy.

Bloom's Revised Taxonomy was modified and renamed "Bloom's Digital Taxonomy" by Churches (2009), who noted that the digital taxonomy is not only limited to the cognitive domain but also provides methodologies and tooling for conceptual comprehension. It highlighted the digital tools and verbs that corresponded to each stage.

B. Bloom's Digital Taxonomy.

Bloom's Digital Taxonomy is not about using the tools; it's about using the tools to encourage learning. (Navita Malik 2016), There it highlights the fact that a variety of activities and methodologies used in smart classrooms assist teachers in achieving their educational objectives. All of Bloom's digital taxonomy domains, including High Order Thinking Skills (HOTS) and Low Order Thinking Skills (LOTS), are followed in Smart Board Classrooms by using various activities in teaching and learning. Also, the old concept objectives have transformed into a digital taxonomy for technology-facilitated classrooms. It also reflected various activities and methodologies for smart classrooms to achieve instructional objectives. Here, she considered instructional media used in face-to-face Smart Board Classroom but not the Online Distance Learning (ODL) technologies that could be used in the classroom. Here we can get only Bloom's Digital Taxonomy related to face-to-face classroom sessions.

"Digital verbs" are defined as verbs employed in digital environments that change depending on their academic practice. Nikolic and Dabic (2016) Many of Bloom's Digital Taxonomy's suggested digital activities include editing, creation, sharing, and interaction. However, according to (Hart 2015), using digital verbs in the academic context has two limitations. First, classifying digital tools given to their appropriate level is complicated as many tools can be used for multiple actions. Second, the popularity of the tools varies

depending on the circumstance. According to (ISTE 2003), technology assists in creating efficient and effective learning environments, and experiences offer a vast number of instructional strategies and curriculums that enhance student learning.

According to N. Husain, F. (2021). The proposed model shows Bloom's model to create digital online assignments using ICT tools to add a new dimension to online assessment. His main objective is to utilize Bloom's taxonomy's common language and terminology to assess the learners depending on their needs and abilities to accomplish the targeted learning outcomes. Online teaching and learning could prove very effective if Digital Bloom's Taxonomy and ICT tools were utilized to design teaching-learning and assessments.

Using Bloom's cognitive domain to connect with the Digital Bloom's taxonomy by integrating Information and Communication Technology Tools for creating online assessments can cater to the needs of different ability students during these pandemic times. If the online assessments are designed as per Bloom's teaching and learning taxonomy, this will help the educators to use the LOT skills to HOT skills to teach and assess their students in the most reliable way. (Emerald Insight 2020) study reveals that the students of ODL (Online and Distance Learning) are far better at using digital tools and activities: googling, Skyping, and collaborating. They are great at understanding and application levels and are involved in higher-order thinking tasks, such as publishing and podcasting. Unlike the learners, the teachers at the virtual university are using digital tools for Lower-Order Thinking Skills (LOTS).

The authors conclude that the students and teachers at online universities are using digital tools frequently because of the demands of the Online Distance Learning (ODL) environment. These findings recommend further research to explore the factors that hinder the teachers' use of higher-order thinking skills in the online environment. The study suggests using Bloom's digital taxonomy in teaching-learning activities, such as curriculum, instructions, and assessment for recent generations. Because learners in the digital age are already deeply involved with digital tools, the findings may drive online and traditional higher education institutions to use digital pedagogy for instructional objectives. These technological tools are everywhere, and students are being exposed to a plethora of information. Digital Taxonomy advises that digital tools can be used in conjunction with traditional pedagogies to make learning experiences more significant and constructive.

Additionally, instructors must adequately train in the theory of digital pedagogy and ways to apply Bloom's Digital Taxonomy into all phases of their teaching-learning. (Manochehri and Sharif 2010) measured attitudes toward learning with various classroom technologies. They found that technology increased students' capacity for self-directed learning and that overall acceptance of the technology was related to student perception of the relevance of the learning experience. (Mishra and Koehler 2006) addressed this approach and emphasized the necessity of discovering the connection of technological, pedagogical, and content knowledge. They argue for pedagogies that

incorporate interactive learning techniques, Web 2.0 tools with a social focus, micro-content orientation, and open access, all of which apply to a particular subject's content.

III. METHODOLOGY.

This study is mixed-methods research. The questionnaire design is going to combine elements of quantitative research and qualitative research to answer the research questions. The questionnaire is about Technological Tools and digital verbs that participants use. The sampling method is the convenience sampling method. (Non-probability)

The total population is about 600. (Undergraduates of the University of Vocational Technology)

The target population is approximately 150. (Undergraduates 2017/18, 2018/19 B. Ed and ELT)

Accessible population 40.

Sample Ratio: - {40: 150} = {1:4}

Table: 1

Step	Activity
Step-01	Select the target population.
Step-02	Select a convenient sample (who is familiar with Bloom's Taxonomy).
Step-03	Create questionnaires.
Step-04	Categorize questions.
Step-05	Distribute questions.
Step-06	collect responses.

A. Research Design.

This study is mixed-methods research. A mixed-methods study design is a way of gathering, analyzing, and presenting data. In a single study, "mixing" quantitative and qualitative research and methodologies. The sampling method is the convenience sampling method. (Non-probability)

B. Research Sample.

The selected convenience sampling method is (non-probability sampling). The sample will be taken from the population who are easy to reach. Here the researcher chooses undergraduates who are familiar with the concept of Bloom's Taxonomy and digital educational tools and should have attended Online Distance Learning (ODL).

C. Total Population.

UOVT undergraduates are the total population. These participants should have an interest in this research study. The criteria for the undergraduates who are familiar with the concept of Bloom's Taxonomy and digital educational tools, and they should have obtained knowledge about the teaching-learning process and experience in both online classes and face-to-face classes at the University of Vocational Technology.

Target Population.

In this research, the researcher was dealing with Bloom's Digital Taxonomy Digital verbs and apps (We 2.0 tools) that undergraduates use often and some web tools that not aware of. For each level Of BDT what extent undergraduates are involved with web tools and digital verbs associated with 6 levels remembering, understanding, applying, analyzing, evaluating, and creating perceptively. The target population is approximately 150. (Undergraduates 2018/19 2017/18 B. Ed and ELT B1 B2.

D. Data Analysis Methods.

Eighteen questions have been asked in the questionnaire underlying six levels of Taxonomy and undergraduates' suggestions. The questions were developed one by one considering levels of remembering, Understanding, Applying, Analyzing, Evaluating, and Creating. And the digital verbs that consist in each level. Final questions are prepared to identify participants' suggested apps and suggestions on applying Bloom's Digital Taxonomy for University Education.

The questionnaire was made by the Google Forms platform and sent to the participants through WhatsApp. The researcher was able to collect data from 40 participants as expected through convenient sampling and the respondents answered all the questions.

IV. ANALYSIS AND DISCUSSION.

A. Remembering – Level 1

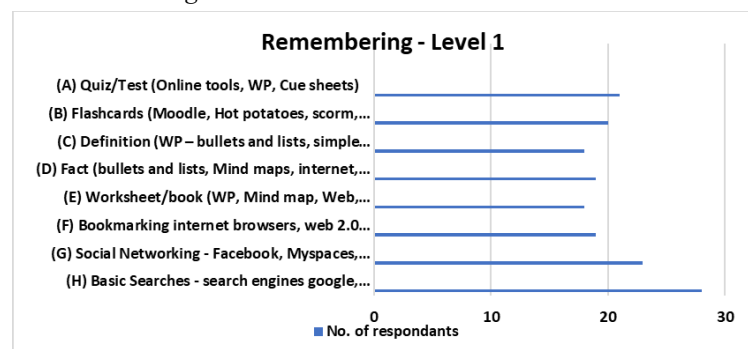


Fig. 1. (Remembering)

Undergraduates have ranked Basic Searches as the highest rank at 66.7% including- search engines Google, Microsoft Edge, Firefox, and Internet Explorer. Search engines, sometimes known as "googling," are becoming essential components of student research. At its most basic level, (here) students are just typing a key term or phrase into the search engine's basic entry window. Beyond the core phrase or keyword, this talent does not refine the search according to the level.

Understanding – Level 2.

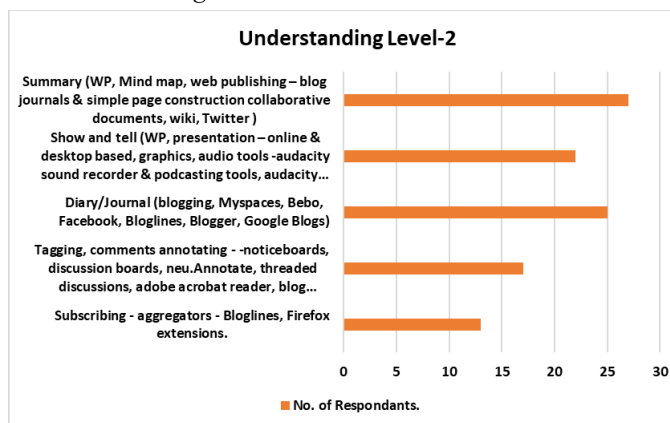


Fig. 2. (Understanding)

In the second level (understanding stage) of BDT, the highest number of respondents 64.3% do summaries by using web 2.0 tools, Mind map, WP-, web publishing – blog journals & simple page construction collaborative documents, wiki, Twitter. As second-highest score, 59.5% Diary/Journal (blogging, Myspaces, Bebo, Facebook, Bloglines, Blogger, Google Blogs). The least student usage is 31% for subscribing-to Bloglines, and Firefox extensions.

B. Applying – Level 3.

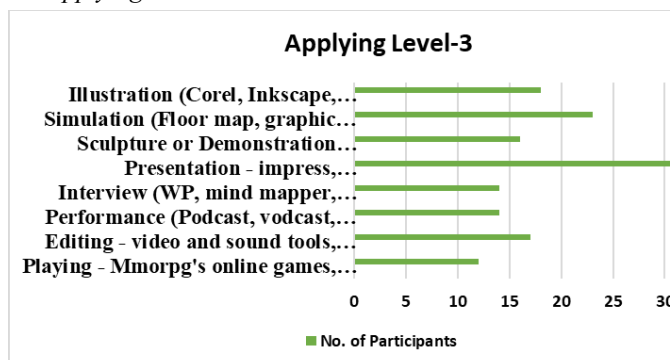


Fig. 3. (Applying)

75.6% of students stated that they use presentation tools (Google Presentation, Impress, PowerPoint, Skype, Zoho presentation, interactive whiteboard, SonicPics, Keynote, collaboration using E-tools, audio and video conferencing). 56.1% of students use simulation web tools to apply the concepts (Floor maps, graphic tools, Google Sketchup, Crocodile software simulating science experiments, Global Google SketchUp, Crocodile software). 29.3% of students use online games and simulations for the application-level minimum.

Analyzing – Level 4.

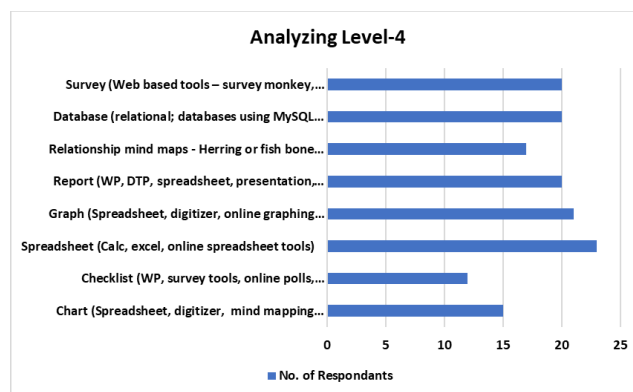


Fig. 4. (Analyzing)

For BDT fourth level (Analyzing level), respondents responded that they use spreadsheets often for analyzing things. It's 54.8%. The tools related to that are Calc, Excel, and online spreadsheet tools. Their students learn data processing, manipulation, presentation, and analysis. The next highest used web tools are graph tools. It's 50%. The tools included are a spreadsheet, digitizer, and online graphing tools). The least used is charts 35.7%. Here include digitizer, mind mapping tools online tools.

C. Evaluating – Level 5.

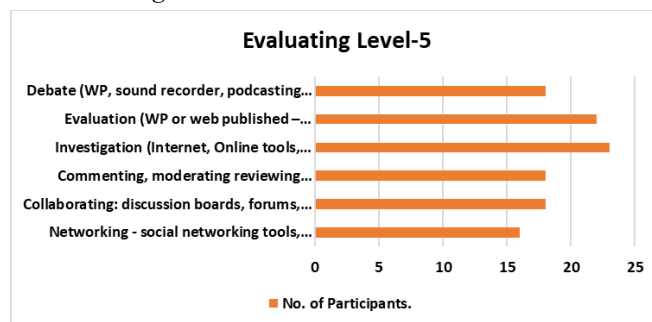


Fig. 5. (Evaluating)

In the fifth level of BDT, 56.1% of respondents stated that they did an investigation. Internet, Online tools, camera, WP, GIS Google Earth, Google Maps, Flickr ArcView/Explorer web tools are used for that purpose. The next highest use of digital verbs at this level by respondents is Evaluation. It's 53.7%. WP or web-published –Report blog entry, wiki entry, web page, DTP, Mind Map, Presentation, the camera is used for that verb. Finally, undergraduates have used the least networking for evaluating the level of BDT.

D. Creating – Level 6.

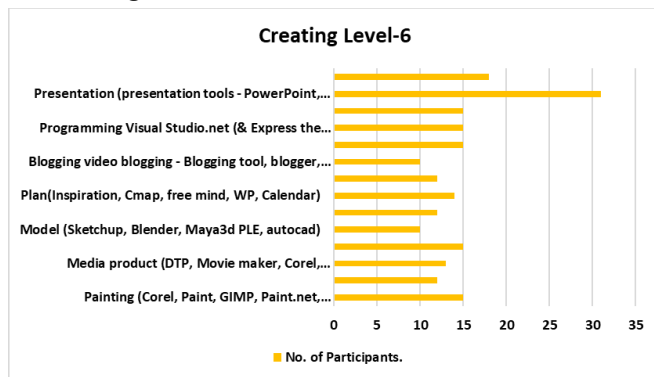


Fig. 6. (Evaluating)

In the final phase, when comparing the percentages 75.6% of undergraduates chose presentation tools as their final creating phase web tools they usually use. It is a significant amount compared to other percentages. It is the only web tool that exceeds half of the participants. All other tools are less than 50%. The next highest score in this creating phase is Filming web tools. It's 43.9%. Undergraduates identify these tools as they create their outcomes tools.

Objective 3: What are the most appropriate technological tools for university education?

The categorized count of the apps (Web 2.0 tools) mentioned for "remembering things":

Table 1: Apps (Web 2.0 tools) students mentioned for "remembering things."

Web 2.0 Tool	Frequency	Web 2.0 Tool	Frequency
Google	8	Spreadsheet	2
Notebook	7	Excel	2
Facebook	6	Mind Map	2
Notebook Software	3	Notepad	2
Presentation	2	Moodle	1
Wiki	2	Hot Potatoes	1

- **Google** is the most frequently mentioned tool, suggesting it's the most popular among respondents for remembering things.
- **Notebook** (including variations like Notebook Software) is also highly favored, indicating a preference for traditional note-taking methods, even if

in digital form. **Facebook** is mentioned several times, which might be surprising unless students use it as a collaborative tool or to save and share educational content.

- A variety of tools are mentioned only once, showing diverse preferences among respondents.

Table 2: The apps (Web 2.0 tools) students mentioned for "understanding things"

Web 2.0 Tool	Frequency	Web 2.0 Tool	Frequency
Google	18	Social Bookmarking	1
Facebook	6	Creating	1
Wiki	4	Twitter	1
Yahoo	2	Blog	1
Edu blogs	2	Chrome	1

- **Google** clearly dominates as the most frequently mentioned tool, suggesting it's the primary platform respondents rely on for understanding various topics.
- **Facebook** and **Wiki** (likely referring to platforms like Wikipedia) are also frequently mentioned, indicating they are commonly used sources of information and understanding.
- The presence of tools like **Oxford Dictionary**, **Trivia Crack**, and **Flowcharts** suggests diverse methods of seeking understanding, ranging from direct definitions to interactive quizzes and visual representations.
- While **Google** is dominant, the diversity of tools mentioned reveals that respondents use a combination of search engines, social media, educational platforms, and specific apps for different understanding needs.

Table 3 the categorized count of the apps (Web 2.0 tools) mentioned for "applying":

Web 2.0 Tool	Frequency	Web 2.0 Tool	Frequency
Mind Map	18	Story	1
PowerPoint	2	Correl	1
MindMeister	2	Painting	1
Spread Sheets	2	Podcast	1
Blog Journal	2	Google Docs	1

- **Mind Map** is overwhelmingly the most frequently mentioned tool for "applying", indicating its popularity and perceived utility in this context.
- Tools like **PowerPoint**, **MindMeister**, and **Spread Sheets** are also mentioned multiple times, suggesting their value in application-based tasks.
- A variety of tools have been mentioned only once, showcasing a diverse set of preferences and perhaps the specific needs of certain tasks or subjects.
- The presence of tools like **Podcast**, **Vodcast**, and **Blog Journal** suggests that respondents view content creation and sharing as a form of application in learning.

Table 4: The apps (Web 2.0 tools) students think most suitable to use for analyzing stage

Category	Frequency
Survey Tools	10
Spreadsheet Tools	10
Other	3
Presentation Tools	2
Database Tools	1
Mapping/Planning Tools	0

From the data, we can infer that:

1. **Survey Tools** and **Spreadsheet Tools** are the most frequently mentioned tools, each with 10 mentions. This indicates a high preference for these tools among respondents.
2. **Other** tools, including HubSpot, Google forms, Programming, and Charts, were mentioned 3 times.
3. **Presentation Tools**, specifically PowerPoint, were mentioned twice.
4. **Database Tools** (MySQL) were mentioned once.
5. Interestingly, **Mapping/Planning Tools** were not mentioned, indicating a potential lack of awareness or usage of these tools among the respondents.

Table 5: The apps that students use to evaluate a concept.

Web 2.0 Tool	Frequency	Web 2.0 Tool	Frequency
Email	4	Twitter	2
Gmail	3	Slack	2
Email Threader	3	Survey Monkey	2
Excel	2	Yandex	2
Discussi on Boards	2	Activity Apps	1

1. **Email** (including Gmail and Email in general) is the most frequently mentioned tool, indicating it's a commonly recognized tool for the evaluating stage.
2. **Email Threader** is another popular choice, which is mentioned three times.
3. Tools like **Excel**, **Discussion Boards**, **Twitter**, **Slack**, **Survey Monkey**, and **Yandex** are also mentioned multiple times.
4. Several other tools like **Duolingo**, **Power Point Presentations**, **Google Class Room**, etc., are each mentioned once.

Table 6: The frequency table about tools used for creating:

Web 2.0 Tool	Frequen cy	Web 2.0 Tool	Frequency
PowerPoint	19	Video Editing Tools	1
Edu Blog	5	Visual Studio	1
Canva	4	Video Editing	1
Photoshop	2	Adobe Premiere Rush	1
Word	1	Programming	1
Project	1	Facebook	2
Presentation	1	Adobe Illustrator	1

1. **PowerPoint** is by far the most frequently mentioned tool, indicating its significance as a preferred tool for creating something that participants learned
2. **Edu Blog** is mentioned five times, showing its importance as an educational blogging platform.
3. **Canva**, a graphic design tool, is mentioned four times, highlighting its usage for creating visually appealing content.

4. Tools like **Photoshop**, **Word**, and **Video Editing Tools** also appear in the list, suggesting participants use a mix of text, graphic design, and video tools for content creation.
5. Other specific tools like **Adobe Premiere Rush**, **Visual Studio**, and **Vodcast** indicate specialized use cases like video editing, programming, and podcasting respectively.

Objective 4: Do undergraduates have appropriate digital literacy upon above listed technological tools?

1. **Digital Literacy** is a dominant theme among participants' opinions. It's evident that many respondents recognize the importance of digital literacy in the context of implementing technological tools in university education. They emphasize that having the necessary skills to navigate and use these tools is crucial.
2. A significant number of participants have provided **suggestions or recommendations**. These suggestions typically revolve around the need for training sessions on digital literacy, the appropriate timing for introducing these apps, and the requirement for awareness programs for students.
3. The opinions such as "Very helpful", "Very useful to apply, gain and experience the knowledge", and "All the above software helps to create assignments, presentations, articles" indicate a positive sentiment towards the implementation of technological tools in university education. Participants seem to believe that these tools can aid in their learning process and make tasks like assignments and presentations more manageable.
4. However, there are also concerns regarding the early implementation of digital apps in education and the challenges faced by those with low digital literacy.

How to implement these new tools to our learnings.

1. **Quizzes** seem to be a popular suggestion among participants. Many of them believe that incorporating quizzes using the new tools can enhance the learning process. This could be due to the interactive and engaging nature of quizzes, which can help reinforce the learning material.
2. **Games** are also suggested a few times, indicating the potential of gamification in education. Through games, students can learn while also being entertained, which might lead to better retention of information. **Presentations**, particularly with tools like PowerPoint, are another area where participants see potential. Incorporating presentations can allow students to visually and interactively engage with the content.
3. Some participants have highlighted the importance of **familiarizing** students with the software. They believe that before diving deep into these tools, students should be given an introduction or orientation, which can smooth the transition.
4. There are also suggestions related to

material sharing and **classroom management**, suggesting the holistic integration of these tools in various facets of education – from content delivery to assessment.

V. CONCLUSIONS AND RECOMMENDATIONS.

Finally, it's clear that BDT is not new to university education, but only touches a very narrow area of BDT. All the students have positive ideas about web tools and how to use them. Since the technology is there, obviously we can use it to understand things easily as technology is time-saving. These technological tools are more effective nowadays. It will save time and make it easier to direct students to studies. It's trending with the pandemic situation & and economic crisis occurring in the country & also it's better to enter the digital modern world too. Low digital literacy is an identified problem in this study. Therefore should teach digital tools before implementation. Implementing new technology is challenging but good for the generation. Undergraduates do not have access to license apps. Financial problems occur when purchasing apps. First, it is very helpful to have an introductory session on digital literacy in the orientation part of the course. It is good and needs technology facilities to implement. First of all, students must be aware of these apps and must learn how to use any of the apps for a particular purpose.

Respondents suggested making the learning environment enjoyable with digital tools. Small educational games throughout these apps, Puzzles, apps for classroom management strategy, platforms for education material sharing, PowerPoint presentations, games, internet homework assignments, and online grading systems with new technology that can be used for effective E-learning, understanding the lessons with mind map apps, Giving spot tests using these apps, use these apps to cooperate with students easily by sending learning materials, Small quizzes after the lesson using these apps, Ease the learning materials with apps, computerize the classroom, Evaluate their studies. Apps increase interest in learning subjects when used to deliver content. Respondents stated that it's better than traditional learning methods.

VI. RECOMMENDATIONS.

With the arrival of the COVID epidemic, undergraduates have engaged in Online Distance Learning (ODL) and that made this study easier to implement in the current situation as everybody thinking of technology to improve O.D.L. education.

Based on the given findings several recommendations concerning Applying Bloom's Digital Taxonomy for University Education.

These recommendations are as follows.

- Carry out a program to increase digital literacy about these web tools and skills.

Respondent recommendation: "I think these apps and tools can teach in our foundation period then it is easy to improve our learning level."

- Use new software to create assignments, presentations, quizzes, articles, etc.

there is a vast number of apps. As university students, we must use suitable official apps.

- make learning easy with apps by making video records with smart apps, exciting.

learning ways with digital tools, using gamification for lessons.

- If the university can provide necessary, license apps to students by giving students.

access to a platform it's very useful and easy to do tasks.

- Create a digital learning system in the university so that students can access the web.

tools easily.

"Better if introduce a new online platform in our university like other private universities and

government universities such as SIIT, Horizon, CINEC, Moratuwa University, etc....

- Register for online educational platforms as a university. So that students can get service free of charge by giving a university code. Ex Microsoft Office, Zoom, E-Library services,

REFERENCES

- [1] Ackerman, E. (n.d.). Piaget's constructivism, Papert's constructionism: What's the difference? MIT Publications. Retrieved from: <http://learning.media.mit.edu/content/publications/EA.Piaget%20%20Papert.pdf>
- [2] Cardoso, S. (2019), "New technologies and new literacies in the English classroom: a study," *Revisit Intersaberes*, Vol. 14 No. 31, pp. 168-186.
- [3] Center for Digital Education. (n.d.). Retrieved 5 30, 2022, from <http://www.centerdigitaled.com/>
- [4] Churches, A. (2009), "Taxonomia de Bloom para la era digital," *Eduka. Recuperado*, Vol. 11, pp. 1-13.
- [5] Comparative study of knowledge and use of Bloom's digital taxonomy by teachers and students in virtual and conventional universities | *Emerald Insight*. (2020, September 7). <https://www.emerald.com/insight/content/doi/10.1108/AAOUJ-01-2020-0005/full/html>
- [6] Considine, D., Horton, J., & Moorman, G. (2009). Teaching and reaching the millennial generation through media literacy. *Journal of Adolescent & Adult Literacy*, 52(6), 471-481.
- [7] Cruz, E. (2003). Bloom's revised taxonomy. In B. Hoffman (Ed.), *Encyclopedia of Educational Technology*. Retrieved February 13, 2008, from <http://coe.sdsu.edu/eet/Articles/bloomrev/start.htm>.
- [8] DiMarco, J. (2014). Using Andragogy and Bloom's Digital Taxonomy to Guide E-Portfolio and Web Portfolio Development in Undergraduate Courses. Retrieved 5 30, 2022, from <https://igi-global.com/chapter/using-andragogy-and-blooms-digital-taxonomy-to-guide-e-portfolio-and-web-portfolio-development-in-undergraduate-courses/113246>
- [9] Google. (2008, July 15). Our Googley advice to students: Major in learning. Official Google Blog. <https://googleblog.blogspot.com/2008/07/our-googley-advice-to-students-major-in.html>
- [10] Hart, J. (2015), Top 100 Tools for 2015. Preuzeto 2016 Sa Top 100 Tools for Learning, available at: <http://c4lpt.co.uk/top100tools/>
- [11] Koeller, M. (2012). From baby boomers to generation Y millennials: Ideas on how professors might structure classes for this media conscious generation. *Journal of Higher Education Theory and Practice*, 12(1), 77.
- [12] Lightle, K. (2011), "More than just the technology," *Science Scope*, Vol. 34 No. 9, pp. 6-9.
- [13] Manochchri, N., & Sharif, K. (2010, January 1). A Model-Based Investigation of Learner Attitude towards Recently Introduced Classroom Technology. *Learning & Technology Library (LearnTechLib)*. <https://www.learntechlib.org/p/111355/>
- [14] N. Husain, F. (2021). Use of Digital Assessments how to Utilize Digital Bloom to Accommodate Online Learning and Assessments? *Asian Journal of Education and Training*, 7(1), 30-35. <https://doi.org/10.20448/journal.522.2021.71.30.35>
- [15] Nikolic, M. and Dabic, T. (2016), "The Bloom's taxonomy revisited in the context of online tools," in Paper
- [16] Nm (2016). Role of bloom's digital taxonomy in smartboard classrooms. Role Of bloom's digital taxonomy in smartboard classrooms, 1(2), 204-209.
- [17] O. (2003). understanding the new learners. Boomers, Gen-Xers, and Millennials, 37-46.
- [18] Out of Our Minds Learning to Be Creative. (2002). *Work-Study*, 51(1). <https://doi.org/10.1108/ws.2002.07951aee.005>
- [19] Presented at Sinteza 2016-International Scientific Conference on ICT and E-Business Related Research. DOI: 10.15308/Sinteza-2016-315-320.
- [20] Purushothaman, A. (2016). Applying Blooms Digital Taxonomy For Learning To Use The Internet For University Students: A Creative Approach To Address The Digital Divide. Retrieved 5 30, 2022, from [http://vbn.aau.dk/da/publications/applying-blooms-digital-taxonomy-for-learning-to-use-the-internet-for-university-students-a-creative-approach-to-address-the-digital-divide\(f7a12215-af89-4688-8b4f-07c4e3dfac78\).html](http://vbn.aau.dk/da/publications/applying-blooms-digital-taxonomy-for-learning-to-use-the-internet-for-university-students-a-creative-approach-to-address-the-digital-divide(f7a12215-af89-4688-8b4f-07c4e3dfac78).html)
- [21] Raymundo, MRDR (2020), "Fostering creativity through online creative collaborative group projects", *Asian Association of Open Universities Journal*, Vol. 15 No. 1, pp. 97-113.
- [22] Skiba, D. J. (2013). Bloom's digital taxonomy and word clouds. *Nursing education perspectives*, 34(4), 277-280. Retrieved 5 30, 2022, from <https://ncbi.nlm.nih.gov/pubmed/24187736>
- [23] Stanford University School of Education. (n.d.). Retrieved 5 30, 2022, from <http://ed.stanford.edu/>
- [24] Strauss, W., & Howe, N. (2000). *Millennials rising: The next great generation*. New York: Vintage
- [25] T. (1998). *The Rise of the Net Generation*. Growing Up Digital, 131.
- [26] V. A. P. B. P. M. (2008, January 12). Mishra & Koehler, 2006 – Punya Mishra's Web. Technological Pedagogical Content Knowledge: A New Framework for Teacher Knowledge. <https://www.punyamishra.com/2008/01/12/mishra-koehler-2006/>

Sustainable Construction Practices and Built Environment for Sustainable Future

Investigation of the Effectiveness of Strength of The Alluvial Deposit Mix with Rice Husk Ash for Soil Stabilization of Backfilling

D.P. Ileperuma

*Department of Construction Technology
The University of Vocational Technology, Ratmalana,
Colombo, Sri Lanka
dilini1017@gmail.com*

T.D. Denagama

*Department of Construction Technology
The University of Vocational Technology, Ratmalana,
Colombo, Sri Lanka
tdenagama@yahoo.com*

Abstract— Dump soil is widely distributed all over the world, especially in river basins, desilting areas, and coastal areas. When construction is going on in those areas, the lot of existing soil behaves as waste material. In engineering practice, dump soil cannot be used to build any construction in its natural condition and needs to be improved or treated before being used in construction. Rice husk ash (RHA) is a byproduct of the milling process. Rice is the main meal in 70% of countries around the world. Every year, a large amount of rice and its byproduct, rice husk ash (RHA), is produced. A huge amount of Rice Husk was wasted annually. To improve the characteristics of the soil mixture, various percentages of alluvial soil from rivers were added as a geotechnical material. Where RHA can be a binding agent for improving soil characteristics, both RHA and alluvial soil were waste materials. This addition helps in soil conservation and its use as a natural construction material, which helps reduce excavation. The objective of this experiment is to Investigate the optimum mix proportion of RHA and alluvial deposit to produce an improved filling material for earth backfilling. Various percentages like 10%, 20%, and 30% of RHA were added as a partial replacement to alluvial soil and tested for Compaction, LL, PI, and CBR. From the test results, it is identified that the addition of RHA to the Alluvial soil decreases the MDD and CBR values rapidly. But up to 30% of RHA will give MDD values up to 1500 kg/m³ and CBR values up to 12%. According to the results obtained by adding RHA to alluvial soil, adding more RHA does not have an effective result compared to rapid reduction. Both the selected soil sample and RHA were non-plastic materials, where the values of LL and PI were zero. Hence, according to the results obtained from the research, by applying these soil mixtures for backfilling, settlement reduction can be beneficial in the construction industry.

Keywords—*Rice Husk Ash, Alluvial soil, Maximum Dry Density, Optimum Moisture Content, California Bearing Ratio*

I INTRODUCTION

Soil is a directly used basic construction material. It always supports the substructure of any structure. But sometimes the existing natural soil at some locations may have poor bearing capacity and higher compressibility, which is not acceptable for construction. In those cases the existing soil cannot be used and is needed to replace applicable soil material; this will generate existing soil into a waste material. By such process, existing ground conditions may vary, Soil waste should be dumped to separate dumping locations and will impact the natural environment in several ways [11].

If a method can be invented to use those weak soil again in the construction industry with some strength upgrading, and improving its qualities it will provide a positive outcome rather than creating a simple waste.

On the other hand, rice husks are hard protective coverings of rice grains and bulky waste in the agricultural industry. They are mostly considered as a common wasting material in the milling process [3]. Rice husks are commonly generated in Asia and other rice-producing countries. In Sri Lanka, rice production is 2.6 million tons annually. From that 2.6 million tons 20% of the weight will be rice husk. Generally, rice husk will incinerate and after burning fully there will be only 5% of rice husk ash [1]. Farmers in Sri Lanka used rice husks as fertilizer and as pesticides. However, if the rice husk does not burn properly the smoke generated will act as an air pollutant inclusive with silicate compounds which has a bad impact on the environment. But if it is completely combusted then it will produce RHA (Rice Husk Ash) which contains amorphous silica with cellular structure [2]. This ash is commonly used as a construction material considering its additive characteristics such as good filler, abrasive agent, and oil absorber. This can provide chemical purity for raw materials [3].

With global development, Climate changes and changes in the environment show the neediness of irrigation management and agricultural management and ensuring natural disasters due to soil erosion in the modern world [11]. Hence, the requirement of embankment, retaining wall construction, and strengthening existing soil plays a major part in the field of civil engineering. Several methods are commonly used to reduce soil erosion and post-construction settlement.

1. Enhance the shear strength of the soil system.
2. Increase the bearing capacity of the soil.
3. Improve the stability of the soil etc.

Therefore, Soil improvement in engineering practice has been widely discussed and engineers and Scientists are seeking solutions. The main purpose of providing such a solution is to help the soil meet the,

1. Minimum hardened strength to withstand their self-load,
2. Requirement to support engineering projects at the foundation level,
3. Requirement to support Embankments.

4. Retain soil and support the ground while minimizing erosion & etc.

Therefore, the thought of combining above mention two waste materials may generate an improved material then the gain for the construction industry will be the gap of improving soil.

II THEORETICAL BACKGROUND

Rice husk ash consists of rich silica content. In general, more than 80- 85%. RHA to be used as pozzolan in cement and concrete, should satisfy requirements for the chemical composition of pozzolans as per ASTM C618. There are combined proportions of oxide and dioxides in the RHA. They are silicon dioxide (SiO_2), aluminum oxide (Al_2O_3), and iron oxide (Fe_2O_3). They should not be less than 70%.

Table 1 Chemical Composition of RHA

Chemical Composition	Rice Husk Ash (%)
SiO_2	93.0
Al_2O_3	0.17
Fe_2O_3	0.35
$\text{SiO}_2 + \text{Al}_2\text{O}_3 + \text{Fe}_2\text{O}_3$	93.5
SO_3	0.11
CaO	0.91
MgO	0.42
Na_2O	0.63
K_2O	2.82
LOI	4.70

[2]

Currently, there are so many ongoing construction works. The construction works involved along in river play a major part all over the country. When it comes to river construction, river sand with deposited material is dumped as a waste called alluvial deposit. The larger amount of alluvial deposit is wasted when a larger amount of construction going on. Therefore, this alluvial deposit will used as the main material for this investigation.

Waste materials will improve their engineering properties. Engineering properties are permeability, strength, compaction characteristics, reactions, etc.. Therefore, considering improvement and investigating the effectiveness of the compound material of RHA and waste alluvial for its applicability in the Sri Lankan context will be an advantage in the construction industry.

III RESEARCH OBJECTIVES

Alluvial soil can not be used for construction in its natural condition. So, a lot of alluvial soil is dumped as waste material. Therefore, it should be improved or treated before being used in construction. Since RHA is also a waste material, farmers tend to burn rice husks.

It cannot be used for any purposes and the stacking of this rice husk reduces the valuable space. When burning rice husk, these fires release large amounts of carbon plus silica pollutants, if partially combusted to the air and generate greenhouse gasses.

Considering using waste material of rice husk ash after a full combustion under a control plant to mix with alluvial soil and using the compound material in soil improvement will be a new invention. Hence This research contains experiments on the effectiveness of the strength of these two waste materials where this improved soil will be expected to be used in backfilling.

The objective of the present study is:

Investigate the optimum mix proportion of rise husk ash and alluvial deposit to produce an improved filling material for earth backfilling.

IV METHODOLOGY

Rice-husk ash is generated by burnt rice husk. The environment of burning yields better quality of rice-husk ash as its particle size and specific surface area are dependent on burning conditions. Completely burnt rice husk is grey to white, while partially burnt rice husk ash is blackish.



Fig 1 River sand and Rice husk ash

Samples, materials, and locations

1. Alluvial deposit

The soil sample of river sand used for this study was collected from the project name of rehabilitation of Walawe right bank at a depth of 1.0m using the method of disturbed sampling.

2. Rice husk

Rice husks are taken from farmers and converted them into ash at the site by burning.

Table 2 Mixing proportions of alluvial deposit and RHA

Sample type	Proportion			
Soil (%)	100	90	80	70
Rice husk ash (RHA)(%)	0	10	20	30

A total of four test samples of soil and RHA were prepared in various ranges. The initial specimen was 100% of soil only. Previous research has shown that 30% RHA resulted in the reduction of strength. Hence soil mixtures were mixed with different replacement levels of alluvial soil varying as 0%, 10%, 20% & 30% with RHA. The details of the samples are shown in Table 2.

Methods of Testing

The laboratory tests were carried out to determine the particle size distribution of the alluvial soil sample when tests were carried out for tests sample and raw soil sample including cone

penetration, Proctor compaction, and California Bearing Ratio Test. Specimens for California Bearing Ratio (CBR) tests were prepared at the Optimum Moisture Content (OMC) values and Maximum Dry Densities (MDD).

Sieve analysis Test

The natural soil samples were oven-dried for a day. After the drying period, the soils were disaggregated and sieved with orderly arranged BS sieves; 20mm, 14mm, 10mm, 6.3mm, 5.0mm, 2.36 mm, 1.18 mm, 0.600 mm, 0.300 mm, 0.150 mm, 0.075 mm. Weighted amounts of the dried soil samples were poured into the stack of sieves and covered with a lid. This was later transferred to the mechanical sieve shaker and vibrated for 15 min. Draw particle size distribution graphs according to the passing percentage details. Sieve analysis was done to determine the size range of the soil particles which is expressed as a percentage of the total dry weight.

Atterberg Limit Test

The Atterberg limit test was used to determine the liquid limit of the soil samples. The Atterberg limit test was carried out according to AASHTO (American Association of State Highway and Transportation Officials) T90. At different water contents, fine-grained soil can exist in several states of consistency. The treated soil samples and natural soil samples were oven-dried for a day and passed through a 300µm (0.300mm) micro meter sieve to have fine-grained soil. Casagrande's Apparatus uses a manually cranked cam or a small motor to lift a brass cup to a prescribed height and allow it to drop onto a hard rubber base. A portion of the soil sample is spread in the brass cup and divided using a grooving tool. The moisture content when the groove closes for 1/2in after 25 drops of the cup is defined as the Liquid Limit.

The plastic Limit is determined by repeatedly remolding a small ball of moist plastic soil and manually rolling it out into a 1/8in thread. A plastic limit roller device can also be used to perform this test. The Plastic Limit is the moisture content at which the thread crumbles before being completely rolled out.

Proctor compaction Test

Standard Proctor compaction test (AASHTO T180-90) was used to determine the maximum dry density (MDD) and the optimum moisture content (OMC) of the soils. Used light compaction of 4.5 kg rammer with a free drop of 45.7cm. The soil samples were mixed with various percentages of RHA. Soil samples were mixed with various moisture contents. It was filled with treated soil in 5 layers with a compaction of 62 blows. The first series of compaction tests was aimed at determining the compaction properties of the un-stabilized soils. Secondly, tests were carried out to determine the proctor compaction properties of the soil upon stabilization with 10%, 20%, and 30% amounts of rice husk ash.

California Bearing Ratio Test

The preparation of samples and procedure of the CBR test was based on AASHTO T193. This study used both soaked samples. The tests were done in one day. The samples of the CBR test were in cylindrical shape of 150mm diameter and 175mm height. It was filled with treated soil in 5 layers with a

compaction of 15 blows. In the soaked method, the compacted samples were taken to the CBR test machine after soaking for 4 days. The CBR machine was where the load was applied by a rigid plunger and the corresponding penetration of the soil was recorded.

V DATA ANALYSIS AND DISCUSSION

Sieve Analysis Test

Table 3: Results of Sieve Analysis Test

Size (mm)	Retaining weight (g)	Cumulative retaining weight (g)	Cumulative passing weight (g)	Passing (%)
50.000	0	0	996	100.0
37.500	0	0	996	100.0
28.000	0	0	996	100.0
20.000	0	0	996	100.0
14.000	0	0	996	100.0
10.000	0	0	996	100.0
6.300	10	10	986	99.0
4.750	19.8	29.8	966.2	97.0
2.360	6	35.8	960.2	96.4
1.180	82	117.8	878.2	88.2
0.600	61	178.8	817.2	82.0
0.300	109.4	288.2	707.8	71.1
0.150	129.6	417.8	578.2	58.1
0.075	149.4	567.2	428.8	43.1
Pan	428.8	996	0	0.0

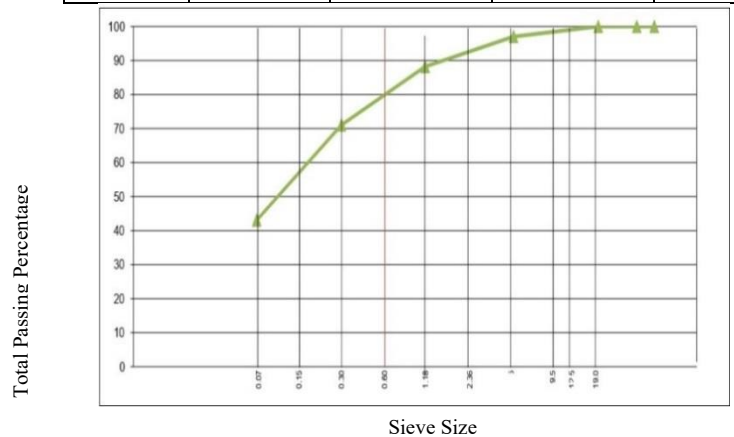


Fig. 2 Sieve Analysis Result

$$\begin{aligned} \text{Sieve size (0.075) \%} &= 43.1 \\ \text{Sieve size (4.750) \%} &= 97.0 \\ \text{Sand \%} &= 97.0 - 43.1 = 53.9 \end{aligned}$$

The alluvial soil sample is shown to be in the soil zone of sand. The gradation curve shows that more than 50% of the sample lies below the size of 0.075mm. According to the Unified Soil Classification System (ASTM D2487-06), this submerged soil is classified as silty sand, a poorly graded sand-silt mixture.

Table 4: Physical Properties of Alluvial Deposit

Optimum moisture content (OMC)	1.80
Gravel	0%
Medium Sand	53.9%
Gravel	3.0%
Fine	43.1%
Liquid Limit	21
Plastic Limit	19
Plastic index	3
Classification of soil (USCS)	SM

Atterberg Limit Test

Table 5: Results of the Atterberg Limit Test

Sample	Liquid Limit	Plastic Limit	Plastic Index
Alluvial soil	21	19	3
Alluvial soil + 10%	0	0	0
Alluvial soil + 20%	0	0	0
Alluvial soil + 30%	0	0	0

Liquid limit (LL) and plastic limit (PL) tests were conducted on soil with and without replacements as per ASTM code D4318-10. The plasticity index (PI) was calculated from the deduction of PL from LL. Tested Index properties, LL, and PL for soil replaced with 10%, 20%, and 30% of RHA to dry weight of soil.

According to sieve analysis, this is a poorly graded silty sand soil. For the initial sample, the liquid limit is 21% and the plastic index is 3%. Liquid limit and plastic index not exceeding 50% & 25% for backfilling according to SCA 5. The selected soil sample had more than 50% of sand. RHA also has a non-plastic property when water is mixed with it. But by adding RHA to this soil sample, this soil mixture becomes semi-solid. Hence the value of the liquid limit and plastic limit cannot be obtained.

Proctor Compaction Test

Table 6: Result of Proctor Compaction Test

Sample	Maximum Dry Density (g/cm ³)	Optimum Moisture Content %
Alluvial soil	1.80	4.1
Alluvial soil + 10%	1.72	12.5
Alluvial soil + 20%	1.66	14.5
Alluvial soil + 30%	1.51	21.0

Standard proctor Compaction tests were conducted on soil with and without RHA. Compaction characteristics, maximum dry

density (MDD), and optimum moisture content (OMC) are presented in Table 6.

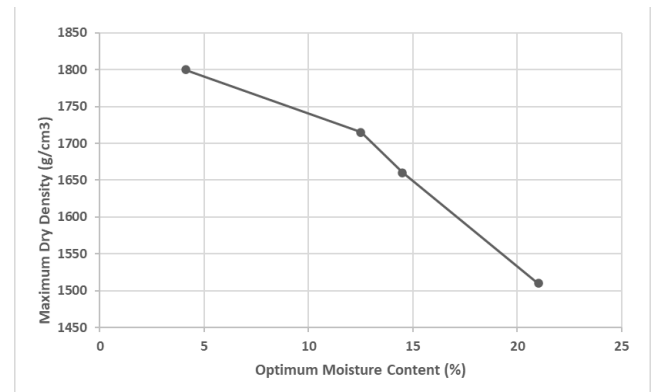


Fig.3 Summary of Proctor Compaction Result

From fig. 3 above, shows the value of dry density variation with moisture content. When observing alluvial soil, it showed that the dry density of the sand increased up to some extent of water increase. Then increment of water content decreases the dry density of alluvial soil. This is because, when water is added to the soil during compaction, it acts as a softening agent on the soil particles. The soil particles slip over each other and move into a densely packed position. Beyond certain moisture content, any increase in the moisture content tends to reduce the dry unit weight. This situation happens because of the water covers the areas, where the soil particles must occupy.

According to SCA-05, the maximum dry density for backfilling should be 1500 kg/m³. This value has been achieved up to the addition of 30% RHA to the soil sample. But after 30% RHA, its MDD drops rapidly. Considering this result, soil usage can be reduced only by adding 30% RHA. Refer to Figure 2 accordingly.

California Bearing Ratio Test

Table 7: Results of CBR tests

Sample	Dry Density (g/cm ³)	Optimum Moisture Content (%)	CBR value
Alluvial soil	1.80	4.1	22
Alluvial soil + 10%	1.72	12.5	19
Alluvial soil + 20%	1.66	14.5	16
Alluvial soil + 30%	1.51	21.0	14

California bearing ratio tests were conducted on alluvial soil with and without RHA. Strength characteristics are presented in Table 7. CBR value was decreased with 10%, 20% and 30% RHA. However, according to the SCA-05, the required CBR value is not less than 5%. Hence all mixtures achieved their strength by the SCA-05.

VI CONCLUSIONS

With the research investigation variation of index properties, compaction characteristics, and CBR values were analyzed for the mixture of alluvial soil sample + RHA. From the results the following conclusion drawn

1. According to the Unified Soil Classification System (ASTM D2487-06), this submerged soil is classified as silty sand with a poorly graded sand-silt mixture.
2. The Maximum dry density decreased from 1.80 g/cm³ to 1.51 g/cm³ in the case of the addition of % RHA to alluvial soil. The Optimum moisture content increased steeply with % RHA 4.10% to 21.0%.
3. Liquid limit and plasticity Index are behaving oppositely with a mixed of %RHA. Liquid limit and plasticity Index decreased from 21% to 0% & 3% to 0%, respectively. According to this RHA is a non-plastic material.
4. The soaked CBR value of the soil decreased from 22% to 12% only in the case of the addition of %RHA to alluvial soil.

Rice husk ash is a porous material with a high amount of honeycomb voids. Also, RHA is a non-plastic material. These properties of RHA have resulted in the high capacity of water absorption. Hence, the water content & plasticity index of the soil-RHA mixture have been affected by the property of the RHA. Some other physical properties of RHA have affected the effectiveness of RHA in soil improvements such as specific density, particle size & CBR value.

In the case of alluvial deposits, the characteristic of the soil extends over a wide range. The soil sample was taken randomly from the soil removed from the work site for this research. It was identified as a poorly graded silty sand. There was less amount of soil contained in this initial sample. The plastic index of the sample was also low. Therefore, considering the above facts, this selected soil sample is not the most suitable for this research because it is non-plastic.

According to this research, the soil mixture may store water if it is sufficiently wet. While soil mixture allows water to drain, it can only do so up to a limit, and if the soil mixture becomes saturated, it will cease draining. Because the grains are tiny and so densely packed together, only a limited amount of water may gather there and the backfill becomes saturated. If there is a heavy rain at once, it will be caused to the erosion.

VII RECOMMENDATION

The research results show some possibilities of using only RHA with the selected soil for soil improvement. But it showed only little improvement in soil. Both selected soil samples and RHA are non-plastic materials. The bond between each other decreases. Hence the strength of the improved soil mixture is reduced. It is therefore suggested that RHA can be used with ordinary Portland cement as a binder material for both waste materials soil and RHA. Using cement for the formation of a secondary cementation compound with the calcium hydroxide Ca(OH)₂ produced from the hydration of cement will improve the soil sample strength.

The proportions of cement addition are to be carried out as the second stage of this research.

ACKNOWLEDGMENT

The author wishes to express their special thanks to the Faculty of Engineering Technology, University of Vocational Technology for providing necessary assistance in carrying out the research work presented in this paper.

REFERENCES

- [1] D.A.R. Dolage, K.Mylvaganam, P.Mayoorathan and S.Inparathnam, "Use of RHA Blended Cement to Produce Cement Sand Blocks," The Institution of Engineers, Sri Lanka, Sri Lanka, 2011.
- [2] B.H.J. Pushpakumara & G.H.M.J. Subashi De Silva, "Characteristics of Masonry Blocks Manufactured with Rice Husk Ash (RHA) and Lime," *Engineer - Journal of the Institution of Engineers, Sri Lanka*, p. 10, April 2016.
- [3] M. A. a. A. M. MUSTAPHA, "Effect of Rice Husk Ash on Cement Stabilized Laterite," Department of Civil Engineering, Federal University of Technology, Minna, Nigeria, Nigeria, 2007.
- [4] F. a. N.E.Mochtar, "MIXING OF RICE HUSK ASH (RHA) AND LIME FOR PEAT SOIL STABILIZATION," www.researchgate.net/publication/268382121, Indonesia, 2010.
- [5] R. Raj, "Stabilization of soil using Rice Husk Ash," *International Journal of Computational Engineering Research*, 2016.
- [6] G. A. A. M. Gupta M.A, "SOIL STABILIZATION USING WASTE RICE HUSK ASH, CEMENT, LIME & GYPSUM," India, 2020.
- [7] F.E.Yulianto, "MIXING OF RICE HUSK ASH (RHA) AND LIME FOR PEAT SOIL STABILIZATION," Faisal estu Yulianto, Indonesia, 2010.
- [8] R. H. Emhammed A. Basha, "Effect of the Cement - Rice Husk Ash on the Plasticity and Compaction of Soil," *Electronic Journal of Geotechnical Engineering* , 2003.
- [9] Pornkasem Jongpradist, Watee Homtragoon, Raksiri Sukkarak, Warat Kongkitkul and Pitthaya Jamsawang, "Efficiency of Rice Husk Ash as Cementitious Material in High-Strength Cement-Admixed Clay," *Hindawi*, vol. 2018, p. 11 pages, 21 June 2018.
- [10] Sadegh Ghavami, Hadi Nematpour, Mehrdad Rajabi, Mohammad Hossein Mobini, "Evaluation of the strength characteristics of clayey soils stabilized with rice husk ash and cement," Iran, 2019.

- [11] Duong Thanh Nguyen, , Nu Thi Nguyen, Ha Ngoc Thi Pham, Hai Huu Phung, Hung Van Nguyen, "Rice husk ash and its utilization in soil improvement," *Journal of Mining and Earth Sciences*, vol. 61, p. 11, 2020.
- [12] Nguyen Thanh Duong, Nguyen Thi Nu, "EFFECT OF DIFFERENT TYPES OF RICE HUSK ASH ON SOME GEOTECHNICAL PROPERTIES OF CEMENT-ADMIXED SOIL," *Iraqi Geological Journal*, vol. 2C, p. 12, 2020.
- [13] Ibrahim Adewuyi Oyediran, Oladunni Olufunmi Ayeni, "Comparative effect of microbial induced calcite precipitate, cement and rice husk ash on the geotechnical properties of soils," *Springer Nature Switzerland*, no. SN Applied Sciences (2020), p. 12, 2020.
- [14] Kajanan Selvaranjan , J.C.P.H. Gamage , G.I.P. De Silva , Satheeskumar Navaratnamc, "Development of sustainable mortar using waste rice husk ash from rice mill plant: Physical and thermal properties," *Journal of Building Engineering*, no. 6 May 2021, 2021.

Determination of Effective Area of a Salinity Barrier to Control Salt Water Intrusion to Paddy Lands in Weligama, Matara

R.M.T. Chathurika
*University of Vocational Technology
Sri Lanka*

T.D. Denagama
*University of Vocational Technology, Sri
Lanka*
tdenagama@yahoo.com

Abstract—High salinity in soil is a serious threat to coastal agriculture and has resulted in a significant reduction in agricultural output in many regions of Sri Lanka. High levels of salt in the soil adversely impact and serious ecological and socio-economic implications to the agricultural productivity of the fertile coastal lands. Weligama is located in Matara district of the southern province of Sri Lanka, is also a victim of the adverse effects of coastal salinity for cultivation. For the study, an area was selected near Weligama bay which known as “Jamburagodayaya”. The selected land is approximately 3.5 km away from the coast (Weligama bay). The region is highly exposed to coastal hazards, including sea-level rise and flooding, which increases the risk of soil and aquifer salinization. This study is mainly focused on finding the effective area of the existing salinity barrier. Five branch canals can be identified in this area, which affected by tidal waves and sea water intrusion, The Pamanella canal is one of those which contains salinity barrier across the canal. This study is mainly focused on finding the effectiveness and effective area of the existing salinity barrier. Soil samples were collected from the area and EC, pH values were tested to determine the salinity. A control test was conducted to determine the interval which the soil samples need to be collected. According to the control test 200m intervals were selected. Accordingly, whole land was divided into 200m*200m grids. There after soil samples were collected from the area at selected locations (grids) and EC and pH readings were taken into account when creating the soil maps.

Keywords— Effectiveness, Paddy Cultivation, Salinity Barrier, Salt Water

I. INTRODUCTION

Paddy is the staple food crop in Sri Lanka. The productivity of most of the paddy lands in the coastal zone of Sri Lanka declines every year due to salinization caused by tidal waves and seawater, which are linked to climate change-induced sea level rise. The intrusion of seawater into inland areas causes coastal soil salinity. Soil salinity is a serious threat to coastal

agriculture and has resulted in a significant reduction in agricultural output in many regions.

Over the last 30 years, large areas of previously cultivated lands have been abandoned, and have now been overtaken by shrubs or are just lying bare. Weligama is located in Matara district of the southern province of Sri Lanka, is also a experiencing of the adverse effects of coastal salinity and is one of the worst affected regions of the country, where increasing coastal salinization is being blamed for decreasing agricultural productivity and abandonment of previously cultivated lands.

II. RESEARCH PROBLEM

According to the data collected from Agrarian Development Department it shows that more than 50% of the total area in Jamburagodayaya is abandoned due to the salinity effect. In the selected area the Polwathumodara river is flowing at the boundary of paddy fields and it meet the sea at weligama bay.

Due to tidal waves, water flows reverse direction through the polwathumodara river and also the canal system. Then the all area flooded by salty water (Saline water+ freshwater)

This remains for 4-5 days and then it started to flow to the sea. After 3-4 days the land becomes dry as usual. But salts remained in the soil also during the dry season water will be taken from the canals for irrigation purposes. This also led to adding saline water to the soil surface. This has become a major issue for paddy cultivation in this area.

There are many negative impacts of the salinity for paddy growth. Decreasing plant growth and yield, ion toxicity, decreasing photosynthesis, inducing oxidative stress, and decreasing nutritional status of plant are some them.

There is a constructed salinity barrier in the branch canal 4 which is known as “Paman ela” and the farmers idea is that it controls salinity in the paddy lands which belongs to the salinity

barrier. Therefore they are requesting salinity barriers to all five canals. But it may take a very large cost. Therefore it will be very use full to conduct a study to check the effective area of the salinity barrier before constructing the new barriers. For the study, a land closer to Weligama bay was selected which is known as “Jamburagoddayaya”. The land is much closer to Ocean and has no distance more than 3.5 km from the coast (Weligama bay). Therefore, the region is highly exposed to climate change-induced coastal hazards, including sea-level rise and flooding, which increases the risk of soil and aquifer salinization. According to the data collected from Agrarian Development Department it shows that more than 50% of the total area in Jamburagoddayaya was abandoned due to the salinity effect.

In the selected area “Jamburagoddayaya” there are 5 branch canals which flows to Polwathumodara river which carries excess water from all the paddy lands in the selected area. In the selected area the Polwathumodara river flows at the boundary of paddy fields and it meets the sea at Weligama bay. For the Pamanella canal, (one canal from above mentioned 5 canals) an existing salinity barrier can be observed. Main aim of constructed barrier is to prevent the salinity water intrusion to the paddy cultivated lands. Due to tidal waves, water flows reverse direction through the polwathumodara river and also the canal system. This led to mixing of salt water with fresh water. The use of this salty water for irrigation purposes also increases the salt content in agricultural lands and it will reduce the paddy yield. This has become a major issue for paddy cultivation in this area.

There are many negative impacts of the salinity for paddy growth. Decreasing plant growth and yield, ion toxicity, decreasing photosynthesis, inducing oxidative stress, and decreasing nutritional status of plant are some them.

As stated, there is a constructed salinity barrier in the branch canal 03, which is known as “Pamanella ela” and the farmer’s prespective is that it controls salinity in the paddy lands which belongs to the salinity barrier. Therefore they are requesting salinity barriers to all five canals. But it may take a very large cost. Therefore it will be very use full to conduct a study to check the effective area of the salinity barrier before constructing the new barriers. The main aim of this study is to determine the effective area of a salinity barrier to control salt water intrusion into paddy lands in the selected area (Jamburagoddayaya).

The main objective of the study is to compare the salinity of the soil samples which were taken from the paddy lands belong to the salinity barrier and paddy lands not belong to the salinity barrier. By this study it is easy to identify the extent which the salinity barrier can control and prevent the salt water intrusion.

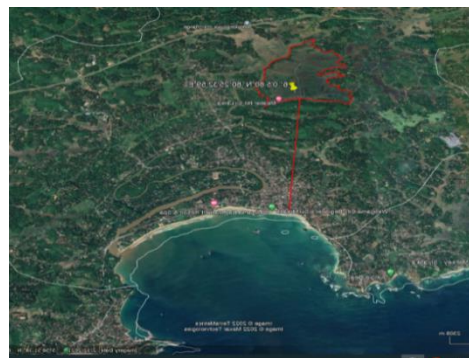


Figure 1: Study Area with coast Source: Google Map



Figure 2: Study Area, Salinity Barrier Source: Google Map

III. METHODOLOGY

Soil Sampling -A soil-sampling campaign was conducted in the selected area (Jamburagoddayaya) When collecting samples .Top-soil samples were collected to a depth of 225-300 mm using a hand auger. This depth is selected by considering the root system depth of the paddy plant (A hand augur was selected to dig the earth up to selected depth. The locations of the samples were recorded with a portable GPS device. Then soil samples were taken out by using the hand augur and collected to small steel containers. The containers are named with its own number. Then the containers were closed with the lids and sealed with tapes.

Control test - Samples were collected to conduct the control test along selected lines (Along horizontal and vertical directions of the existing salinity barrier) Locations were selected along proposed two lines. 16 samples were collected and sealed. Then those samples were sent to the laboratory for test pH and EC values of samples.



Figure 3: Control Points Source: Google Map

Collecting soil samples for the test - After obtaining the control test result and by analyzing those values locations were identified to collect samples. Whole area was divided into 200*200 m grids. By considering the control test values 200*200 m grids were selected and marked in the Google maps. Then the coordinated were written in the note book.

Samples were collected at the noted locations; Locations were founded by using a hand GPS device by selecting the locations samples were collected as same as the procedure followed during the control test. Collected samples were sent to laboratory to check pH and EC values.

Laboratory procedure

Groline portable pH, EC (Electric Conductivity & TDS meter was used for testing. It was a one combined, pre amplified pH ,EC,TDS probe for hassle free measurements. This instrument is a lightweight, waterproof meter supplied with a specialist multipara-meter probe designed for hydroponics, and agriculture applications.

Analyzing the test result (pH and EC values)- Test results were recorded with the location of the sample. By comparing the values along selected lines it was easy to identify the varying range. By studying and analyzing these results soil sample collecting intervals were determined as 200m.

Then samples were collected at selected locations and obtained Ec and pH values were analyzed. Then two soil maps were prepared according to the Ec and pH values. These maps give a clear idea about the effective area of the salinity barrier

Other factors considered- Since the area is flooding within the first 4 days after the full moon day (Due to tidal waves) samples need to be collected after 8-10 days after the full moon day (Because water retain for 4-5 days in the paddy lands.) But rainfall should be minimum during these 8-10 days. Rainfall is highly affects for the salinity change. After the rain salinity washed off with surface water.

Therefore in this study special care was taken to check the rainfall. Rainfall data were collected by Meteorological

Department rainfall forecasting and “DIYAWITHARA” magazine which is published by Department of Agrarian Development. Also, the fertilizer may affect the salinity therefore planned to take preventive actions to collect samples from lands which use same types of fertilizer. This was confirmed by the Agricultural Instructor and ARPA (Agricultural Research and Production Assistant) of the Jamburagoda area.

IV. RESULTS

For the control test samples were collected at (approximately) 150m intervals. When considering about the Ph value change it doesn't show a much variation along the lines. The highest difference between points is 0.72 and average of variance is 0.5. Therefore 200m intervals has been selected to collect samples for the test. When considering about the Ec variance, values doesn't show a significance variance in 150m intervals. The highest change is 0.11 and average value for variance is 0.11. Therefore 200 m intervals were selected to collect samples.

The electrode cap on both the pH meter and the E.C. meter were removed and their electrodes were immersed in tap water for one hour before use. Meters should not immerse above their color band. Both meters were calibrated according to their instructions.

Collected samples were air dried for 24 hours. Soil samples were crumbled to break down any clumps. Then samples were sieved with 2mm sieve. A 20 g of soil was collected from the sieved soil samples. Measured 20g of soil was added to a 250 ml beaker. Then 100 ml of distilled water poured to the beaker. This gives 1:5 ratio of soil to distilled water. Then it was stirred for two minutes, and leave to settle for five minutes. The electrode cap was removed from the pH meter and switched on. The electrode was dipped 1-2 cm into the solution and stirred. Waited for the display to stabilize, and readings were recorded in the record sheet. The electrode was rinsed in distilled water between each sample. Then electrical conductivity was measured by dipping the electrode in the solution and recorded the result.

According to the control test the land area were divided into 200*200m grids. Then the test was conducted for selected locations. The test results were marked in the grids and the marked values were interpolated to create soil maps. Two separate maps were drawn for pH and EC values.



Figure 4: pH values in grid lines Source: Google Map



Figure 5: EC values in gridlines Source: Google Map

Above figures 4 and 5 shows the EC and pH value variation along the gridlines of collected soil samples. Since this is grid diagram a contour lines for EC and pH can be prepared by interpolating the test results. Values were interpolated using the Google earth and soil maps were prepared separately for EC and pH values.

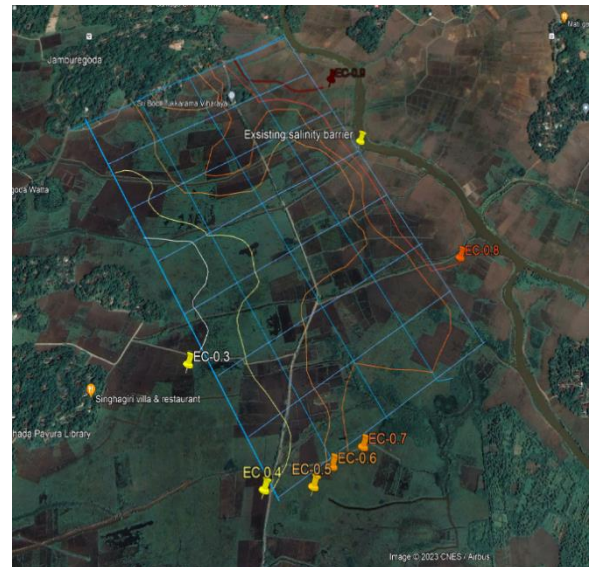


Figure 6: EC value contours Source: Google Map

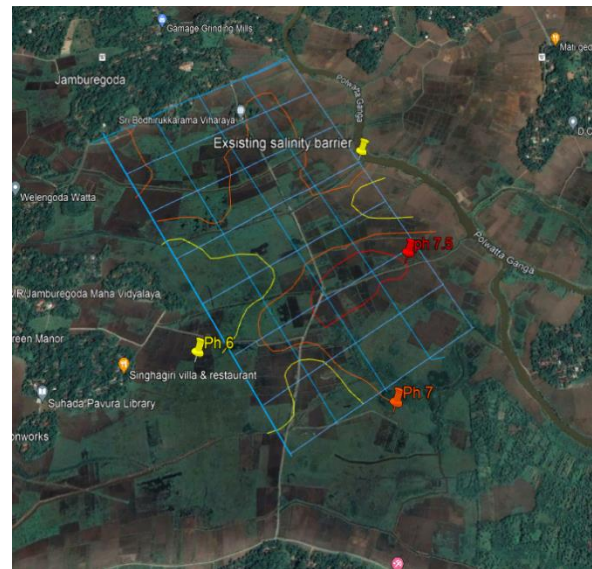


Figure 7: pH contours Source: Google Map

V. CONCLUSION & RECOMMENDATION

While looking at the drawn pH map, it doesn't indicate any appreciable changes to the salinity barrier. Therefore it is much difficult to go for conclusion using the Ph map.

But when considering about the EC map it shows a significance change with the existing salinity barrier. As the Gazette of the Democratic Socialist republic of Sri Lanka no 2148/20 -2019.11.05 EC should be less than 0.7 micro semen per cm to have a favorable condition for

irrigation .(Paddy cultivation) And the ambient pH value is between 6.0-8.5.

Therefore the area below the 0.7 line can be used for irrigation. The area is 86.6 hectares. Selected total area is 111 hectares. Therefore nearly 78.0 % of area can be cultivated in this area without an effect from salinity. This study was done by focusing Maha season. Therefore, $\frac{3}{4}$ of the area can be cultivated successfully under this salinity barrier in Maha season.

This study needs to be conducted for Yala season and it will result the area which can be cultivated in Yala season. Then it will give a clear idea about the whole year.

In this area farmers are requesting to construct salinity barriers for all the 4 remaining canals. But through this study it shows clearly that by this existing salinity barrier it can be cultivated more than 75 % of the land. Only 25% of the land is affecting by salinity. If the salinity barriers are constructing in all 4 canals it may need to spend a very high cost

And therefore, there is no need to build further salinity barriers here in the location. The most effective strategy is to select a paddy variety that can tolerate saltwater environment. The ideal solution would be to cultivate such a paddy in the remaining 25%.

REFERENCES

'Determining sea water intrusion in shallow aquifer using' 2018, International Conference on Agribusiness, Food and Agro-Technology.

'Effect of salinity on food security in the context of interior coast of' 2016, *journal homepage: www.elsevier.com/locate/ocecoaman*.

'Effects of Soil and Water Salinity on Ph, Ec and the Selected Ion Contents in Different Crops Grown in Nonsaline and Salinity Affected Areas of Bangladesh' 2015, *Journal of the Asiatic Society of Bangladesh Science*.

Hideki Araki, MHH&ML 2000, 'Which roots penetrate the deepest in Rice and Maze system', *Plant production science*.

'IMPACT OF SALTWATER INTRUSION ON PADDY GROWTH' 2021, *Journal of Sustainability Science and Management*.

'Linking Long-Term Changes in Soil Salinity to Paddy Land' 2021, Tharani Gopalakrishnan * and Lalit Kumar.

ABBREVIATIONS AND SPECIFIC SYMBOLS

EC – Electrical Conductivity.

ACKNOWLEDGMENT

First and foremost, I am extremely grateful to my research supervisor, from Department of Construction Technology and Resource Management, Faculty of Engineering Technology, University of Vocational Technology, For providing me the great opportunity for doing this research, his continuous support, guidance, supervision, encouragement and invaluable advice given during this study and my deepest thank go to all the officers related to Laboratory of Department of Agrarian Development for their kind support and guidance during the laboratory works.

Commuter Preference Analysis for the Proposed Light Rail Transit Service from Malabe to the Colombo Fort

V. P. Gunawardhane
C3S Business School,
Barcelona, Espagne1
gunawardanev@gmail.com

P. S. Gunawardhane
Kathleen Avenue, Maylands, Western Australia
gunawardanev@gmail.com

G.H.C.S. Amarasooriya
Division of Management Studies,
University College of Ratmalana
Ratmalana, Sri Lanka
chathuamarasuriya@gmail.com

S.S. Wanniarachchi
Division of Management Studies,
University College of Ratmalana
Ratmalana, Sri Lanka
sswucr@outlook.com

Abstract—The purpose of this study was to identify commuters' perceptions of the proposed Light Rail Transit system (LRT system) from Malabe to Colombo Fort to relieve traffic congestion in Sri Lanka's Colombo Metropolitan District. The study's goal was to uncover demand characteristics that would encourage daily commuters to use LRT, and the data gathered will be used to create a model to demonstrate the user preferences in the LRT system. The random sampling procedure was used to collect a sample of hundred and thirty respondents. A questionnaire with twenty-six variables was created with a focus on public and private transport users. This study focuses on the proposed LRT system in Sri Lanka, aiming to make urban transport safer, more efficient, and more sustainable. Factor analysis was used to minimise the number of variables and generate new components. The eight factors influencing the LRT network has been identified from the twenty-six variables used that include, the use include transport service quality, accessibility, comfort, staff behaviour, ICT usage, convenience, punctuality, reliability, and ease toll payment structure. The LRT system, linked to intelligent technology, offers benefits such as congestion control, economics of scale, information and communication technologies, energy, conservation, and environmental pollution control. By upgrading urban transport infrastructure, the LRT system can increase commuter satisfaction, and further research is needed to explore the preference of the other proposed LRT system in the Colombo metropolitan area. The development of the proposed light rail transit system in Malabe – the Colombo Fort corridor will help to increase the satisfaction level and to accelerate the growth in the urban transport structure of Sri Lanka.

Keywords—Commuter, Congestion, LRT

I INTRODUCTION

The National Transport Commission (NTC) and Road Development Authority (RDA) have identified road density issues in Sri Lanka, causing the country's road network to lose over two percent of its gross domestic production. To address this issue, the Light Railway Transport project (LRT project) under the Western Province Metropolis region was proposed. LRT is a train powered by electricity and moves on a raised platform with steel, concrete, and pillar-and-beam construction. The project aims to reduce traffic congestion on the Malabe to Fort route, which has been identified as a main source of heavy traffic congestion. The LRT System, which consists of a seventeen-kilometre-long elevated rail track thru sixteen stops, is expected to be completed in mid-2019.

However, the project was terminated in 2020 due to its ineffectiveness as a cost-effective transportation alternative.

The Sri Lankan government is considering restarting the \$2.2 billion LRT project from Colombo Fort to Malabe starting in April 2023. The project aims to avoid overloading existing transit systems, minimize private vehicle usage, improve rider quality, attract more investors and tourists, and solve road widening issues. The study aimed to understand commuters' preferences for the LRT system from mid-June 2019 to Feb 2021, focusing on the Malabe Corridor and its impact on Sri Lanka's economic growth and public satisfaction [1].

The Colombo district LRT system will make travel easier from Battaramulla, Borella, Malabe, and Fort o (Pettah), by connecting key transit nodes. Starting at Fort station, the route includes one depot and sixteen stations, passing through locations like Denzil Kobbekaduwa Mawatha, Kaduwela Malabe Road, Chandrika Kumaranathunga Mawatha, Lipton Circus, Ward Place, Borella Junction, Polduwa Road, Diyawanna Lake Sethsripaya, Pannipitiya Road, Batteramulla Junction, Palan Thuna Junction, and the depot site on the Madewela East Diversion Canal [2].

II LITERATURE USE

The Colombo congestion is a major study area in transport and traffic engineering. Limiting the number of automobiles that may enter Colombo is the best way to reduce traffic. The proper parking plan in heavily trafficked locations might ease congestion and could encourage people to use LRT systems [3]. Traffic congestion in Rajagiriya, Colombo Metropolitan Area, has primarily caused by the location of three intersections on the Sri Jayewardenepura main road.

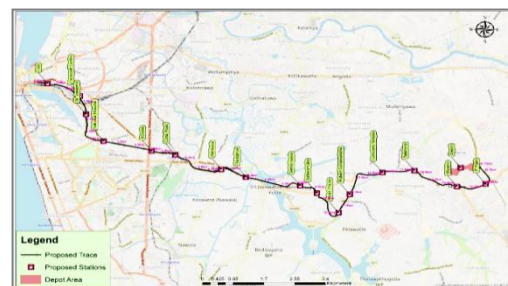


FIGURE 1 PROPOSED LRT DIRECTION AND MAIN ATTRACTIONS [4]A flyover and roundabout design could alleviate congestion, but the elevated roadway is currently insufficient for rising

vehicle numbers. A study aims to introduce sustainable transportation options to change public attitudes and habits, benefiting individuals, the economy, and the environment [5]. This model explores alternative transportation solutions in the Colombo Metropolitan Area, focusing on long-term strategies to alleviate traffic congestion. The model aims to change public attitudes towards sustainable options, resulting in mutually beneficial outcomes for individuals, the economy, and the environment.

III METHODOLOGY

Study design and population

This research is quantitative research using primary data inductive and empiricist's approaches to develop a model to find the influencing factors to attract commuters to the proposed LRT system at the Colombo-Rajagiriya corridor.

The target population of the study had been consisting of frequent users passing the Colombo-Rajagiriya corridor during the morning/ afternoon peak and had been chosen from the JICA Survey and CoMTrans Screen Line Surveys. The primary collection of data approach has been the random sample method.

Data collection and questionnaire design

Primary data from questionnaire surveys and secondary data preserved from databases were used for further analysis. The survey utilized printed questionnaires and Google forms, with qualitative data weighted using the Likert scale, and quantitative data evaluated using Statistical Package for Social Science (SPSS). The questionnaire is divided into Part A and Part B, focusing on demographics and variables related to the use of the LRT system. A sample of two hundred respondents (200) were initially targeted for the survey using the Random sampling method. A total of hundred and thirty (130) valid responses were received for the survey.

Analysis method and tools

The primary data had been used in this study. The data collected was analysed to extract the results to fulfil the objective of the study. The principal component analysis (PCA) is a quantitative method for factor analysis, simplifying data by identifying factors and reducing variables, resulting in a comprehensive understanding of the data reduction process. The data are considered acceptable for PCA if the data set's Cronbach Alpha value is in the range of 0.6 to 0.9. The Kaiser-Meyer-Olkin (KMO) test measures sampling adequacy for factor analysis, with values between 0.7 and 0.9 considered acceptable. KMO measures the sampling adequacy of research, eliminating highly correlated variables.

Factorial analysis and descriptive analysis methods has been used in this study to acquire the results. The subsequent procedures were taken when examining the data with the help of statistical tools. Before entering software, the data has been coded, parameters have been set and the data has been entered to formulate analysis.

IV ANALYSIS AND RESULTS

Descriptive analysis results

The summary of descriptive analysis showed that LRT has been accepted by both the male and female commuters. Regardless of travel time, the male made up most of the responders in the study. University graduates between the ages of 20 and 49 account for a larger percentage, i.e., seventy-eight (78%) percent of commuters. The majority of the sample's respondents are from the public and private sectors, who had travelled through Malabe- Colombo corridor to satisfy their requirements for business, official, or education purposes. The majority has used the route for daily travel. Many commuters had taken public or staff service and personal car/ van as their present transportation method. The majority had spent an average time of forty-five to one-hour time on daily trips.

Most of the trips had been originated from the Malabe bus terminal and are destined at Fort or Borella bus station. The LRT corridor, primarily in the Sethsiripaya region, attracts commuters who travel over halfway to their destinations. It has been noticed that government buildings in the region, including Baththaramulla, attract private automobiles during rush hour. The corridor's utility is highly praised. The descriptive data analysis of the commuter trip origin and destination with pie charts is provided below. The journey origin and destination are critical considerations in determining the commuter attack strategy for the LRT system.

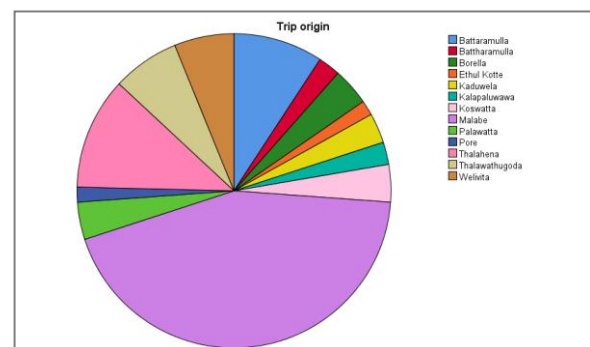


FIGURE 2 ANALYSIS OF TRIP ORIGIN OF COMMUTERS ANALYSIS

According to the pie chart in FIGURE 2, the majority of commuters begin their journeys at Malabe, Koswatta, and Baththaramulla, and the majority of commuters complete their journeys in Colombo Fort, Borella, and Transport Centre Station, respectively as in FIGURE 3. As a result, planned stations appear to be well suited to the needs of the commuters.

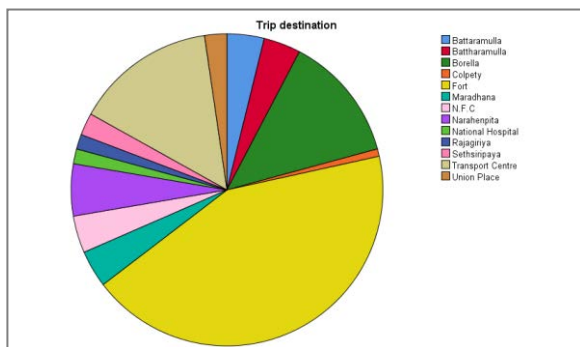


FIGURE 3 ANALYSIS OF TRIP DESTINATION OF COMMUTERS

It was feasible to describe the aspects influencing commuters' perspectives on the proposed LRT from Malabe to Fort, as well as data analysis and the theoretical contribution. Furthermore, independent of different demographical characteristics, the majority of the respondents are the travel origin (Malabe) and destination (Colombo Fort).

Principal component method for factorial analysis

Before doing factorial analysis, the data's originality and reliability have been verified. The study's Cronbach's alpha is 0.690, indicating acceptable reliability, and the KMO value of 0.603 indicates adequate sample size. The sphericity test yields 0.000, indicating dimension reduction potential due to the non-identity matrix. Factorial analysis analysed twenty-six (26) variables, including travel cost, toll scheme, convenience, an online recharge system, schedule frequency, punctuality, reliability, and efficiency, reduces travel costs, offers punctuality, reliability, and efficient transportation. Analysis generated eight (08) factors with more than seventy percent (73.89%) of variability, with twenty percent (26.111%) of loss. The model has been generated using component score coefficients to express the relationship between observed variables and generated components.

$$fx = \sum (\text{The Component Score Coefficient Matrix of each variable} \times \text{each variable in the computer generated factor } i)$$

EQUATION 1 MODAL TO IDENTIFY COMMUTER PREFERENCE OF LRT

Here the

f = Function of the customer fondness

x = Factor (1, 2, 3, 4, 5, 6, 7, 8)

i = Variables used (1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26)

The key factor (f1) "transport service quality" is made of having good security, connections with other trains, assistance for disabled elderly commuters, cleanliness/ maintenance of the station, LRT reduce travel cost per day, an online recharge system for ticketing, stations located every major trip attraction zone, real-time tracking and information and efficiency and the speed of LRT and with excellent Cronbach alpha value to prove the consistency of the data. Combining variables of proposed sixteen stations are enough, locations of the stations easily accessible, easy to travel using LRT and providing access modes to LRT stations has created the factor

"accessibility of LRT network (f2)". The factor "comfortability (f3)" is the other computer-generated factor that incorporates the quality of the facilities, comfortability of the ride in LRT, adequate secured parking for own vehicle, and easy to travel than a private vehicle. The factor "accessibility of LRT network" and "comfortability" of LRT network has reasonable reliability value. The factor "staff behaviour (f4)" is a combination of variables that include having friendly staff available servicing, complaint handling mechanism, and have sufficient capacity in LRT. The fifth factor "ICT usage (f5)" contain variable-updated schedules on mobile apps. The variable, higher frequency of LRT schedule, many trains available in peak hours and Rs.100 per head from Malabe to fort created the factor "convenience of LRT (f6)". The punctuality and reliability of LRT (f7) and ease toll payment structure (f8) has been last computer-generated factors that have an impact over using LRT network.

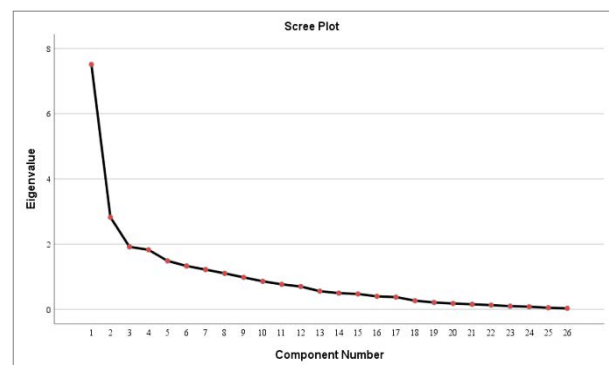


FIGURE 4 SCREE PLOT ANALYSIS

All of the major components have been plotted in the scree plot analysis in FIGURE 4. The component on the steep slope in the figure illustrates the components well. They describe the underlying link between the factors in the process of identifying customer happiness. This research has eight first-rate main components. Research includes the twenty-six components on a shallow slope, which has been considered a little contribution to the selection process. It was feasible to describe the aspects influencing passengers' perspectives on the proposed LRT from Malabe to Fort, as well as data analysis and the theoretical contribution. Furthermore, recommendations were made based on the discoveries. Most notably, it was determined that, regardless of different demographical characteristics, the majority of respondents are eager to switch to LRT transit from their current forms of transportation.

The study's findings will aid in designing the LRT system to meet user needs and reduce traffic. By considering the travel preferences of the sample population, the proposed system can be designed to encourage more people to switch from their current mode of transportation. The economic effects of the LRT system in the Colombo urban area and its contribution to reducing general congestion in the roadways require more study. Further studies should focus on factors affecting the system's construction and commuter experience, including the projected LRT in other project areas.

In accordance with the study, commuters choose high-quality transit services. The responses demonstrated that another significant contributing element is the LRT terminal's accessibility. More people will utilise the LRT as a result of its accessibility from their own automobiles, another shuttle service, or intermodal networks. When it comes to the terminal's accessibility, the egress mode connectivity is equally crucial. Having the right number of seats and a decent carriage will make travel more comfortable. Although there would be a lot of questions and information needs once the LRT is put into operation, staff behaviour, and the complaint handling process also required to be addressed. One of the main factors attracting commuters to the projected LRT has also increased as a result of how simple it is to purchase a ticket and use ICT. Commuters will use LRT services for everyday trips to work and home because of ease, timeliness, and dependability of the service. To attract more commuters, the transportation system's affordability must be improved, and one of the key variables in this is the toll payment structure.

To improve the model's optimal fitness, the research can be expanded by adding more data. Data collection for this study has been limited to the Malabe-Fort route. As a result, only daily commuters who had travelled along the corridor were eligible to participate. The other urban cities where the construction of LRTs has been proposed are not included in this study. If such as the population has been addressed the number of observations could have been increased resulting more accurate model.

This study also reveals that, as LRT being a recent technology to the urban transit system in Sri Lanka, commuters know truly little to nothing about utilising it. The study's findings will guide the development of an LRT system to meet user demands and reduce traffic. It aims to persuade more individuals to abandon traditional transportation and move towards a more digitalized urban transport structure. Further research is needed on economic impacts and commuter experience in other project regions. Utilising this LRT system in the future will upgrade the quality of urban transit towards sustainability.

ACKNOWLEDGMENT

Express our gratitude to the research team for their assistance, hard work for the survey and all participants for their support in participating the survey. Especially wish to acknowledge Dr A.M.C.P. Atapattu of University of Colombo, Faculty of Management and Finance, for his immense guidance throughout the study.

- [1] "National Highways in Sri Lanka," 2020. [Online]. Available: <http://www.rda.gov.lk>. [Accessed 2019].
- [2] M. Ruskin, "Man-hours lost due to traffic congestion," 13 February 2019. [Online]. Available: <https://www.dailymirror.lk/feedback>.
- [3] A. A. Thathsarani and G. H. J. Lanel, "A Model To Reduce Traffic Congestion In Colombo City," *International Journal of Scientific and Research Publications (IJSRP)*, vol. 9, p. 112, 2019.
- [4] "Colombo light rail transit project," Central environmental authority, Colombo, 2018.
- [5] M. Fernando and K. S. Fernando, "Reducing traffic congestion in Colombo metropolitan area through adaptation of alternative personal transportation methods: barriers and long-term strategies," *Logistics conference Trincomalee Journal*, 2016.
- [6] L. Dell'Olio, A. Ibeas, A. Dominguez and F. González, "Passenger preference analysis: Light rail transit or bus versus car," *Transport*, vol. 27, pp. 276-285, 01 09 2012.
- [7] "Preparatory survey on the project for the establishment of new rail transit system in Colombo," Japan international consultants for transportation co., ltd., Colombo, 2018.
- [8] L. B. Benjamin, "Regulation, activity and consumer complaints in France's rail transport sector," Network Support Department, 2013.
- [9] Syed, Daisy Mui Hung Kee and Shahbaz, "Service Quality and Rail Transport in Pakistan: A Passenger Perspective," *World Applied Sciences Journal*, 2012.
- [10] s. Vishnuvarthan and D. A. Selvaraj, "Railway passengers' satisfaction: a study in Salem division of southern railway," *International Journal of Advanced Research in Management and Social Sciences*, 2012.
- [11] S. K. S. Yadav, "An analytical study of emerging economic trends of Indian railways," 2008.
- [12] Indian Railway Catering and Tourism Corporation, "IRCTC – Structure, Functions and Role," in *Indian Railway Catering and Tourism Corporation*, pp. 157-197.
- [13] JICA, "Preparatory Survey on the establishment of New LRTon Colombo," JICA, 2027.

Optimising Technical Properties of Concrete Bricks with Waste Steel Powder

K. G. A.lahapperuma

Department University of Vocational Technology

Sri Lanka

kgalahapperuma@uovt.ac.lk

K.A.H.H. Rasanjana

Department of Mechanical and Manufacturing Technology

University of Vocational Technology

Sri Lanka

hasarangarasanjana@gmail.com

Abstract—Modern-day building construction is mainly based on concrete bricks, rather than mud bricks. However, with the economic crisis and inflation rates of prices on raw materials and manufacture, both the construction industry and consumers are in a problematic situation. As a result, alternative ways for cost reduction are being attempted by the researchers. Besides, the environmental issues with industrial discards are now greatly exacerbated. Since steel is the most widely consumable category of metals, steel industry discards, which aren't easily degradable are accumulated and occupy valuable land areas. This study was attempted by considering both of these factors. Waste steel powder has been considered an additive material of concrete bricks. It also tries to add value to non-degradable waste. In this study, the physical and mechanical properties of concrete bricks prepared by adding this waste in different percentages were presented. Visual appearance, percentage of water absorption, density and compressive strength were the considered properties. The best and optimum amount of steel powder to preserve the expected properties and minimise the cost was revealed as 30%.

Keywords— concrete bricks, steel powder, technical properties

I. INTRODUCTION

Concrete brick forms a composite made of Portland cement and sand. Nowadays, the majority of constructions are based on concrete bricks. However, the cost spent on these concrete bricks is also inflated at a fast rate.

In another way, present day world's one of the main concerns is sustainable development. Concepts of sustainable development, when applied to the construction industry, both, environmental well-being and economic well-being have to be addressed simultaneously. Instead of investigating new products and processes, advancing the existing materials and processes is taking place, while greening the masonry industry.

The responsibility of the construction industry towards environmental health is not so small. Usually, almost all building materials, during the production and construction phases cause any form of effect on the environment. In the case of concrete bricks, among all participating materials, cement plays a major role in forming the required properties. Nowadays, alternative partial substituents for concrete mixes are investigated by researchers, preferably due to high-cost involvements.

In other way, climate changes and atmospheric warming are resulting due to straight effects of the manufacturing

processes. During the manufacture of cement, a considerable environmental threat of a similar nature happens due to the emission of CO₂ gas. Also due to the high consumption of concrete bricks, natural resources such as sand, stone and apatite deposits have been consumed at a fast rate. Additionally, environmental harms such as floods and the decay of riversides are a result of drastic consumption of natural resources.

Ferrous-based metals are the most widely consumable category of metals throughout the world, which leads to a huge accumulation of the industrial waste of discarded steel pieces. Since not easily bio-degradable, accumulated steel pieces pose a considerable environmental threat, due to the occupation of valuable land areas.

To seek a solution to all these problems, it was decided to make concrete bricks by replacing the entire concrete mix with another additive of waste steel powder. This saves the cost of major raw materials of cement and sand. Since the usage of original raw materials of cement and sand is reduced with this study, it will contribute to the reduction of harmful effects, generated due to the emission of CO₂ gas and the riverside decays etc. Furthermore, this will be an environmentally friendly project in another way also, since a non-biodegradable and environmentally problematic industrial waste is used productively, as the substitute to the concrete brick mixture.

Here steel powder was added in different volume percentages, and the physical and mechanical properties of those bricks were tested to select the optimum steel powder percentage to be added, considering the performance of bricks also.

The main objectives of the project were to make concrete bricks at low costs, aid environmental sustainability by reducing the use of original construction materials, and remove harmful industrial waste material from the environment in a productive way.

II. LITERATURE REVIEW

As per in all other areas, multiple details of past experimental studies, as well as review studies are found in this area also. Most of those studies are still being continued. Some of such studies, that are found in the literature are summarised below.

In 2021, Dawood and Mohmood conducted their study to investigate the effects of the addition of different industry waste materials of glass powder and steel slag powder, as

replacements for cement in bricks. Properties were observed under two curing methods; normal curing method at $23 \pm 2^\circ\text{C}$ and boiling water added at 100°C , which was tested for 03 ages; 03, 07 and 28 days. Different 06 mixes were cast with each addition, and cured under different curing conditions before testing. As per the results, the density of bricks, replaced with steel slag powder increased due to the high specific gravity of steel powder. Water absorption and density variation are linear; when density increases, water absorption decreases. In the study, the approximate reduction of CO_2 emission was recorded as 29% with a 30% replacement of glass powder or steel slag powder by weight [3].

In 2020, Fang et al presented the production of concrete bricks using steel slag powder and fly ash. The use of steel slag powder and fly ash instead of cement to manufacture concrete bricks can promote the secondary use of industrial solid wastes and protect the environment. In addition, with the use of these wastes, the cost spent on raw materials can be reduced and saved. In this study, the appearance of the concrete bricks and the compressive strength were checked. Steel slag can be used as a supplementary cementing material which enhances the strength of concrete with time, while fly ash can enhance the workability of concrete and enhance the after strength of concrete. The recommended optimal composite substitution ratio of cement and steel slag powder to fly ash was 12:5:3. In this experiment, the optimum replacement percentages of steel slag powder and fly ash were 25% and 15%, respectively [1].

A by-product of steel making through the Linz–Donawitz process is called Linz–Donawitz (LD) slag. Due to volume instability caused by high amounts of sulfur and phosphorous in LD slag, it is not generally used in construction applications. However, the review study conducted by Singh and partners in 2020 describes the possibility of using this waste in a wider range of applications. The study was based on recent studies as well as past studies, published during the past decade [4].

Zhang and his group had a study in 2012, to investigate the properties of steel slag blended cement paste. Initially, there wasn't any contribution to the addition of slag waste to the paste. However, with the introduction of a chemical activator, both early as well as late compressive strength values of 30% steel slag and 35% cement clinker added are almost the same as normal Portland cement paste [2].

Barcza and Nelson conducted a review study in 1990, to study the different technological methods that are used for treating steel plant dusts. The different involved methods mainly considered the amount of hazardous elements contained in steel in steel, such as lead, cadmium, nickel and chromium, which usually come from the scraps of steel that are used during steel –production. Treatment of waste steel dust containing these hazardous elements needs a highly critical analysis since it is essential to address environmental and economic concerns. As per this study, even though several processes are used to recover nickel, chromium, molybdenum and vanadium, for many years, these approaches haven't fully met the environmental

requirements. The final decision of selection of a process ultimately depends on all aspects such as quality and quantity of steel dust, cost for disposal, environmental legislation applied in each community, transportation costs, energy requirements, quality and value of the product as well as technological support etc which evaluate an option is a complex task. As per this review study, there are four broad process options; chemical treatment, recycling, non-electrical-thermal and electrical-thermal processes. Industrial steel dust is also of four major types; carbon steel- low zinc, carbon steel high zinc, alloy steel low zinc and alloy steel high zinc. Of these, the treatment of alloy steel high zinc has to pay environmental concerns much more critically. Ultimately, the evaluation of each proposal is dependent on its own advantages and disadvantages [8].

III METHODOLOGY

A. Materials

The used raw materials were Ordinary Portland cement (OPC), natural river sand and steel powder. Steel powder was collected from metalworking workshops, in the Homagama area. The other two materials were bought from a retail seller of building materials. Fig. 1 shows a sample of steel powder, used for this study.



The used steel powder

B. Preparation of Bricks

The percentage of additive steel powder was decided upon literature review. Several different compositions were prepared by replacing the sand and cement (concrete) mixture with various additive amounts. Five bricks were made from each composition. In the concrete mixture, the cement: sand ratio was kept constant at 1:4 for all compositions.

The selected raw materials were measured in percentage by volume. In preparation for each composition, the raw materials were initially mixed well, and a sufficient amount of water was added to make the mix. Then the set of moulds was filled well with the wet mixture, and those moulds were compacted with the aid of a flat end of a wooden bar. When the moulds were packed well and filled completely, the excess mixture was wiped off.

Table 1 indicates the amount of each material used in each mix design.

Sample	Percentage of cement	Percentage of sand	Percentage of steel powder
1	20	80	0
2	18	72	10
3	16	64	20
4	14	56	30
5	12	48	40

PERCENTAGE OF MATERIALS USED FOR CONCRETE BRICKS

C. Curing

After removing from the moulds, the concrete bricks were placed in a shady area to harden. When they were dried for 24 hours in the shade, they were damped twice a day for seven days.

D. Drying Process

Then the concrete bricks were left to dry in the shade for another 21 days.

E. Testing of Bricks

When all bricks were dried well, they were subjected to the tests of visual appearance, density, water absorption, and compressive strength tests.

F. Visual Appearance

After drying well, each of the concrete bricks was visually observed for any cracks, warps, colour and dimensional changes.

G. Density Measurement

With the use of the dimensions and weight of each brick, density values were calculated. Then, all such values of each brick design were averaged, to present the respective density value.

H. Water Absorption Test

Two bricks from each mix design were subjected to this measurement. The initial weight of each brick was measured, and then they were fully soaked in water for 24 hours. Then the wet weight of each brick was measured. With the use of weight difference, the percentage of water absorption was calculated.

Equation (1) was used to calculate the percentage of water absorbed into the bricks.

$$W = \frac{W_2 - W_1}{W_1} \times 100\% \quad (1)$$

Where,

W = Percentage of water absorption

W_1 = Weight of dried block (before immersion in water), in grams

W_2 = Weight of brick with absorbed water, in grams

After the percentage water absorption of each brick was calculated, two values of each composition were averaged, to express the result.

Compressive Strength Test

Compressive strength was measured by using the (compressive strength) testing machine (Model No. CT7comTest). For each composition, three bricks were taken for measurement.

IV. RESULTS AND DISCUSSION

In this study, tested technical properties of different compositions were compared to those of the original concrete brick composition.

Visual Experience

Compared to ordinary concrete bricks, almost all bricks, tested showed the same ash color. No other change occurred.

Density measurement

The tests indicate that, as the percentage of the replaced steel powder increases, the density decreases. Even though the density is expected to increase with the steel powder, it has been reversed. Since steel in powder form was used (approximately 01 mm in size), there was more free volume among the 'steel dust' particles.

Additionally, since collected from a metal workshop, there might have been a certain amount of 'non-steel' particles, such as dust contained in it, affecting the result.

Whether there is a reduction in density, the obtained values of all these compositions are of the range of high- density bricks [6].

Fig. 2 shows the variation of density concerning the percentage of added steel powder.

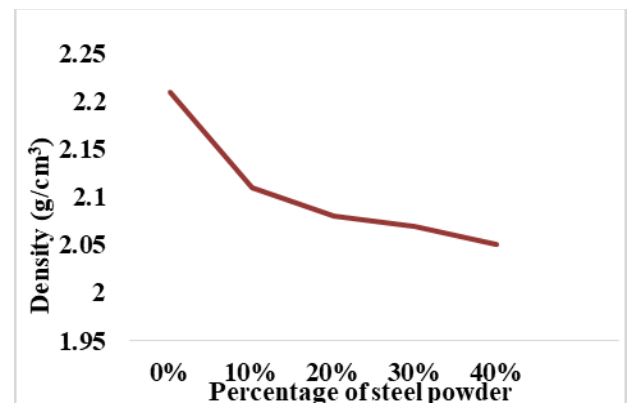


Figure 2. Density variation with steel powder addition

Water Absorption Test

Figure. 3 shows the results of water absorption of the tested bricks.

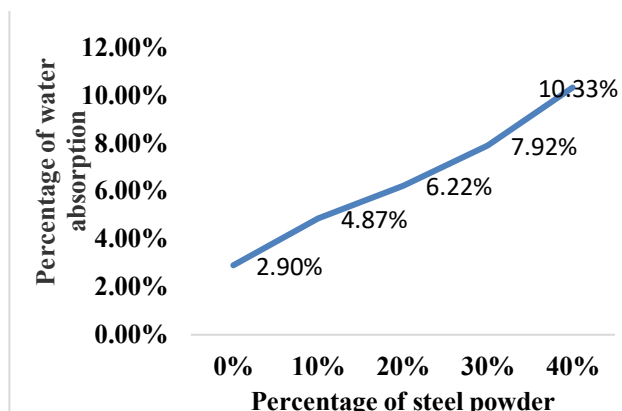


Figure 3. Water absorption with steel powder addition

The results indicate that the water absorption of the control sample is minimal at 2.9%, while it almost gradually increases as the additive steel powder increases. This increase in absorption is a sign of more free volume among the particles of the concrete mix. On one side, it might be due to low packing density, with irregular shapes of concrete mix materials, preferably of steel particles. On the another side, there might be a substantial contribution to water absorption due to accidentally added 'dust' particles, if any.

Even though a sharp rise in water absorption is clearly indicated, almost all those compositions are in the range of standard concrete bricks, with respect to this property [7,9].

Compressive Strength Test

Fig. 4 shows the results of the compressive strength test.

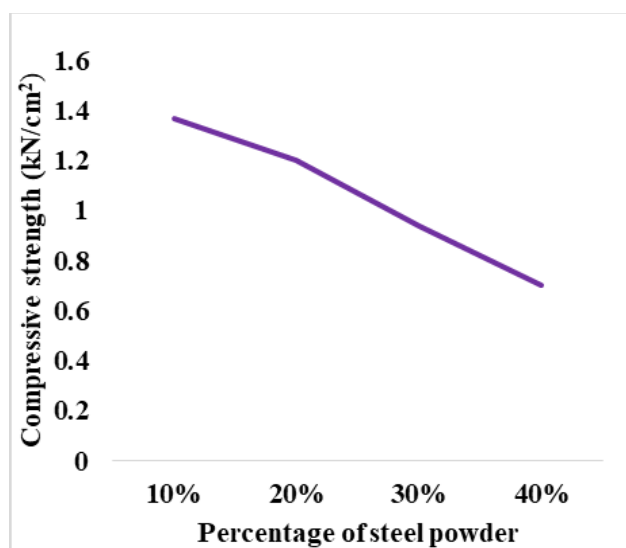


Figure 4. Variation of compressive strength with steel powder addition

The obtained values of compressive strength of concrete bricks that were produced by adding steel powder are in the range of the standard concrete bricks.

With the addition of steel powder, a reduction of compressive strength also happens, implying low-strength bonding forces among particles of added materials. The nature of bonding that forms between usual brick materials of either cement or sand and steel powder particles might be of low strength. In case of a foreign material type such as dust is added, it also might have affected the internal bonds.

Concerning this essential property of compressive strength, even with a reduction of strength values, all mix compositions are within the acceptable range. Generally, the average compressive strength of concrete bricks ranges from 0.35 kN/cm² of non-load-bearing bricks to 1.25 kN/cm² of medium-density, load-bearing bricks [5].

In this study, up to 40% steel powder was used to replace the mixture of the concrete bricks. The density of bricks varies from 2.21 g/cm³ for 0% steel powder to 2.05 g/cm³ for 40% steel powder. The water absorption of concrete bricks varies from 2.90% for 0% and 10.33% for 40% of steel powder. The compressive strength of bricks varies from 1.37 kN/cm² for 0% and 0.70 kN/cm² for 40% steel powder.

According to all tested properties, compositions with all mixed proportions of steel powder are suitable to be used as serviceable bricks.

However, critically considering quality as a prime factor, the optimum brick mixture was selected as the one with 30% steel powder. Test results obtained for that mix were 2.07 g/cm³ of density, 7.92 % of percentage water absorption and 0.94kN/cm² of compressive strength.

According to Alonso et al (1990), bricks with these technical properties are suitable to be used in load-bearing applications, also [9].

If bricks of this selected (30% steel powder) composition are produced, it will cause a 30% reduction of the usual concrete brick mixture, for every single brick produced. This will cause a substantial saving of both ingredients, cement and sand. Accordingly, related environmental damages that happen during the production of cement and sand are also reduced. Additionally, a substantial proportion of waste steel powder is also productively removed from the environment, which will enable to release of the land area, occupied by this steel waste. Above all these factors, a major saving of cost on raw materials is not a negligible benefit for all connected parties.

The suggested bricks are of lower density compared to the original concrete bricks and are suitable to be used in load-bearing applications also. Therefore, they can be used in the majority of engineering applications, in the construction industry, indicating numerous advantages.

V. CONCLUSION

The technical properties of concrete bricks were optimised using industrial waste-steel powder as a reinforcing additive. The optimum percentage of steel powder waste was decided as 30%, to comply with mainly, technical properties and economical cost savings, in addition to the environmental benefits of different ways. Other than usual construction work, these bricks can even be applied to load-bearing walls also, since they conform to relevant standards.

VI. REFERENCES

- [1] M. Fang, G. Fang, Y. Xia and H. Wang, “Compressive strength of concrete mixed by steel slag powder and fly ash”, IOP Conference Series: Earth and Environmental Science, 2020
<https://doi.org/10.1088/1755-1315/508/1/01218>
- [2] T. Zhang, Q. Yu, J. Wei and J. Li, “Investigation of mechanical properties, durability and micro-structural development of steel slag blended cements”, *Journal of Thermal Analysis and Calorimetry*, *Journal of Thermal Analysis and Calorimetry*, vol.110, 2012, pp. 633-639.
- [3] E. T. Daewood and M. S. Mohmood, “Production of sustainable concrete brick units using nano-silica”, *Case Studies in Construction Materials*, vol. 14, June 2021.
- [4] S. K. Singh, P. Rekha and M. Surya, “Utilization of Linz–Donawitz slag from steel industry for waste minimization”, *Journal of Material Cycles and Waste Management*, volume 22, pp.611–627, 2020.
- [5] Web page, compressive strength of concrete block: everything you should know, 12, June 2022 [Assessed at 07 August 2023].
- [6] Web page: Masonry at your Fingertips –Masonry Densities [Assessed at 07. August. 2023].
- [7] Website: The Constructor-2019-2021.“Standard specifications of hollow and solid concrete blocks” [Assessed on 07 August. 2023].
- [8] N. A. Barcza and L. R. Nelson, ‘Technology for the treatment of steel plant dusts’, *World Steel Review*, vol.01, issue 01, November 1990.
- [9] M. A. Alonso, O. R. Suarez, P. Rodriguez, M. Cantarel and J. M. B. Sanchez, ‘Concrete blocks. analysis of UNE, ISO en standards and comparison with other international standards’ *Materials De Construction*, vol. 40 (220) October/November/ December 1990. DOI:<http://doi.org/10.3989/mc.1990.v40.i22>

Economic Analysis of an Inverter and Non-Inverter Type Split Unit Air-Conditioners for Hotel Buildings in Coastal Belt of Sri Lanka (Case Study)

Nuwan Fernando
Department of Building Services Technology
University of Vocational Technology
Sri Lanka

Chamila Sumathiratna
Department of Building Services Technology
University of Vocational Technology
Sri Lanka

Abstract -This study presents an analysis to investigate the life cycle cost between inverter and non-inverter split type air-conditioners for hotel room application in “The Villas ABC” in coastal belt. The selected air conditioners used in this study are 4000BTU inverter and non-inverter type split air conditioner units. The operating cost for each air conditioner was determined from the data provided by the manufacturers as well as the data collected during the study. In this analysis, the life cycle cost of the inverter type split unit air conditioner was compared with same aspect of non-inverter type split unit air conditioner. It is found that an inverter type air conditioner life cycle cost with considering its maintenance cost is Sri Lankan Rupees 5,600,971.00. The percentage of energy saving has dominant effect on life cycle cost followed by the effect of operating hours per day. Inverter type split air conditioner has higher maintenance cost compared with non-inverter type. The life cycle cost calculated including maintenance cost of non-inverter type air conditioner is Sri Lankan Rupees 5,502,425.00. The results of the study show that there is no cost saving for the option of inverter type AC and non-inverter AC has saving of Sri Lankan Rupees 98,546 compared to inverter type split air conditioner with percentage of 2%. During this study it was found that the non-inverter type is more economical to the Hotel “The Villas – ABC” due to the higher maintenance cost. Other than the cost saving the low breakdown rate minimized the additional stress on maintenance staff and the guests were not disappointed.

Keywords—life cycle cost, inverter type air conditioner, repair cost, cost of energy use, maintenance cost

I INTRODUCTION

The coastal belt of Sri Lanka is famous for its scenic beauty among local and foreign tourists. Statistics of Sri Lanka Tourism Development Authority shows that more tourists prefer Boutique Hotel, Boutique Villa, Bungalow, Guest House etc. to star type hotels [1]. The popular air conditioner type for these kind of hotels is split type air conditioners (AC) as they are stand alone equipment easy installation and low cost etc.

There are two types of split type AC machines namely the inverter type and non-inverter type. The inverter type is pronounced for energy saving. It has been proven that 58% of energy could be saved in inverter type split AC [2].

Non inverter technology the compressor starting and stopping, hard running, resting, starting and stopping once again uses more energy to control the temperature inside the room.

Inverter technology uses the speed control of the compressor motor depending on the temperature requirement inside the room. Inverter type AC machines are more popular than non-inverter type as they are powerful, save energy and comfortable [3]. The cost difference of inverter and non inverter AC machines generally around 10% or more for 12000 BTU machine. Despite the fact that the inverter technology AC machines are expensive, people recommend them as, it is economical in terms of energy usage.

The Villa ABC is one of popular villa hotels in Sri Lanka situated in the coastal belt which consists of 32 no's of guest villas each installed with a split type AC machine. A villa is like a private standalone home. This means a villa is completely self-contained with all the facilities and usually more than one building is situated in hotel premises. The most suitable type of air conditioning for this type of hotel building is split unit air conditioners. As per the initial design concept inverter type split AC units were fixed to all villas. In the beginning the inverter type split AC system was economical and with the time it was observed that the rate of break downs were increasing. As it was badly affecting on the guest satisfaction, as a remedial measure, the management has decided to replace inverter type AC units with the non-inverter type AC units. With that decision 15 no's of non-inverter type AC units have been fixed in place of inverter type air conditioners. This study was carried out to select most appropriate AC system from split unit air conditioners of inverter type and non-inverter type for these villa type hotel buildings.

As a practice normally the method used to select a split AC system is the initial cost (IC), the installation cost (INC) and operational cost (OC). But it is required to consider the maintenance cost (MC) as well. This study is to show that when split AC machine is selected it is required to consider the maintenance cost (MC) as well specially for the coastal areas.

In the literature survey hard to find papers relevant to this topic so that there is an indication of there is a research gap in this area of study

The objectives of the study were to determine the energy cost

of inverter and non-inverter type split AC systems of The Villas-ABC, calculate the life cycle cost of split AC systems of the hotel and to compare the difference of lifecycle costs

II METHODOLOGY

Two split AC units, an inverter and a non-inverter were tested. Details of the name plate of the two split units AC are given in Table-01. The two AC units kept under similar operating conditions. Both were rated single-phase 240V, 50Hz. Each unit was mounted on the same side of the wall of hotel rooms and the temperature control settings of the units were set to 24°C. The energy drawn by the two AC units were measured by using energy meters and the data recorded daily for one month period. The non-inverter AC, and the inverter AC was operated continuously during one month study period. Initial installation cost and the maintenance costs of the relevant air conditioners were collected from the accounts details and the maintenance records. The two types of split units used are old by same number of years. There records were available for both inverter and non-inverter type for the past years. The LCC was calculated for the two types of AC units and the cumulative LCC values were given in graphs for twenty months

A Life Cycle Cost (LCC)

Life cycle costing is the process of compiling all costs that the owner or producer of an asset will incur over its lifespan. These costs include the initial investment, future additional investments, and annually recurring costs, minus any salvage value [8]. In this study the salvage value has been considered as zero.

Life Cycle Costs (LCC) consists of five main components Initial Cost (IC), Installation Cost(INC) , Energy cost (EC), repair cost (RC) and maintenance/service cost (MC), maintenance/service cost (MC) where:

$$LCC = IC + INC + EC + RC + MC \quad (01)$$

B Initial Cost (IC)

The IC depends on type and model of the unit as specified by the manufacturer. Common practices in Sri Lanka is to include both in retail sales price

C Energy Cost (EC)

The energy usage (EU) depends on three factors; unit capacity, energy efficiency ratio (EER) and operating time [2]where:

$$EU = (\text{Unit Capacity}) / \text{EER} \times \text{Operating time} \quad (02)$$

Then, the energy cost can be determined if the cost per unit of energy (CUE) is known. Where:

$$EC = EU \times CUE \quad (03)$$

According to Public Utility Commission Sri Lanka, Hotels

of inverter and non-invertor split Air conditioners of this hotel.to identify the most suitable type of split system.

are categorized under “Other consumer category” and the tariff structure was obtained from Public Utilities Commission Sri Lanka .

Since the contribution of other loads except AC machines to the maximum demand charge of the electricity bill are negligible when it is compared with maximum demand charge of thirty two split type AC units. Therefore it can be considered that the energy cost calculated according to this method sufficiently represent the of contribution from AC units under study to the electricity bill.

D Repair Cost (RC)

Normally, the time and cost required for repair work of any type of breakdown and etc. is unpredictable. However, proposed simple correlation between repair costs (RC), IC and unit's life time[2] where;

$$RC = \frac{0.5 \times IC}{\text{Units Life Time}} \quad (04)$$

E Maintenance/Service cost (MC)

To ensure an optimal performance of the air conditioners, manufacturers recommended to perform scheduled maintenances of filter cleaning for every 2 weeks, and chemical cleaning for every 12 to 18 months . [5][2] highlighted that the MC of the air-conditioner is 2.5% of the unit price. Where;

$$MC = 0.025 \times IC \quad (05)$$

TABLE 01

	Invertor Type	Non Invertor Type
Capacity	24000BTU	24000 BTU
Rated Voltage	220V-240V	220V-240V
Frequency	50Hz	50Hz

III CALCULATION OF LIFE CYCLE COST

The equation 01 is used to calculate LCC separately for the two types of AC machines

A Calculation of Cost of Unit of Energy

Calculation was done for the month of February as a sample calculation here.

Electricity Bill Value of the Month = LKR 1,160,296.85

Units Consumed in the Month of February 2023

Day = 16905

Peak = 3915

Off-Peaks = 6311

Total Units Consumed in the Month February 2023

16905+3915+6311 = 27131

Unit Cost for the Month February 2023

CUE is $1,160,296.85 / 27131 = \text{LKR } 42.77$

B Calculation of Cost of Energy

EC was calculated for the month February 2023 by using total power consumption by the AC and the energy tariff published by the PUCSL. To get most accurate EC value, equation 03 was used.

For Inverter type air conditioner,

No of Units consumed by AC = 769.2

Energy cost = $\text{LKR } 42.77 \times 769.2 = \text{LKR } 32,898.68$

For Non-Inverter type air conditioner,

No of Units consumed by AC = 945.6

Energy cost = $\text{LKR } 42.77 \times 945.6 = \text{LKR } 40,443.31$

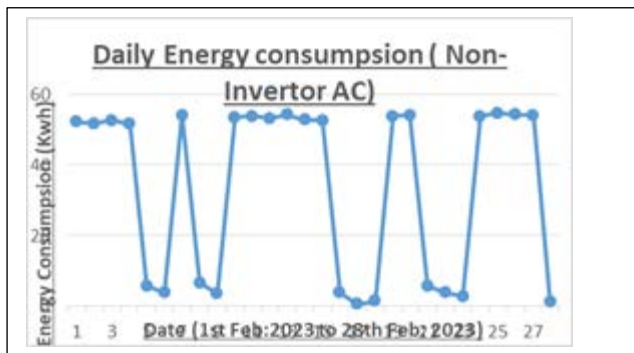
Using collected data for Initial or unit cost (IC), installation cost (INC), repair cost (RC) and maintenance/service cost (MC) and the calculated Energy cost (EC), the total cost for the month was calculated by using equation 01. To get projected values for the cost, the Net Present Value Present Value of Money was calculated by using equation 07.

$$\text{Present Value} = \text{Future Value} \times 1/(1+r)^n \quad (7)$$

here; r = Interest rate (assumed as 10 %) n = Time in years

The time vs. cumulative cost with MC is shown in Figure 01 .

The cumulative LCC discounted values were plotted in Figure 02. It is shown that the two lines are going to meet. The two cost values are going to be same in long run.



IV CALCULATION OF COST SAVING

Saving from inverter type split AC without maintenance cost = $4,510,668.00 - 3,923,487.00 = \text{LKR } 587,181/-$

$$\text{Percentage of Saving} = \frac{(4,510,668.00 - 3,923,487.00)}{3,923,487.00} \times 100 \% = 15 \%$$

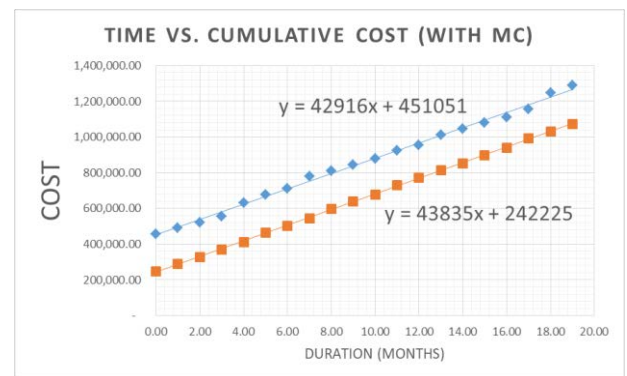
Saving from inverter type split AC with maintenance cost = $5,600,971.00 - 5,502,425.00 = \text{LKR } 98,546 /-$

$$\text{Percentage of Saving with maintenance cost} = \frac{(5,600,971.00 - 5,502,425.00)}{5,502,425.00} \times 100 \% = -02 \%$$

IV RESULTS

The energy output of the energy meters were plotted in Figure 01 and Figure 02 for 28 days of the month of February. With the help of data collected the best fit line was plotted by using Microsoft Excel software, The life cycle cost calculated by using the equation 01 with and without maintenance costs drawn in two graphs in Figure 03 and Figure 04

FIGURE 01: DAILY ENERGY CONSUMPTION INVERTER AC



Cost Saving with inverter type of split air conditioner is -02% whereas saving without inverter type Split air conditioner is 15% for Villa ABC

FIGURE 02: DAILY ENERGY CONSUMPTION INVERTER AC



FIGURE 04: Cumulative LCC with MC

The cumulative LCC discounted values were plotted in Figure 03& Figure 04. It is shown that the two lines are going to meet in Figure04. The two cost values of split AC without inverter and split AC with inverter are going to be same in the long run. The Table 02 shows the LCC values for inverter and non inverter split AC , LCC for 10 years

FIGURE 03: Cumulative LCC with MC

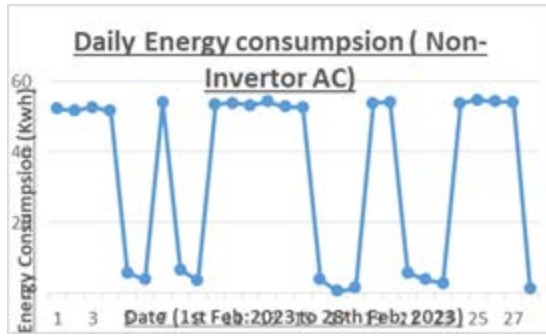


TABLE 02: LCC FOR 10YEARS

Type of AC	Life Cycle Cost (10 years)	Life Cycle Cost (10 years)
Inverter Type	3,923,487.00	5,600,971.00
Non-inverter Type	4,510,668.00	5,502,425.00

V CONCLUSION AND RECOMMENDATIONS

This project was conducted to evaluate the LCC of both inverter and non-inverter type split unit air conditioners of the hotel The Villas ABC. The Life Cycle Cost is the only selection criteria considered in this study. With the help of collected data and data analysis LCC without maintenance cost and LCC with maintenance cost were extrapolated. As per the values the inverter type has 15% saving than the non-inverter air conditioner without considering the maintenance cost. But it has found that the LCC with maintenance cost is higher in inverter type air conditioner. Non-inverter type air conditioners has 2% saving in LCC at the end of 10 year period.

It shows that the maintenance cost is considerably higher in the air conditioners for inverter type used in The Villa ABC in coastal areas. As per the LCC point of view the non-inverter type air conditioners are economical for the hotel The Villas ABC.

REFERENCE

- [1] SLTB, "Progress Report," SLTB, 2022.
- [2] G. T. J. B. A. D. N. K Almutairi, "Life Cycle assessment and economic analysis of residential air conditioning in Saudi Arabia," *Energy and Buildings*, vol. 102, pp. 370-379, 2015.
- [3] O. L. P. L Prez-Lombard, "A review on Buildings Energy Consumption Information," *Energy and Buildings*, vol. 40, pp. 394-398, 2008.
- [4] T. Y. M. A Aktacir, "Life cycle cost analysis for constant

air volume and variable air volume air conditioning systems," *Applied Energy*, vol. 83, pp. 606-627.

- [5] Panasonic, "The perfect energy saving match," 2017. [Online]. Available: http://www.panasonic.com/my/consumer/homeappliances/air-conditioner/single-split-air-conditioner/css13skh-1_5hp.html. [Accessed 2022].
- [6] 2022. [Online]. Available: https://www.daikin.com/air/daikin_techknowledge/benefits/inverter.
- [7] 2022. [Online]. Available: [https://www.daikinsrilanka.com/inverter-technology-0\[3\]](https://www.daikinsrilanka.com/inverter-technology-0[3]).
- [8] 2022. [Online]. Available: <https://www.accountingtools.com/articles/life-cycle-costing.html>.

Investigation of Acceptability of Offshore Sand for the Construction Industry in Sri Lanka

D.M.N.Niranjaya
Department of Construction Technology
University of Vocational Technology,
Ratmalana, Sri Lanka
nuwanniranjaya@gmail.com

A. A. S. U. Gunarathna
Department of Construction Technology
University of Vocational Technology,
Ratmalana, Sri Lanka
shankanigunaratna@yahoo.com

Abstract— The construction industry in Sri Lanka faces a critical challenge in the supply of river sand, for various construction applications. To address this issue, offshore sand has emerged as a potential alternative for river sand in construction. However, despite its abundance in coastal areas, offshore sand's acceptability in the construction industry remains limited due to concerns about its quality and suitability.

This research aims to bridge the gap between public perceptions and the technical suitability of offshore sand. The study identifies the factors influencing the acceptability of offshore sand through a questionnaire survey, expert interviews, and a comprehensive literature review. Experimental investigations concluded that the properties of offshore sand are in accordance with British and Sri Lankan Standards. The results demonstrate that offshore sand meets the required standards for compressive strength, workability, chloride content, shell content, and other impurities, making it a suitable alternative for river sand in construction applications.

Based on the research findings, a set of recommendations was formulated to enhance the acceptance and usage of offshore sand. These recommendations include conducting awareness, updating mix design guidelines to accommodate offshore sand properties, and implementing policy decisions to promote its use in government projects.

Keywords— compressive strength, workability, chlorine, construction material, river sand

I INTRODUCTION

The construction industry plays a critical role in the development and growth of a nation, and the availability of high-quality construction materials is essential for ensuring the durability and longevity of infrastructure projects. In Sri Lanka, river sand has been the traditional choice for fine aggregates in concrete and mortar due to its favourable properties as in many other regions. However, concerns about the environmental impact of excessive sand mining from riverbeds and the depletion of river sand reserves have prompted the exploration of alternative sources.

One such alternative is offshore sand, which is extracted from the seabed. Offshore sand possesses the potential to become a

viable substitute for river sand in the construction industry. However, its acceptability and suitability for various construction purposes have been debated and warrant thorough investigation. This research focuses on exploring the feasibility of using offshore sand as an alternative to river sand, aiming to bridge the gap between public expectations and the actual quality of this alternative construction material.

The primary objectives of this study are two-fold: first, to identify the factors influencing the acceptability of offshore sand in the construction industry in Sri Lanka, and second, to assess the suitability of offshore sand compared to river sand for various construction applications. To achieve these objectives, a multifaceted approach was adopted, literature reviews, qualitative data analysis and laboratory testing.

By the conclusion of this research, it was found that the usage of offshore sand is minimal due to concern with quality, cost, and presence of chlorine and seashells. However, the laboratory experiments prove that the quality of the offshore sand is on par with the acceptable ranges. Hence, the awareness of the industry and society has to be enhanced to increase the acceptability of offshore sand.

II BACKGROUND STUDY/ REVIEW OF LITERATURE

The literature review provided an overview of existing research and studies related to offshore sand, its properties, acceptability, and issues for construction applications. It helped to establish the context and knowledge base for the research, highlighting the gaps and areas where further investigation is needed.

Properties of offshore sand

Mainly the composition or the properties of the offshore sand may depend on the source [1]. Further, the gradation of the offshore sand may not be on par with the required gradation, hence sea sand may process to obtain a mix within the range [2]. However, the mineral composition may have similar properties compared with river sand, but with a different surface texture [2]. Moreover, offshore sand consists of

particles of seashells as well as salt, which can affect the concrete or cement negatively [1].

It was noted that there are contrasting conclusions regarding the workability of concrete produced from offshore sand. Liu et al. have concluded that there are no significant changes in slump with the introduction of offshore sand while Limeira et al. have found the slump decreased with the introduction of offshore sand [1,3]. Further, conflicting findings were observed with the compressive strength of concrete with offshore sand. It was found the compressive strength was decreased by incorporation of offshore sand [4]. Moreover, in other studies, it was found that the change in the strength is not significant [3,5].

Issues identified in using offshore sand

Corrosion and Reinforced Concrete: When the free chlorine (Cl) percentage is higher than 0.3% the reinforcement in the concrete is susceptible to corrosion [6]. However, with accelerated wet-dry cycles, the free Cl can be reduced, and corrosion and pitting can be mitigated [7].

Sea Shells in Concrete Aggregates: Many research has proved that there is no significant impact on compressive strength by the sea shell content in the offshore sand [8,9].

III METHODOLOGY

In the case of a research project, the usual information may be an essential summary of the study design, study setting, study population, sample, sample size, sampling methods, instruments, data collection, data analysis etc. The author shall explain the research question, and describe the research framework, and the methods applied in detail. It should be furthermore highlighted why the research question is relevant to theory and practice, and why the chosen method(s) are suited for the problem.

The following methodology outlines the systematic approach adopted to investigate the acceptability and suitability of offshore sand for the construction industry in Sri Lanka.

The selection of a Sample was conducted for the collection of information from experts, professionals, contractors and society to gather insights from various stakeholders, employing a stratified sampling technique. One sample consisted of one hundred participants, categorized as, fifty participants from public and private organizations and contractors dealing with the Sri Lanka Land Development Corporation (SLLDC), the remaining fifty participants were randomly chosen from the general public to represent society at large. In the laboratory testing of the Engineering Material Laboratory, both river sand and a composite offshore sand sample were taken.

The preparation of the expert interview outline and expert interview were conducted as a vital role in framing the research questions and refining the questionnaire. Several experts and professionals involved in the relevant field were consulted. Subsequently, two distinct sets of questionnaires were formulated. Under that, the first section was designed for the

general public and contractors, focusing on non-technical aspects related to offshore and river sand use, the second section was tailored for experts and professionals, delving into technical matters associated with the use of offshore sand in the construction industry.

For the preparation of questionnaires and collection of information from contractors and society, data from contractors and the general public were collected via questionnaires created using Google Forms. These questionnaires contained both general and technical questions aimed at assessing awareness and opinions regarding offshore sand use.

Two specific tests were conducted using standard methods in Engineering Material Laboratory Testing. The 'Compressive Strength of Concrete Cube' testing followed the guidelines set by BS EN 12390: Part 3:2019 and the ASTM - C143/C standard method was applied for the 'Workability of Concrete' testing. These tests were performed on concrete samples produced using both river sand and offshore sand. The samples were tested at various time intervals, enabling the analysis of compressive strength over time.

Analysis of data was conducted effectively, adopting a multi-faceted approach.

- Text Analysis - Open-ended responses in the questionnaires were subjected to text analysis techniques.
- Descriptive Statistics - Basic data summaries were presented through pie charts, bar charts, and tables.
- Analytical Method (Relative Importance Index - RII) - The RII was used to rank and evaluate factors based on expert opinions and questionnaire responses.

The conclusion and recommendations were drawn based on the findings and analyses from the preceding steps, both in expert interviews and laboratory testing, with a specific focus on how these elements intertwined.

The results were compared with similar studies conducted in Sri Lanka and other countries, taking into account research to provide a broader context for the conclusions and recommendations.

IV RESULTS AND DISCUSSION

An expert interview was conducted to identify the factors and issues affecting the acceptability of offshore sand for the construction industry in Sri Lanka. Recognized experts with substantial knowledge, experience and contributions in fields related to construction materials, environmental impact assessment, civil engineering and similar areas have shared their expertise. Professor Ranjith Dissanayake is a prominent expert in the field of Civil Engineering and construction materials in Sri Lanka. He holds a doctorate in civil engineering and has made significant contributions to the understanding of construction materials and their suitability for various applications, including offshore sand. Further, Dr. Chethika

Gunasiri is an expert in environmental science with a specialization in Sustainability Science. Her expertise in Sustainability Science signifies that she likely has a deep understanding of various aspects related to sustainability, environmental conservation and the intersection of science and sustainable practices. Moreover, experts such as Chartered Engineers and Civil Engineers were consulted for the preparation of the questionnaire.

The questionnaire was compiled with data from experts and professionals which is based on the technical matters related to the offshore and river sand focusing on the following;

- The issues caused by off-shore sand, when used as a fine aggregate
 - Demand for offshore sand in the Sri Lankan market
 - Negative thoughts among people about the use of offshore sand
 - The actions to be taken to reduce that negative mindset of the people
 - The measures to be taken to enhance the use of offshore sand in the construction industry of Sri Lanka
 - Ideas and experience about off-shore sand as a construction material in Sri Lanka

Experts pointed out that when selecting suitable material, they mainly focused on quality. Availability and the cost of the material. The issues noted by the experts are low workability, environmental issues with dredging sand, the presence of seashells and the effect of salts. Further, it was evident that the main issue of the usage of offshore sand in Sri Lanka is the unawareness of the industry on its properties. Moreover, the experts stressed having more standards to improve the quality of offshore sand and to hold workshops to enhance awareness of the usage of offshore sand.

The questionnaire was formulated by considering the factors and data collected through the interview with the experts. The fifty (50) number of persons (Contractors and society) consists of male as 58% and the female as 42%. Half of the selected sample is employed in the private sector and 82% of the sample is engaged in the field of Civil Engineering. Only 24% of the sample considers offshore sand as an alternative to river sand. Further, only 32% use offshore sand for mortar and plastering and only 10% use offshore sand for concrete works.

28.5% of the sample is concerned on Cl content and 30.5% of the sample is concerned with seashell content. Moreover only 18% have the experience with usage of offshore sand in the construction sector. The measure for enhancing the usage of offshore sand is illustrated in figure 3.1.

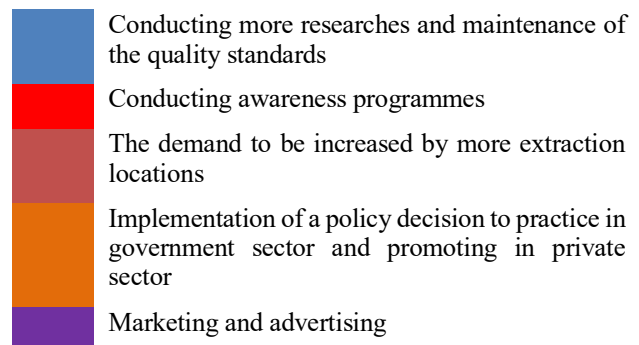
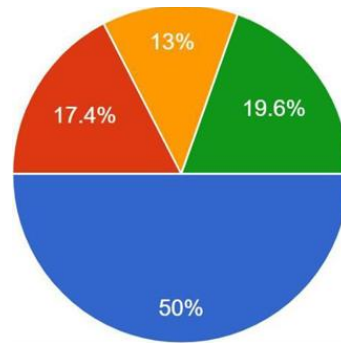


Figure 3.1: Measure for enhancing the usage of offshore sand

TABLE 3.1: CHEMICAL PROPERTIES OF OFFSHORE SAND

Parameter	Test Method	Conclusion
Chloride content for marine aggregate.	BS 1744 – 1: 1998	<0.01 m/m% (Within limits given in SLS 1397. Should be less than 0.01 m/m%)
Acid Soluble Sulphates	BS 1744-1 1998	<0.01 m/m% (Within limits according to SLS 1397. Should be less than 0.2 m/m%)
Total Sulfur Content	BS 1744 - 1: 1998	<0.01m/m% (Within limits according to SLS 1397. Should be less than 1 m/m%)
Shell Content	SLS 1397: 2010	1.9 m/m% (Within limits according to SLS 1397. Should be less than 15 m/m%)

Table 3.1 describes the chemical properties of the offshore sand conducted according to the BS test method. It is evident that all the parameters are within the required SLS standards. Hence, the quality is acceptable to be used in the construction work.

TABLE 3.2: TEST RESULTS OF CHEMICAL PROPERTIES OF OFFSHORE SAND

Parameter	Test method	Test result (Sample 1)
Water soluble chloride (as Cl ⁻), m/m%	BS EN 1744-1	< 0.001
Acid soluble sulphate (as SO ₃), m/m%		< 0.001
Total sulfur content (as S), m/m%		< 0.001
Fine content (SE value), %	BS EN 933-8	4
Shell content		1.9

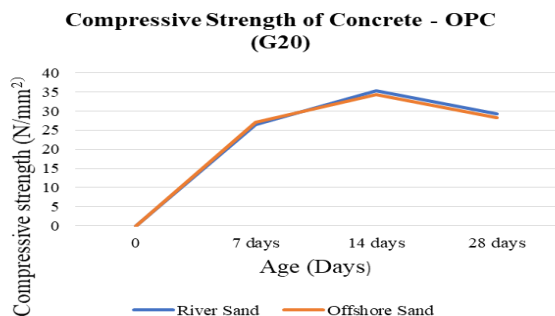


Figure 3.2 Compressive Strength of OPC - Grade 20

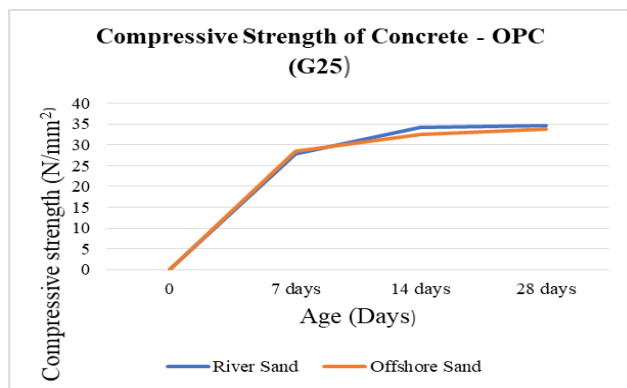


Figure 3.3 Compressive Strength of OPC - Grade 20

Above figures (figure 3.2 and 3.3) shows the compressive strength variation with time for OPC for the grades 20 and 25 respectively. It is evident that the strengths are above the required level after 28 days. Further, no significant difference was observed with the strength variation of the river sand.

Compressive strength variation with time for BHC for grades 20 and 25 are illustrated in Figures 3.4 and 3.5 respectively. The required strength achievement is obtained in both grades

for offshore sand. However, a change of trend in the strength class 20 was observed with respected river sand.

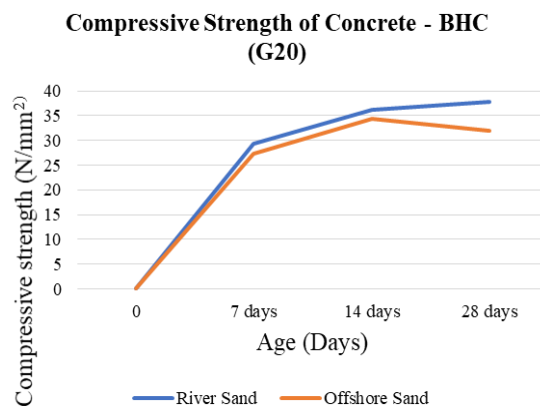


Figure 3.4 Compressive Strength of BHC Grade 20

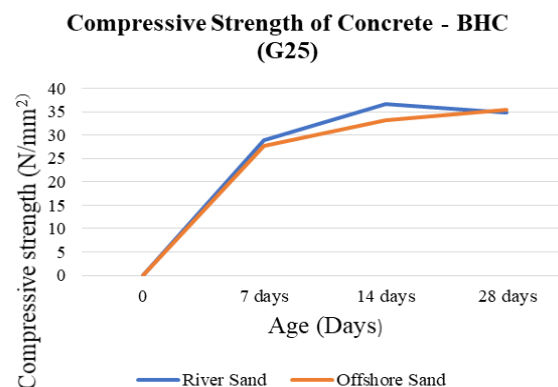


Figure 3.6 Compressive Strength of BHC Grade 25

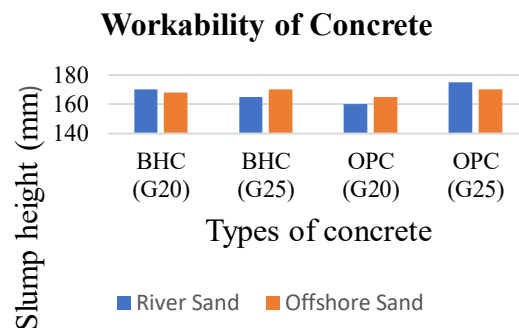


Figure 3.7: Workability of the Concrete Mixes

The workability of the concrete is illustrated in Figure 3.7 and the results are conclusive with the findings of the literature review.

In accordance with the Figure 3.6, the slump test results enhance the understanding of workability with different combinations of cement and sand types, comparing river sand and offshore sand for various cement types (BHC and OPC) with different grades (G20 and G25), providing valuable insights into the workability of concrete.

Comparison by cement type and grade can be stated as follows,

- For BHC (G20), the slump values for river sand (170 mm) and offshore sand (168 mm) are quite similar. This suggests that offshore sand has comparable workability with river sand for this cement type and grade.
- For BHC (G25), the slump value for offshore sand (170 mm) is slightly higher than that of river sand (165 mm). This indicates that, in this case, offshore sand might have slightly better workability.
- In the case of OPC (G20), the slump value for river sand (160 mm) is lower than that for offshore sand (165 mm). Offshore sand seems to exhibit better workability for this particular combination.
- For OPC (G25), both river sand and offshore sand show similar slump values (175 mm and 170 mm, respectively).

V CONCLUSION

The research conducted to investigate the acceptability of offshore sand for the construction industry in Sri Lanka has yielded significant insights and valuable findings. The study aimed to bridge the gap between public expectations and the technical viability of offshore sand as a substitute for river sand in construction projects. Through a combination of survey data, in-depth interviews, laboratory testing, and chemical analysis, a comprehensive analysis was carried out to assess the acceptability and suitability of offshore sand.

Sri Lanka had been facing challenges in the construction industry due to the depletion of river sand resources. Research studies and reports within the country focused on alternative sources of sand, including offshore sand. They were concerned with environmental, economic and technical aspects of using offshore sand. These studies had generally indicated that offshore sand had potential as a substitute for river sand, but concerns remained about its acceptance in the construction industry. Challenges in Sri Lanka are as follows,

- Depletion of river sand due to over-extraction.
- Environmental concerns regarding river sand mining.
- A growing demand for construction materials.

Benefits of offshore sand in Sri Lanka,

- Potential as a substitute for river sand.
- Support to mitigate environmental issues related to river sand mining.
- As an economical alternative.

Internationally, the researches related to the use of offshore sand in construction, aimed to address issues like chloride content, corrosion, workability, and structural performance. Some countries had successfully integrated offshore sand into their construction industry, while others faced acceptance challenges similar to Sri Lanka.

Challenges in Other Countries,

- Managing chloride content and corrosion issues.
- Achieving the right workability and performance.
- Gaining industry acceptance for offshore sand.

Benefits of offshore sand internationally,

- A potential solution to depleting river sand resources.
- Leading to better management of coastal sand resources.
- Providing economic benefits.

The research on 'Investigating the Acceptability of Offshore Sand for the Construction Industry in Sri Lanka' contributes to this body of knowledge by providing specific insights into the acceptability of offshore sand in Sri Lanka's construction industry. It has the potential to provide valuable insights for policymakers and industry stakeholders. Nonetheless, it is essential to conduct further research to bridge the gap between expert opinions and laboratory findings and provide concrete recommendations. By conducting expert interviews and laboratory testing, this study is uniquely positioned to highlight the factors contributing to the acceptability issue and provide recommendations based on data and observations.

Based on the expert interviews and research findings, the comparisons recommendations can be stated as follows. The survey results highlighted a notable discrepancy between public perceptions and the actual quality of offshore sand. Lack of awareness emerged as a major contributing factor to its lower acceptability. However, stakeholders in the construction industry expressed a willingness to consider using offshore sand if its quality could be assured and supported by appropriate government policies.

In-depth interviews with experts provided deeper insights into the challenges faced in adopting offshore sand. Cost considerations and concerns about potential impurities and environmental impact were key factors influencing decision-making. Nevertheless, the interviews also revealed that with proper quality assurance measures, offshore sand could be a viable alternative to river sand.

Laboratory testing of offshore sand samples, including compressive strength and workability tests, demonstrated that concrete mixes incorporating offshore sand exhibited comparable performance to those with river sand. The results suggested that offshore sand can meet the required technical criteria for construction projects, making it a feasible substitute. Chemical analysis of offshore sand samples revealed that they met the permissible limits set by Sri Lankan Standards for construction materials. The low chloride content and minimal presence of impurities ensured that offshore sand adheres to the required quality standards, further supporting its acceptability.

Comparative analysis between different types of offshore sand, such as Blended Hydraulic Cement (BHC) and Ordinary Portland Cement (OPC), showed that both types exhibited similar patterns in terms of compressive strength, workability, and adherence to quality standards. This finding indicated that offshore sand can be effectively used with different cement types in construction projects.

The expert interviews provided insights into the perceptions and opinions of professionals and specialists in the construction industry regarding the use of offshore sand. The data collected from expert interviews helped in understanding the current state of awareness and acceptability of offshore sand within the construction sector in Sri Lanka. The interviews revealed that there is a prevailing skepticism and reluctance to use offshore sand and this was attributed to concerns about the quality of offshore sand compared to river sand, particularly regarding chloride content and its potential impact on corrosion and efflorescence. In parallel, the laboratory testing

conducted on both river sand and offshore sand samples allowed for a direct evaluation of the physical properties and suitability of offshore sand for concrete production. The test results revealed that offshore sand met the standards of SLS 1397: 2010, validating its potential for use in the construction industry. It was particularly significant that the compressive strength of concrete made with offshore sand was comparable to that made with river sand. Furthermore, the workability of concrete using offshore sand was found to be acceptable, indicating its usability in practical construction applications.

The results suggest that the workability of concrete is influenced not only by the type of sand (river or offshore) but also by the type and grade of cement. In some cases, offshore sand appears to perform as well as or even better than river sand in terms of workability. This indicates that the choice of cement type and grade, along with sand source, should be carefully considered in construction projects to optimize workability. To draw more conclusions, it would be beneficial to conduct additional tests and examine the variability in slump values. Consistency in workability across different batches is a critical factor in construction. These results have practical implications for the construction industry in Sri Lanka. Depending on the specific project requirements and the available cement types, Engineers and builders can make informed decisions about whether to use offshore sand or river sand for concrete.

Environmental and Cost Considerations. The study could further investigate whether the improved workability of offshore sand in certain cases might lead to cost savings or environmental benefits, considering that offshore sand is more abundant and less environmentally impactful to extract than river sand.

The synergy between expert interviews and laboratory testing is evident in the conclusions drawn from the research. The expert interviews indicated a lack of awareness and understanding among industry professionals regarding the quality and suitability of offshore sand. However, the laboratory testing provided concrete evidence that offshore sand could meet the required standards for construction materials.

This linkage between expert opinions and scientific data formed the basis for the following recommendations;

- **Educational Initiatives** - To bridge the gap in awareness and understanding, educational initiatives and training programs should be designed and offered to industry professionals. These programs can focus

on the technical properties of offshore sand, its preparation and treatment, and its potential benefits in various construction applications.

- **Promotion of offshore sand usage** - Authorities and industry organizations should actively promote the use of offshore sand by providing case studies and practical examples of successful projects where offshore sand was used. This can help in dispelling misconceptions and building confidence in the construction community.

- **Quality Control measures** - Continuous quality monitoring and control of offshore sand, particularly regarding chloride levels, should be established. Regulations and standards should be developed to ensure that offshore sand used in construction meets specific quality criteria.

- **Research and Development** - Continued research into the use of offshore sand in specialized applications such as Fiber Reinforced Polymer (FRP) reinforcement and Recycled Coarse Aggregate (RCA) incorporation can help address potential concerns and expand the range of applications.

- **Environmental Considerations** - Environmental sustainability should be a key factor in the adoption of offshore sand. Research should focus on assessing the environmental impact and sustainability of offshore sand mining and the effects on coastal ecosystems.

In conclusion, the research has shed light on the potential of offshore sand as a sustainable alternative to river sand in the construction industry. By

addressing concerns, raising awareness, and ensuring quality, the acceptability of offshore sand can be improved, leading to its wider adoption in construction projects. Embracing offshore sand as a viable construction material will not only address the scarcity of river sand but also contribute to more sustainable and eco-friendly construction practices in Sri Lanka.

REFERENCES

- [1] Xiao J, Qiang C, Nanni A, Zhang K. "Use of sea-sand and seawater in concrete construction: Current status and future opportunities". *Construction and Building Materials*. 30;155:1101-11. 2017.
- [2] Limeir J, Agulló L, Etxeberria M. "Dredged marine sand as construction material". *European journal of environmental and civil engineering*. 1;16(8):906-18.2012
- [3] Liu W, Xie YJ, Dong BQ, Xing F. "Study on characteristics of dredged marine sand and the mechanical properties of concrete made with dredged marine sand". *Bulletin of the Chinese ceramic society*;33(1):15-22., 2014
- [4] Girish CG, Tensing D, Priya KL. "Dredged offshore sand as a replacement for fine aggregate in concrete". *International Journal of Engineering Sciences & Emerging Technologies*.;8(3):88-95.2015.
- [5] Chandrakerthy SD. "Suitability of sea sand as a fine aggregate for concrete production".1994
- [6] Dias WP, Seneviratne GA, Nanayakkara SM. "Offshore sand for reinforced concrete. *Construction and Building Materials*". 1;22(7):1377-84.2008.
- [6] Jau WC, Tan JC, Yang CT. "Effect of sea sand on concrete durability and its management". *Journal of Southeast University (Natural Science Edition)*. 2006;36(2):161-6. 2006.
- [8] Chapman GP, Roeder AR. "The effects of sea-shells in concrete aggregates". *Concrete (London)*. 1970.
- [9] Yang EI, Yi ST, Leem YM. "Effect of oyster shell substituted for fine aggregate on concrete characteristics: Part I". *Fundamental properties. Cement and Concrete Research*. 1;35(11):2175-82.2005

Surge Protection Device Monitoring System

R.I Udayanga

Department of Building Services
Technology
University of Vocational Technology
Rathmalana, Sri Lanka
udayangaishan1997@gmail.com

A.R.H.M Rajapaksha

Department of Building Services
Technology
University of Vocational Technology
Rathmalana, Sri Lanka
hansirajaksha126@gmail.com

K.M.P.P Kumara

Department of Building Services
Technology
University of Vocational Technology
Rathmalana, Sri Lanka
pradeepkondhasingha@gmail.com

P.Madhavi Perera

Department of Building Services
Technology
University of Vocational Technology
Rathmalana, Sri Lanka
madhavikdy@gmail.com

Abstract— Surge protection devices are commonly used in street lighting applications to reduce the effects caused by lightning surges. Street lighting systems are highly prone to lightning since they are installed in outdoors. Surge protection devices are used in order to protect street lights from lightning however these devices can fail after being in operation for some time and such devices should be replaced immediately since the street light and the power distribution system will be at a risk. The device contains an indicator which shows the operational status. Since the street lights are installed at a considerable height it is not practically possible to monitor the working status of the surge protection device. This paper describes the development of a IR sensor based system to monitor the status of the surge protection device and when it fails the system will generate a notification. The architecture and design of the system is discussed in detail. The practical challenges were identified while developing the prototype and innovative solutions that were implemented in order to overcome the issues and maintain accurate detection are discussed. The developed prototype was able to successfully identify the surge protection devices and it was verified through testing. The paper also proposes future improvements that is needed to use the system in real life situations since the module may have to installed in adverse outdoor conditions.

Keywords—surge protection device, failure notification, maintenance

INTRODUCTION

Lighting is a natural phenomenon that affects different man made structures all over the world. Street light poles are one such structures that can get easily be damaged by lightning. The lightning poles either can get hit by a direct lightning strike or the power lines connected to the street lights can get induced by a transient voltage due to a lightning strike in

the surrounding environment.

The damages due to lightning on street lights is further increased when they are LED street lights. According to [1] the probability of damage increases even more when considering the global use of LED lights that are more sensitive to surges than previous technologies. [1]Further states that although the statistics are rare, as per the lighting manufacturers, 25% of damages to LED lights are due to surges. Throughout the world, many millions of streetlights illuminate roadways and public space, they are susceptible to damage by overvoltage transients.

LITERATURE REVIEW & PROBLEM IDENTIFICATION

According to [1] the direct protection against surges in any circuit is surge protection devices (SPD) and it has been proved by them through a risk assessment that in most of the cases, for LED street lighting circuits its economical reasonable to install SPD s.

[2] Identifies three locations in which SPDs should be installed. Class I SPD should be installed in the power distribution panel, Class II SPD should be at the power connection terminal at the bottom of the mast and the Class III SPD should be installed at the luminaire.

A first stage (typically a Type 1 or Type 2 SPD) provides robustness, thus diverting most of a spike's energy, while a second stage (typically a Type 2 or Type 3 SPD) provides 'fine' protection. As a result, the peak voltage reaching the equipment always stays below the critical level. [2]

[3] Identifies two connection methods to connect the SPD at the bottom of the mast; in series and in parallel to the load.

In series connection, priority is protection and if an SPD reaches end-of-life, the luminaire is disconnected. Parallel:

Priority is continuity of service, if an SPD reaches end-of-life, visual indication of SPD becomes red but the luminaire remains on. [3]

The same two connections can be used when connecting SPD at the luminaire level. If the SPD is connected in series when the SPD reaches end of life the luminaire will stop working and the maintenance staff will know that SPD has to be changed. However in parallel connection, even after the SPD has reached end of life, the luminaire will still work. The maintenance staff will have to visually inspect the SPD and replace. If a transient voltage appears in the line before the SPD is replaced the luminaire has a risk of getting destructed. This problem is particularly a problem in the case of the SPD installed in the luminaire since it is not practical to conduct routine visual inspection.

Therefore a system is proposed to monitor the status of the SPD and notify the maintenance team regarding the failed SPD. With necessary space and installation modifications this system can be used in all three palace suggested by [2].

SYSTEM DESIGN



Fig. 1. Prototype Developed.

The system designed monitors the condition of the SPD,. As soon as the system detects a fault in the SPD, a text message is generated and sent to the predetermined number Further indicator LED in the unit is switched on to indicate that the SPD has failed.

A prototype was developed with the control unit , sensing unit, and notification unit as shown in Fig. 1.

The developed system consists of Arduino Uno R3, SIM-800L GSM Module, TCRT5000 Infrared sensor, LM2596 DC-Buck

Converter step down power module, DC power supply, 2 LED bulb, 470ohm resistor, and Barrel Jack port. The block diagram of the system designed is illustrated in Fig

Arduino Uno R3 module is used as the central controller of the system and SIM-800L GSM Module is used for the communication through GSM network and send notification regarding the SPD has failed.

As mentioned in the literature review when SPD is failed an indicator on the SPD becomes red. An IR sensor is used to detect this and IR sensor provides the input to the system that SPD has failed. Fig 3 illustrates the basic flow chart of the system.

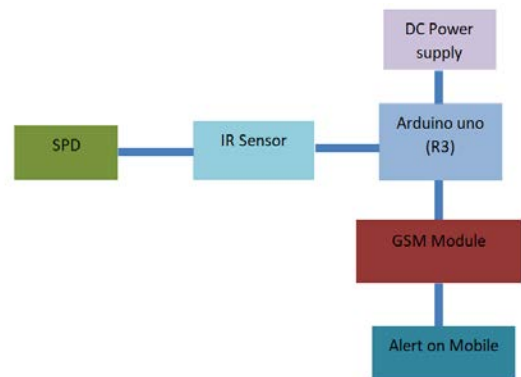


Fig. 2. Block Diagram of the System

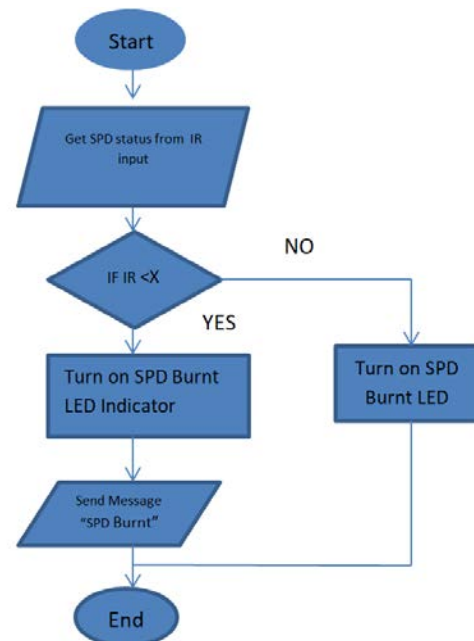


Fig. 3. Flow chart of the System

The TCRT5000 IR sensor was used for this design. When SPD is in working condition the indicator is green and when it fails the indicator would turn red. The IR sensor I designed to

identify black and white, however after few experiments we were able to find a difference in the analog output when the indicator changes to red and it was utilized to differentiate red and green.

Before using the IR sensor for this detection few other options were tested for this purpose. Colour sensor was used as an option but it was noted that colour sensor requires visible light for the detection. However when such system is mounted on a SPD that is installed inside a LED streetlight or a panel board in visible light level will be very low.

As a solution a colour sensor with white LED was used. However this was also not successful, since the light level on the indicator varied in different situations which affected the accuracy of the colour sensor.

Finally IR sensor was selected as the most practical and accurate method for detection of the indicator of SPD. The IR sensor gave a constant output every time the indicator changed to RED and hence IR sensor was identified as the most suitable sensor for the purpose.

SPECIAL DESIGN CONSIDERATIONS

The alignment of the IR sensor is important in order to accurately detect the colour of the PSD indicator. Therefore a special mounting accessory was develop to fix the IR sensor to the SPD and it is indicated in the Fig 4.

The other significant factor of this system is that it is battery operated and do not depend on the power of the LED street light or panel board it is installed in. Therefore even if the LED street lights are not switched on during the daytime still the system would work if the SPD fails due to a lightning strike.



Fig. 4. IR sensor mounting accessory

RESULTS AND DISCUSSION

The developed system was able to accurately detect the failure of the SPD and hence it was concluded that the accuracy of the detection is acceptable. The system designed was developed as a prototype and redesigning of the ` will be required in order to make the system compatible to be installed near a street light or a feeder panel as applicable. In such situation weatherproofing the system may be required.

Further the notification component can be further developed by integrating with a web application where the maintenance staff can see the locations of defective SPDs on the map so that they can plan the maintenance work effectively.

With these future improvements this system can be further improved and used in real applications in order to provide a reliable protection from SPDs for street lighting equipment.

REFERENCES

- [1] A. Rousseau and M. Guthrie, "Lightning Risk Assessment for Street Lighting Systems.," in *34th International Conference on Lightning Protection (ICLP)*, Rzeszow, Poland, 2018.
- [2] Philips Lighting Holding B.V., "The Challenges of Surge Protection," 2019.
- [3] Mersen Electrical Power, "Funndamenntals annnd Solutions for Street & Road Lightinng," [Online]. Available: <https://thehea.org.uk/hea-content/uploads/2019/11/Tofco-CPP-Ltd-MERSEN-2019.pdf>. [Accessed 10 August 2023].

CRACK INVESTIGATION AND PROPOSING REMEDIES : A CASE STUDY IN “JEEWAKA” HOSTEL, BORELLA

G.H.S.Jayangani

Department of Construction Technology
The University of Vocational Technology
Rathmalana, Sri Lanka
sandarekha94@gmail.com

Kasun Nandapala

Department of Construction Technology
The University of Vocational Technology
Rathmalana, Sri Lanka
kasuncn@gmail.com

Abstract—This paper discusses the crack investigation and the proposed corrective and preventive measures for the newly constructed 3-story building named “Jeewaka” hostel in Borella. The building was found to have many cracks, including thermal cracks in the joints between the masonry wall and the RCC (Reinforced Cement Concrete) columns and beams, and shrinkage cracks below the window openings. This paper outlines the type of crack and the cause and suggests preventive and corrective measures to improve building safety and usability. Causes, corrective measures, and preventive measures were taken from expert interviews and analysed using the Delphi technique. According to the findings, it is strongly recommended to provide a chicken wire mesh between the RCC and the masonry joint before starting plaster work. In addition, expansion and construction joints are recommended as good practises. Furthermore, the findings reveal that most cracks under the windows are shrinkage cracks, and it can be recommended to have preventive measures such as providing the sill beam, avoiding the use of rich cement mortar in masonry and by delaying plaster work until the masonry has dried after proper curing.

Index Terms—Thermal cracks, Shrinkage cracks, Structural cracks, Non-structural cracks, Delphi technique, Epoxy grouting

I. INTRODUCTION

Cracks are a common problem in buildings that can be caused by poor workmanship, faulty construction, age, and natural and environmental causes. They can take various forms, including uniform or varying widths, straight, toothed, stepped, map pattern, or random, and can be found in vertical, horizontal, or diagonal orientations [1]. Cracks may be only at the surface or may extend to multiple layers of materials. Although cracks are subjective, they can indicate a serious defect that could affect the stability and serviceability of the building [2]. Building serviceability is the ability of a building to meet the needs of its users in terms of safety, comfort, and functionality. Cracks in a building can impact its serviceability in a number of ways [3]. They can:

- Allow water to enter the building, which can cause damage to the structure and its contents.
- Allow pests and vermin to enter the building.
- Compromise the structural integrity of the building.

- Make the building unattractive and uncomfortable to live or work in.

For these reasons, it is important to repair cracks in a building as soon as possible. The type of repair that is needed will depend on the severity of the crack and the underlying cause of the crack. In some cases, a simple repair with joint compound may be sufficient. In other cases, more extensive repairs may be required, such as injecting the crack with a sealant or reinforcing the structure with steel rods.

The importance of crack repair in a building cannot be overstated. By promptly repairing cracks, building owners can help to ensure the safety, comfort, and functionality of their buildings for years to come.

“Jeewaka” hostel, a newly constructed three-storey building in Borella, provides hostel facilities for students of the Colombo medical college. However, cracks have been visually detected in several locations of the building, including walls, joints between walls and columns, and wall-beam joints, as well as near the corners of the door and window frames. After two years of service, the appearance of cracks seems to have worsened, potentially causing damage to the building. Nevertheless, the building is a valuable resource for the Colombo medical faculty students, and it is important to protect it to extend its usefulness. The study aims to provide technical solutions to protect the building before it deteriorates further. Cracks may vary from very thin hairline cracks with a width of about 0.01 mm to cracks with a width of more than 5mm. Depending on the width of the crack, the classification is as follows.

- Thin cracks – crack width is less than 1mm.
- Medium cracks – crack width is between 1mm and 2mm.
- Wide cracks – crack width is greater than 2mm [1]

The cracks can be classified according to the direction of propagation such as,

- Vertical
- Horizontal
- Diagonal [4]
- Straight

- Toothed
- Variable and Irregular [5]

Cracks are found to be divided into two main categories as structural cracks and nonstructural cracks [6]. Structural cracks occur due to reasons such as incorrect design, improper construction, or overload. Non-structural cracks do not have a direct influence on structural weakening of the structures. [7] Non- structural cracks occur because of excessive internal forces developed in the material due to the effects of gas, water content, temperature variation, moisture variation , chemical reactions, etc.

In addition to the above types, the main types of cracks in the building can be categorised depending on the causes of the crack [6]. They are,

- Thermal cracks
- Elastic Deformation
- Shrinkage
- Creep
- Chemical reaction
- Foundation movement and settlement of soil
- Cracks due to vegetation.

There are many methods and techniques that can be used to repair cracks as follows [8].

- Surface Filling Method
- Cementitious Grouting Method
- Epoxy Resin Grout
- Crack Stitching.

II. OBJECTIVES

The objectives of this study can be listed below.

- To identify the crack types in the “Jeevaka hostel”.
- To identify the causes of the identified cracks.
- To propose the preventive measures and corrective measures for the cracks.

III. METHODOLOGY

Cracks in the buildings were identified by a reconnaissance Survey. In the process, the building inspection was performed to diagnose the cracks in the building, by looking at the entire building from a distance, walking around the building, and inspecting each room to identify the type of crack, measuring each crack in detail and their position in the building. Photographed the cracks and identified the crack type based on shape, and cause through visual identification and knowledge gained by literature review. The fig.1 represent the clear methodology flow chart throughout the case study carried out.

The identified crack types were summarised and a questionnaire was prepared to interview experts in the relevant field of structural engineering to identify the causes, corrective measures and preventive measures of cracks in the identified places. Qualitative data collected by interviewing was analysed using the Delphi technique and Fig.2 shows the methodology of the Delphi technique carried out.

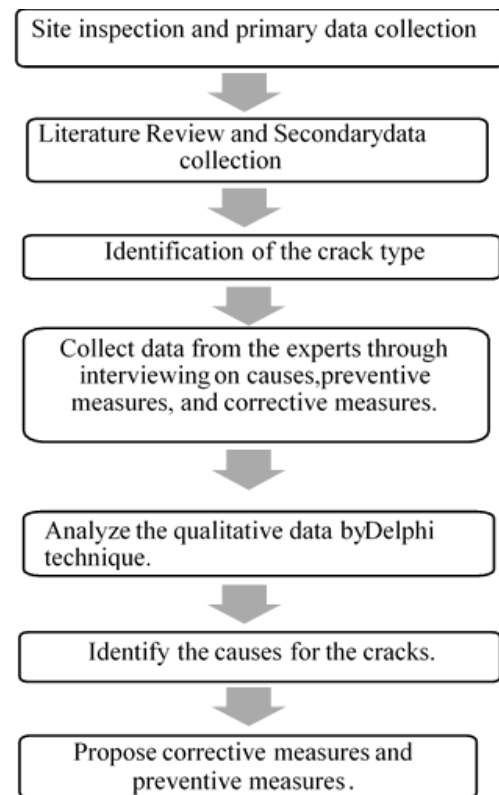


Fig. 1. Methodology flow chart

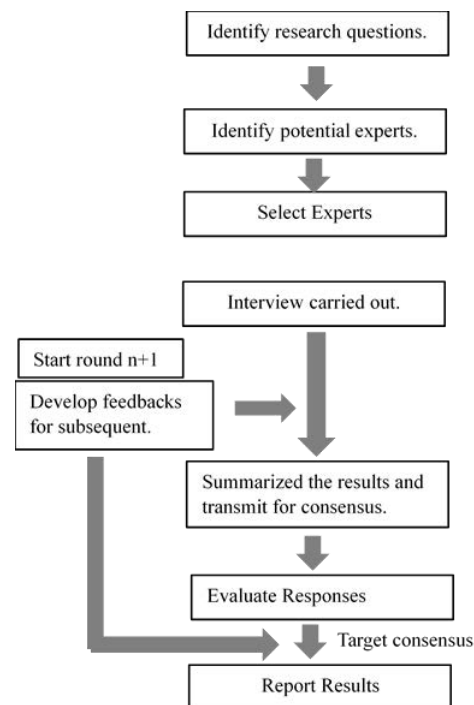


Fig. 2. Carried out Delphi technique



Fig. 3. Ground floor cracks



Fig. 4. First floor cracks

IV. DATA COLLECTION AND ANALYSIS

To achieve these objectives, it is very important to understand the appearance of the building and the locations in which the cracks appeared. Therefore, the cracks were photographed and the floor plans were drawn by numbering the cracks during site inspections. The collected photographs and summarised details are properly arranged and the ground floor crack data are represented by Fig.3 and TABLE I, the first floor crack data are represented by Fig.4 and TABLE II and Fig.5 and TABLE III represent the second floor crack data.

Identification of crack types

According to the above data, it is identified that mainly 3 types of cracks were found in the Jeewaka hostel. They are,

- Vertical cracks at the joint of masonry wall and RCC columns.
- Horizontal cracks in the joints of the masonry wall and RCC beams.
- Diagonal and vertical cracks below the window opening.

According to the literature, it can be classified the crack types with relevance to their causes. Therefore, vertical cracks in



Fig. 5. Second floor cracks

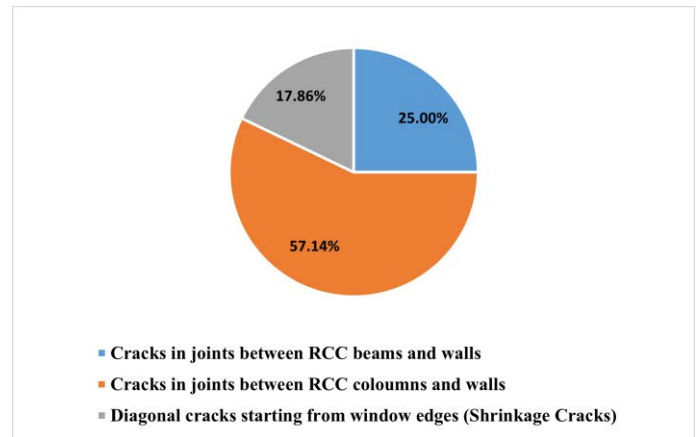


Fig. 6. Crack distribution within the building

the joints of the masonry wall and the RCC columns are thermal cracks. Horizontal cracks in the joints of the masonry wall and RCC beams are also thermal cracks. Diagonal and vertical cracks below window openings are shrinkage cracks. [2] According to the crack classification based on the width of the cracks and based on the primary data collected, all cracks can be classified as 'thin cracks'.

The figure 6 illustrates the summary of crack types within the building and, accordingly, the majority is represented by the cracks between RCC columns and walls, it is 57.14% in percentage.

Identification of causes, preventive measures, and corrective measures for the cracks.

Causes, preventive measures, and corrective measures for the identified crack types were identified by interviewing five structural engineers who are experts in the relative fields. The interviewed questions are as follows in order to carry out the

TABLE I
GROUND FLOOR CRACK DATA

Crack No.	External/ Internal	Crack Type	Structural/Non structural	Width	Location/Description
C1	External	Vertical	Non-Structural	Less than 1mm	Crack in the wall starting from window sill level to down
C2	External	Diagonal	Non-Structural	-do-	-do-
C3	External	Vertical	Non-Structural	-do-	-do-
C4	External	Vertical	Non-Structural	-do-	-do-
C5	External	Vertical	Non-Structural	-do-	-do-
C6	Internal	Horizontal	Non-Structural	-do-	Crack in the wall at the joint of beam and wall
C7	Internal	Horizontal	Non-Structural	-do-	-do-
C8	Internal	Horizontal	Non-Structural	-do-	-do-
C9	Internal	Horizontal	Non-Structural	-do-	-do-
C10	Internal	Vertical	Non-Structural	-do-	Crack in the wall at the joint of the column and the wall
C11	Internal	Vertical	Non-Structural	-do-	-do-
C12	Internal	Vertical	Non-Structural	-do-	-do-
C13	Internal	Vertical	Non-Structural	-do-	-do-
C14	Internal	Vertical	Non-Structural	-do-	-do-
C15	Internal	Vertical	Non-Structural	-do-	-do-
C16	Internal	Vertical	Non-Structural	-do-	-do-
C17	Internal	Vertical	Non-Structural	-do-	-do-

TABLE II
FIRST FLOOR CRACK DATA

Crack No.	External/ Internal	Crack Type	Structural/Non structural	Width	Location/Description
C18	External	Diagonal	Non-Structural	Less than 1mm	Crack in the wall starting from window sill level to down
C19	External	Diagonal	Non-Structural	-do-	-do-
C20	External	Diagonal	Non-Structural	-do-	-do-
C21	External	Diagonal	Non-Structural	-do-	-do-
C22	External	Horizontal	Non-Structural	-do-	Crack in the wall at the joint of beam and wall
C23	Internal	Horizontal	Non-Structural	-do-	-do-
C24	Internal	Horizontal	Non-Structural	-do-	-do-
C25	Internal	Horizontal	Non-Structural	-do-	-do-
C26	Internal	Horizontal	Non-Structural	-do-	-do-
C27	Internal	Horizontal	Non-Structural	-do-	-do-
C28	Internal	Vertical	Non-Structural	-do-	Crack in the wall at the joint of Column and wall
C29	Internal	Vertical	Non-Structural	-do-	-do-
C30	Internal	Vertical	Non-Structural	-do-	-do-
C31	Internal	Vertical	Non-Structural	-do-	-do-
C32	Internal	Vertical	Non-Structural	-do-	-do-
C33	Internal	Vertical	Non-Structural	-do-	-do-
C34	Internal	Vertical	Non-Structural	-do-	-do-
C34	Internal	Vertical	Non-Structural	-do-	-do-
C34	Internal	Vertical	Non-Structural	-do-	-do-
C35	Internal	Vertical	Non-Structural	-do-	-do-

Delphi technique.

- 1) What is the cause of thermal cracking at the joint of column and wall?
- 2) What can do as preventive measures for such type of cracking in future works?
- 3) What can be done as corrective measures for thermal cracking at the joint of the column and the wall?
- 4) What is the cause of thermal cracking at the joint of beam and wall?
- 5) What can be done as preventive measures for such type cracks in future works?
- 6) What can be done as corrective measures for cracking at the joints of beams and walls?
- 7) What caused the cracking of the shrinkage in the walls below the window opening?
- 8) What can be done as preventive measures for such type of cracking in future works?

- 9) What can be done as corrective measures for shrinkage cracking in the walls below the window opening?

The Delphi technique was carried out in 3 rounds.

Round 1 The first questionnaire that was sent to the panel of experts asked for a list of opinions that included experiences and judgments, a list of predictions and a list of recommended activities.

Round 2 As per the above collected data causes, preventive measures and corrective measures were summarised and presented for the second round of interviewing to take their agreements and disagreements. Experts were free to provide their consensus or more views on the summary that was generated by the data taken from round one.

Round 3 The summary of round 2 was provided for experts to make their consensus as agree (1), nominal (0) and disagree (-1) by rated the decisions taken in round 2. Then analysed the final output using SPSS software descriptive analysis

TABLE III
SECOND FLOOR CRACK DATA

Crack No.	External/ Internal	Crack Type	Structural/Non structural	Width	Location/Description
C36	External	Vertical	Non-Structural	Less than 1mm	Crack in the wall at the joint of Column and wall
C37	External	Vertical	Non-Structural	-do-	-do-
C38	External	Vertical	Non-Structural	-do-	-do-
C39	External	Vertical	Non-Structural	-do-	-do-
C40	External	Vertical	Non-Structural	-do-	-do-
C41	External	Vertical	Non-Structural	-do-	-do-
C42	External	Vertical	Non-Structural	-do-	-do-
C43	External	Vertical	Non-Structural	-do-	-do-
C44	External	Vertical	Non-Structural	-do-	-do-
C45	External	Vertical	Non-Structural	-do-	-do-
C46	External	Vertical	Non-Structural	-do-	-do-
C47	External	Vertical	Non-Structural	-do-	-do-
C48	Internal	Vertical	Non-Structural	-do-	-do-
C49	Internal	Vertical	Non-Structural	-do-	-do-
C50	Internal	Vertical	Non-Structural	-do-	-do-
C51	Internal	Vertical	Non-Structural	-do-	-do-
C52	Internal	Horizontal	Non-Structural	-do-	Crack in the wall at the joint of beam and wall
C53	Internal	Horizontal	Non-Structural	-do-	-do-
C54	Internal	Horizontal	Non-Structural	-do-	-do-
C55	Internal	Horizontal	Non-Structural	-do-	-do-
C56	Internal	Diagonal	Non-Structural	-do-	Crack in the wall starting from windowsill level to down

frequency charts.

The causes for the identified Thermal cracks between RCC column and masonry wall was,

- Thermal variation causes the expansion and contraction between two different construction materials with two thermal coefficients and due to not providing adequate reinforcement for expansion between the joint, both had 80% consensus in frequency.

The causes for the identified Thermal cracks between RCC beam and masonry wall was,

- Thermal variation causes the expansion and contraction between two different construction materials with two thermal coefficients and due to not providing expansion joints, which both had 100% consensus in frequency.

The causes for the identified shrinkage cracks below the window openings was,

- Concrete shrinks begin to crack due to not providing a sill beam which had 100% consensus in frequency.

The preventive measures for the thermal cracks between RCC column and masonry wall was,

- Chicken wire mesh should be fixed between RCC and masonry joint before commencing plaster work (Chicken wire mesh of 300 mm width should be fixed along the full joint length with nails.) which had 80% consensus in frequency.

The preventive measures for the thermal cracks between RCC beam and masonry wall was,

- Introduced expansion joints and prior to the plastering and fixed a chicken wire mesh between RCC beam and masonry joint which had 80% and 100% consensus in frequency respectively.

The preventive measures for the identified shrinkage cracks below the window openings was,

- Provide a sill beam and application of sound construction practices which had 80% and 100% consensus in frequency respectively.

The corrective measures for the thermal cracks between RCC column and masonry wall and RCC beam, and masonry wall was,

- Epoxy grouting which had 80% consensus in frequency.

The corrective measures for the shrinkage cracks below the window openings was,

- Use fiber mesh with a sealant and plaster on top of that and use of high-pressure flexible polyurethane which had 100% consensus in frequency.

V. CONCLUSION

The potential causes of crack can be controlled if proper consideration is given to the construction material and techniques used. Based on this study, using the Delphi technique, it is focused on the main causes of cracks in “Jeewaka” hostel and to propose preventive and corrective measures for the identified cracks. The Delphi technique was carried out in 3 expert rounds to take the final output, and analysis was done using SPSS software descriptive analysis frequency tables.

According to the findings, the cracks in the building could be classified into 3 types. They are thermal cracks at the joint of the RCC column and the masonry wall, thermal cracks between the RCC beam and the masonry wall, and shrinkage cracks below the window openings. Ground floor C1-C5, first floor C18-C21, and third floor C56 occurred due to shrinkage and improper construction practises. The corrective measure is to use fibre mesh with a sealant and plaster on top, and high-pressure flexible polyurethane can also be used. The preventive measure for the above-mentioned crack is providing a sill beam down to the windows and following

TABLE IV
CRACK DATA SUMMARY

Crack no	Description	Crack type	Cause	Corrective measure	Preventive measure
C1-C5, C18-C21, C56	Vertical and Diagonal cracks below the window openings	Shrinkage cracks	Concrete shrinks begin to crack due to not providing a sill beam and bad workmanship.	Use fiber mesh with a sealant and plaster on top of that and high-pressure flexible polyurethane also can be used.	providing a sill beam down to the windows and following, sound construction practices.
C10-C17, C28-C35, C36-C51	Cracks at the junction between RCC column and masonry wall	Thermal cracks	Thermal variation causes the expansion and contraction between two different construction materials with two thermal coefficients and due to not providing expansion joints and bad workmanship.	Epoxy grouting	Chicken wire mesh should be fixed between RCC and masonry joint before commencing plaster work (Chicken wire mesh of 300 mm width should be fixed along the full joint length with nails.)
C6-C9, C22-C27, C52-C55	Cracks at the junction between RCC beam and masonry wall	Thermal cracks	Thermal variation causes the expansion and contraction between two different construction materials with two thermal coefficients and due to not providing expansion joints,	Epoxy grouting	Introduced expansion joints prior to the plastering and fixed a chicken wire mesh between RCC beam and masonry joint

sound construction practises. The ground floor cracks C10-C17, the first floor cracks C28-C35, and the second floor cracks C36-C51 occurred due to thermal variation that causes expansion and contraction between two different construction materials with two thermal coefficients and due to the insufficient reinforcement for expansion in the joints. The preventive measure suggested was that chicken wire mesh should be fixed between RCC and the masonry joint before beginning plaster work (Chicken wire mesh of 300 mm width should be fixed along the full length of the joint with nainails). The corrective measure was epoxy grouting the cracks. The thermal variation of the ground floor cracks C6-C9, the first floor cracks C22-C27 and the second floor expansion and contraction between two different construction materials with two thermal coefficients and due to the inability to provide expansion joints, The suggested preventive measure was introduced expansion joints to plastering and fixed a chicken wire mesh between the RCC beam and the masonry joint. The corrective measure was epoxy grouting the cracks. If we were able to take their preventive measures at the start, we will minimise the cracking problem in the hostel. Therefore, the corrective measures for the cracks were proposed, grouting techniques were proposed to minimise them and propose preventive measures to prevent the crack not occurring again in future construction works. The summary of the final output is illustrated in the Table IV.

VI. RECOMMENDATION

There are many types of cracks that can be seen in buildings, and specified corrective and preventive measures are available for them. According to the findings of this project work, it is recommended to have preventive measures for thermal cracks in the joints between the RCC column and the masonry wall, provided that chicken wire mesh should be fixed between the RCC and the masonry joint before beginning plaster work. Chicken wire mesh 300mm wide should be

fixed along the full length of the joint with nails. And for the corrective measures, can recommended grouting methods and epoxy injection, stitching, gravity filling, routing and sealing. Preventive measures for thermal cracks at the joint between the RCC beam and the masonry wall can be recommended, such as introduced slip joints, expansion, and construction joints between them and the joints should be designed at the time of planning and should be constructed carefully. Prior to the plastering, a chicken wire mesh was fixed between the RCC beam and the masonry joint. According to the findings, corrective measures can be recommended as grouting methods, epoxy injection, stitching, gravity filling, routing and sealing. The findings reveal that most of the cracks under the windows are shrinkage cracks and it can recommend having preventive measures such as providing a sill beam, avoiding the use of rich cement mortar in masonry and by delaying plaster work until masonry has dried after proper curing. Masonry work carried out with composite cement-lime-sand mortars (1:1:6, 1:2:9, or 1:3:12), which are weak, will have a lesser tendency to develop cracks. It is due to the accommodation of shrinkage in weak mortar of the individual masonry unit. As corrective measures, it can recommended use fibre mesh with a sealant and plaster on top of that.

REFERENCES

- [1] K. Kunal and N. Killemsetty, "Study on control of cracks in a Structure through Visual Identification and Inspection," *IOSR Journal of Mechanical and Civil Engineering*, vol. 11, no. 5, pp. 64–72, 2014.
- [2] CAMTECH/Gwalior, "CRACKS IN BUILDINGS (Causes and Prevention)," 2004.
- [3] T. Ercio, S. Hipo'lito, R. Humberto, M. John, S. Jose' M., C. Ma'rcio, P. Oscar, L. Paulo B., V. Romeu S., and S. Rui, "Defects in masonry walls - Guidance on cracking: Identification, Prevention and Repair," no. November, 2006.
- [4] R. Pathak and D. Rastogi, "Case Study on Cracks in Public Buildings and their Remedies," *International Journal of Science and Research*, vol. 6, no. 5, pp. 2319–7064, 2015.

- [5] S. Doshi, "Methodology for Prevention and Repair of Cracks in Building," *Global Research and Development Journal for Engineering*, vol. 3, no. 3, pp. 52–58, 2018.
- [6] C. J. Chitte, "Study on Causes and Prevention of Cracks in Building," *International Journal for Research in Applied Science and Engineering Technology*, vol. 6, no. 3, pp. 453–461, 2018.
- [7] B. Das, K. Umnag, and G. Murthy, "Study on causes of cracks and its preventive measures in concrete structures of CCEM building, Raipur," *International Journal of Architecture and Planning*, vol. 1, no. 1, pp. 30–36, 2021.
- [8] A. Verma, D. Yadav, and K. Tiwari, "STUDY , PREVENTION AND REPAIR OF CRACKS IN BUILDING," vol. 1, no. Ii, pp. 104–110, 2022.

Identifying Issues Related to Domestic Plumbing, Corrective and Preventive Measures :A Case Study

K.A.D.S. Karunaratna

*Department of Construction Technology
The University of Vocational Technology, Ratmalana.
Colombo, Sri Lanka
dushansuresh90@gmail.com*

Kasun Nandapala

*Department of Construction Technology
The University of Vocational Technology, Ratmalana.
Colombo, Sri Lanka
kasuncn@gmail.com*

Abstract—Plumbing-related issues (Blockages, Leakages, and damages etc.) after construction are common in any type of buildings. Mostly it leads to damage the building structure, water waste, safety issues of users and as unexpected high maintenance cost etc. This study focuses on proposing corrective and preventive measures for common issues in plumbing and sanitary related. As a case study, three site locations that have plumbing problems have been selected in the Western South Department of Buildings, Survey Department, and Foreign Ministry Quarters. The most common issues have been identified by a technical inspection in the above three locations and using the analysis of financial cost usage for past 5 years of time. The main issues highlighted are leaks and damage to pipe fittings, pipes, sanitary fittings, and blockages in waste lines. It was established through a questionnaire that problems with most caused by poor maintenance. Then, corrective and preventive measures have been identified for these issues. Corrective measures have been proposed to repair, replace, and clean chemical blockages. As preventive measures, implementation of planned maintenance mechanism and facilitation of training for plumbers is recommended. Finally, it is recommended to focus more on preventive measures rather than corrective measures to minimise problems and reduce expenses.

Index Terms—plumbing, sanitary fittings, leakages, blockages, relative importance index value

I. INTRODUCTION

Common issues occurring with plumbing (pipe lines, fittings and sanitary fittings) in bath rooms are common problems in buildings. It is vital to provide effective solutions to the problems because we need to minimise water wastage, as we use the same drinking quality water in bathrooms, except for rain or treated water in Sri Lanka, and to avoid damage to the structure of the building and the interior of the buildings [1].

The aim of any construction project is to deliver a successful quality product or service to the client for as long as possible. In that context, the main possible causes of deviating from the aim qualities arise by arising common issues with pipe lines, fittings and sanitary fittings mainly in bathrooms within a very short time after handing over the project [2].

Relevant to this matter, different key main areas were identified as closely focused, such as blocking, leaking, low water pressure, and poor use of pipes and fittings [3]. By collecting data, with a determination of the related problems

and reasons, preventive and corrective measures could be introduced and scientifically proposed [4].

In the field, when building or maintaining projects, public and private buildings, houses, apartments, quarters, etc. the main area that can be pointed out is the regular encounter of problems and maintenance related to plumbing problems.

A technical inspection performed has identified common problems in the relevant area and has identified feather and relative plumbing problems by considering the most effective samples from the selected buildings.

When attending and identifying some problems, it was directly relevant to the faults of the clients, consultants, or contractors when doing the construction. If anything related to the prevention method identified during the construction stage, it better to attend to those rather than maintaining time to time after the construction, and has been identified as of the preventive measures for all three main parties to lock for in the study. It has covered selected specified areas under these identifications of issues. The preventive and corrective measures have been listed by summarising them under a particular major category, as has also been carried out in previous literature [5].

II. OBJECTIVES

The main objective of this study is to identify the most common problems with pipelines, pipe fittings, and sanitary fittings in bathrooms. Furthermore, it is intended to introduce effective preventive and corrective measures for these common issues.

III. METHODOLOGY

A. Overall Methodology

Three low-rise government quarters domestic type buildings that have raised the highest number of plumbing-related issues have been selected for the study. The three buildings are;

- The quarters of Survey Department, 150, Bernard soysa Mawatha, Colombo 05
- The quarters of Foreign Ministry, A/1/2, Colombo 05
- The quarters of Department of Buildings, 213, Torrington Avenue, Colombo 07

Initially, a visual site inspection survey was conducted of these buildings to identify the plumbing-related issues of the

TABLE I
DETAIL OF SELECTED OF LOCATIONS

Category	Quarters of Survey Dept.	Quarters of Foreign Ministry	Quarters of DoB
Location	Separately Unit	Inside of a Housing complex	Attached to the Office Building
Located Elevation(from G.L)	6 meters	3 meters	6 Meters
Floor area (m2)	750 Sq.ft	900 Sq.ft	1050 Sq.ft
Distance to O.H Tank	5 Meters	10 Meters	4 Meters
Category of Users	Residential Use for Max.5 Years per each users	-Do-	-Do-
Approx.Age of the Building	40 Years	25 Years	15 Years

^a

selected buildings, and the main issues have been identified. Then a questionnaire survey was conducted on the occupants to rank the identified issues according to their severity. And a desk study was conducted to analyse the maintenance expenses related issues of these buildings and ranked them accordingly. After finalising the critical issues, preventive and corrective measures are recommended based on the results obtained by an expert interview.

B. Data Collection methods

The method of collecting data for the study was survey-type data collection, and those have been collected as primary data. In that case, both questionnaires and telephone interview tools have been used to collect data from the technical staff for the study.

The Relative Importance Index (RII) was used to analyse the results of the questionnaire survey. The Relative Importance Index is calculated using the formula in Equation 1 [6].

$$\text{Relative Importance Index (RII)} = \frac{\sum_{i=1}^N W}{A \times N} \quad (1)$$

Where,

W = the weight given to each factor (1-5)

A = the highest weight = 5

N = the total number of respondents

C. Data Collection

Data were collected with the questionnaire from technical personnel who work in the field. Inspections have been carried out before the preparation of questionnaires to identify causes, corrective, and preventive measures for problems with the support of technical staff from the Department of Buildings. The relevant locations in the selected projects for the study are technically evaluated and recorded. Depending on the selected site areas for the reference source of main inspection to prepare the data collection questionnaire has been implemented for subsequent data collection, the responses have been recorded and the ranking order of the issues has been analysed [2].

The common issues of the related area has identified and recorded to furthermore analyze work. And cost of maintenance data were collected with available reports [7].



Fig. 1. Blockages, Leakages and Damages



Fig. 2. Leakages

IV. RESULTS

A. Results of the Visual Site Inspection Survey

As mentioned above, a visual site inspection survey was carried out to identify the extent of plumbing-related issues in the selected buildings. Figure 1 and Figure 2 exhibit some of the observed issues. Additionally, a list of issues has been prepared at each of the three locations and is presented in Table II.

B. Results of the Questionnaire Survey

The questionnaire survey was carried out to determine the perception of the occupants of each of the identified issues by visual site inspection.

- **Rank 1:** Leakages in pipe fittings
- **Rank 2:** Leakages in sanitary fittings
- **Rank 3:** Leakages in plumbing lines
- **Rank 4:** Leakages in waste lines
- **Rank 5:** Blockages in waste lines

TABLE II
LIST OF OBSERVED ISSUES IN EACH LOCATION

Location 1	Location 2	Location 3
Leakages in taps and valves	Damages in plumbing line	Damages in plumbing line
Leakages in Water closets	Damages in fittings due to time	Damages in sanitary fittings
Damages in pipe fittings	Leakages in taps and valves	Leakages in Water closets waste line
Damages in sanitary fittings	Blockages in drainage and waste line	
Blockages in waste line		

- **Rank 6:** Leakages in drainage lines
- **Rank 7:** Damages in sanitary fittings
- **Rank 8:** Blockages in sanitary fittings

By this, it is apparent that leaks in fittings and plumbing lines are frequent and are of high prominence over other issues.

C. Results of the Desk Study Performed to Analyse Expenses

The results of the desk study performed to analyse the expenditure of the identified issues during the last five years are presented in Table III. It presents the percentage of expenditure for each issue for each location, and the total expenditure of the particular issue out of the total cost of maintenance across the last five years. The ranking given in the table is based on the total expenditure for the given issues. The results show that leaks in fittings and plumbing lines cost more than blockages in sanitary fittings and even damages.

D. Results of the RII analysis on the causes of issues

As the next step, we identified the most probable causes of each of the identified issues and performed a relative importance index analysis to rank and identify the most probable cause to be addressed. The results are presented in Table IV. From the table, it can be deduced that poor maintenance is one of the major causes of plumbing-related problems. Moreover, it is apparent that the use of improper installation techniques is a cause that should not be understated.

V. RECOMMENDATIONS AND CONCLUSIONS

The most common and critical plumbing problems have been identified in the previous section. As summary, the following five problems have been prioritized in the above analysis.

- 1) Leakages in pipe fittings
- 2) Blockages in waste lines
- 3) Leakages in waste lines
- 4) Blockages in pipe and sanitary fittings
- 5) leakages in pipe joints

An expert interview was conducted to identify preventive and corrective measures for the identified problems. Expert recommendations are presented in Table V.

According to the table, it is apparent that the planned maintenance could address most of the common plumbing problems. In addition, it can be pointed out that well training of plumbers would prevent most plumbing-related problems in buildings. Since the corrective measures are expensive, focusing high on preventive measures is of utmost significance.

REFERENCES

- [1] "Plumbing problems." *Healthcare hazardous materials management : HHMM*, vol. 4, 1991.
- [2] M. Leslie, "Plumbing problem." *Science of aging knowledge environment : SAGE KE*, vol. 2005, 2005.
- [3] K. Agyekum, J. Ayarkwa, and E. Adinyira, "A case study of dampness in a three bedroom residential building at deduako, kumasi," *Journal of Building Performance*, vol. 5, 2014.
- [4] L. Ragain, S. Masters, T. A. Bartrand, J. L. Clancy, and A. J. Whelton, "Analysis of building plumbing system flushing practices and communications," *Journal of Water and Health*, vol. 17, 2019.
- [5] E. Kleczyk and D. Bosch, *Households' Preferences for Plumbing Materials*, 2012.
- [6] V. D. S. . M. B. Chougule, "Construction equipment monitoring by using relative important indices rii analysis," *International Journal of Trend in Scientific Research and Development*, vol. 4, 2020.
- [7] M. L. Huband, "Problems associated with implant maintenance." 1996.

TABLE III
RANKING ORDER OF ISSUES ON SUMMARY OF MAINTENANCE EXPENSES PERCENTAGE (IN LAST 5 YEARS)

S N	Issue	Quarters Location	% out of cost in Locations	% out of Total Cost	Rank order
1	Leakages in pipe fittings	Foreign Ministry Department of Buildings Survey Department	36.9% 20.6% 42.5%	24.6%	1
2	Leakages in sanitary fittings	Foreign Ministry Department of Buildings Survey Department	38.8% 27.2% 34.0%	23.8%	2
3	Leakages in plumbing lines	Foreign Ministry Department of Buildings Survey Department	61.9% 13.7% 24.4%	20.9%	3
4	Leakages in waste lines	Foreign Ministry Department of Buildings Survey Department	13.0% 68.4% 18.6%	10.5%	4
5	Blockages in waste lines	Foreign Ministry Department of Buildings Survey Department	20.9% 34.4% 44.8%	10.3%	5
6	Leakages in drainage lines	Foreign Ministry Department of Buildings Survey Department	50.4% 14.5% 35.1%	3.9%	6
7	Damages in sanitary fittings	Foreign Ministry Department of Buildings Survey Department	43.6% 43.6% 12.8%	3.5%	7
8	Blockages in sanitary fittings	Foreign Ministry Department of Buildings Survey Department	23.3% 34.9% 41.9%	2.4%	8

TABLE IV
RESULTS OF THE RELATIVE IMPORTANCE INDEX ANALYSIS CARRIED OUT TO RANK CAUSES FOR MOST COMMON ISSUES

Type of issue	Cause	RII value	Rank
Leakages in pipe fittings	Use fewer quality brands for fittings	0.80	1
	Poor maintenance	0.72	2
	Use incorrect installation techniques for fittings	0.57	3
	Use incorrect methods of laying pipes	0.33	4
	Use improper methods for jointing pipes	0.30	5
Blockages in waste lines	Poor maintenance	0.85	1
	Use incorrect installation techniques for fittings	0.77	2
	Use fewer quality brands for fittings	0.70	3
	Use incorrect methods of laying pipes	0.50	4
	Use improper methods for jointing pipes	0.30	5
Leakages in waste lines	Poor maintenance	0.86	1
	Use fewer quality brands for fittings	0.76	2
	Use incorrect methods of laying pipes	0.64	3
	Use incorrect installation techniques for fittings	0.54	4
	Use improper methods for jointing pipes	0.35	5
Blockages in the pipe and sanitary fittings	Use fewer quality brands for fittings	0.83	1
	Poor maintenance	0.77	2
	Use incorrect installation techniques for fittings	0.70	3
	Use improper methods for jointing pipes	0.58	4
	Use incorrect methods of laying pipes	0.32	5
Leakages in pipe joints	Use improper methods for jointing pipes	0.84	1
	Use incorrect methods of laying pipes	0.73	2
	Poor maintenance	0.56	3
	Use fewer quality brands for fittings	0.53	4
	Use incorrect installation techniques for fittings	0.36	5

TABLE V
SUMMARY OF CAUSE, CORRECTIVE AND PREVENTIVE MEASURES FOR COMMON ISSUES

Identified common issues	Reasons for the Issues	Corrective Measures	Preventive measures
Leakages in pipe fittings	Use fewer quality brands for fittings	Repair leaks on pipe valves and taps	Use correct installation techniques for fittings
	Poor maintenance Use incorrect installation techniques for fittings	Replace damaged parts of the fittings	Use best quality brands for fittings Well maintenance
Blockages in waste lines	Use fewer quality brands for fittings	Repair leak joints on pipe lines	Use correct installation techniques for fittings
	Poor maintenance Use incorrect installation techniques for fittings Use incorrect methods of laying pipes	Replace the pipe line newly	Use quality brands for fittings Well maintenance
Leakages in waste lines	Use fewer quality brands for fittings	Repair and Replace damage parts of the fittings	Use best quality brands for fittings
	Poor maintenance Use incorrect installation techniques for fittings Use incorrect methods of laying pipes		Well maintenance
Leakages in sanitary fittings	Use fewer quality brands for fittings	Repair damaged parts of the fittings	Use correct installation techniques for fittings
	Poor maintenance Use incorrect installation techniques for fittings Use incorrect methods of laying pipes	Replace damaged parts of the fittings	Use quality brands for fittings Well maintenance
Leakages in plumbing lines	Use fewer quality brands for fittings	Repair leak joints on pipelines	jointing pipes Use proper methods for
	Poor maintenance Use incorrect installation techniques for fittings Use incorrect methods of laying pipes	Replace damaged parts of the fittings	Use correct methods of laying pipes

a

Impact of Unexpected Rapid Price Fluctuations on Medium-Scale Building Construction Projects in Sri Lanka: A Case Study

R.M.T.K. Ranasinghe

*Department of Construction Technology
The University of Vocational Technology, Ratmalana.
Colombo, Sri Lanka
thanojaranasinghe1990@gmail.com*

Kasun Nandapala

*Department of Construction Technology
The University of Vocational Technology, Ratmalana.
Colombo, Sri Lanka
kasuncn@gmail.com*

Abstract—The construction industry is facing a severe recession. This scenario spreads throughout the country, and contractors related to the construction industry are critically affected. The general objective of this research is to investigate the variation in material prices in the construction industry and its impact on medium-scale building construction projects. This research investigates the effects of unexpected rapid price fluctuations on the capacity of local contractors. The study concepts are developed through a literature survey to identify relevant variables, and project case studies are used to assess the problem. According to the research; market survey details show that the material price increased dramatically after June of 2021, and these followed a steep upward trajectory until June of 2022. When considering other materials, the price of cement is reduced. Figure 2. Most of the material prices increased above 200% compared to the year 2019. The highest increase in the price of the material is cement and increased to 268% in June 2022 compared to 2019. Not only the material but also the labour daily charges have been escalated, as an example, Blacksmith, Plumber, Specials sk labour and Tinker prices are inflated up to 90% in December of 2022 compared to the year 2019. The results presented by the case studies, collectively demonstrate a pattern of price fluctuation across multiple projects and all the projects which are selected for the case study work, suffered from the price escalation. The project which completion date is falling under the month October in year 2022 (3rd part of 2022), shows the significant price increase. The actual completion dates of projects are significantly delayed compared to their scheduled completion dates and it is the major reason for the price increment.

Index Terms—Price escalation, price indices, construction inputs, price fluctuation

I. INTRODUCTION

Sri Lankan Construction Industry continues to play an important role in the country's economy. Construction industry is one of the most significant industries that contributes to socioeconomic growth, especially in developing countries. The construction sector produces a wide range of products, from individual houses to major infrastructure such as roads, power plants, petrochemical complexes, etc. [1].

The construction industry in Sri Lanka has been growing rapidly for years. According to the Central Bank Report (2016), [2] 'The Sri Lankan Construction Industry contributes

7. 6% to the Gross Domestic Product (GDP), and the value added of construction activities rebounded during the year, recording a substantial growth of 14. 9% in 2016 [3].

But unfortunately, since the end of 2019, it has been shrinking; due to the Covid-19 pandemic situation and the current economic crisis in the country, [4]. According to data from the international trade Administration; "This industry is one of the largest contributors to GDP and the source of employment in Sri Lanka and the construction industry contributed 6.2% of GDP in 2020, [5] from the previous year's contribution of 7.6%, employing around 600,000 workers.

Although GDP decreased by an unexpected 8. 4% in the April-June period in year 2022 compared to the same period last year, acute shortages in fuel and other commodities and prolonged power cuts, which began around February, became more pronounced and brought the economy to a near standstill in June. However, many professionals have lost their jobs as a result of this collapse. Marginal workers were the hardest affected, and their daily activities were hampered by the loss of jobs.

According to the National Construction Association of Sri Lanka; "Sri Lanka's construction sector has collapsed, with approximately 90% of its work stalled in the country, resulting in the loss of around 75% of the workforce, mainly due to the shortage of cement, iron and other raw materials and the high prices of the economic crisis. The construction industry has faced various difficulties, which have hindered the growth of the industry [6]. There are several basic problems in the construction sector, which can be classified into two main categories. The first is related to the consequences of joint planning and execution capability (Mishra and Magar, 2017) [7]. The second problem is the shortage of inputs required for construction and fluctuating market prices.

The deficiencies and fluctuation of the market price of the inputs required for construction greatly affected the growth of the construction industry [8]. Enormous price increases affected to completion of the projects; the contractors couldn't complete their projects within an acceptable margin of time and quality and failed to complete within the planned cost

margin, leading contractors to failure.

As a result of this situation, contractors have to suffer significant losses. Due to the losses, construction contractors are facing difficulties building their capacity.

Fluctuations in the price of material pose many challenges and consequences to the construction industry [9]. This phenomenon allows high-end contractors to bid in the non-competitive construction industry. As their economic capacity is greater than that of small-scale contractors, they are able to submit reasonably high bids subject to the prevailing price fluctuations [10].

ICTAD introduced a bulletin of price and cost indices in year 1990 and capitalized it as the base year. Indices can be defined as indicators of inflation in construction inputs such as materials, labour, and fuel [11]. Currently, price indices of 61 items are published including 55 materials (M- indices), 03 labour (L- indices), and 03 Dry Hire Rates for Plant & Equipment (P- indices).

The ICTAD Formula Method for reimbursement of price fluctuation of materials, labour, and equipment in construction projects was introduced in January 1993. The publication is divided into two sections, and Section 1 covers the formula applicable to contracts exceeding Rs.10 million. Section 2 describes the specified method of the Formula Method for contracts not exceeding Rs.10 million. The formula was developed by ICTAD and is the most commonly used method in Sri Lanka, which has been designed to protect both the borrower and contractor from price fluctuations; by allowing the contractors to offer more realistic prices during bidding.

The procurement guidelines (2006) state that a price fluctuation formula should be included in the bidding documents and contract agreements of all Sri Lankan construction projects that are more than three months in duration. The cabinet has granted its approval for the CIDA formula. Due to its inherent characteristics, the government has recommended using the formula as a standard approach in calculating price fluctuations in civil engineering projects [12].

II. OBJECTIVES

Price fluctuation in construction input normally occurs in the construction industry, but after the third quarter of 2021,

it was highly affected by the industry. The following factors mainly affected to this issue;

- Increase in taxes
- Lack of raw materials due to restrictions on import of goods.
- A sharp rise in good prices due to the depreciation of the rupee against the dollar.
- Increase in transport charges due to the increase in fuel prices.

The government increases the VAT rate for the import and / or supply of goods or supply of services from 8% to 15% on the 1st of September 2022. Due to this, the prices of goods and services are rocketed. Additionally, the government has temporarily suspended the import of goods related to the construction industry. To remedy this situation, the Cabinet

decided to allow the Institute of Construction Training and Development (CIDA) price escalation formula to be applied up to an upper limit of 20% of the contract amount, for contracts beyond 3 months where the price escalation clause has been excluded.

The purpose of this research is to analyze the impact of rapid price variation on medium-scale building construction projects. Projects with a project cost between 10-100 million rupees were selected for the case studies.

According to CIDA notice Gov/CIDA/Directive/110/2022, which was published on November 30, 2021, it discussed the importance of applying price escalation provisions in the construction industry in accordance with the Construction Industry Development (CID) Act 33 of 2014. The Construction Industry Development Authority (CIDA) emphasized the need for including these provisions in contract documents for all Identified Construction Works (ICWs), regardless of the contract duration. This notice clarified that, according to the CID Act, ICW refers to construction work for public use exceeding a value of Rupees Ten Million (Rs. 10,000,000.00), or a higher value set by the Minister. So that, this research is based on the medium scale building construction projects which falling under 10-100 million rupees category.

The main objective of this study is to investigate the significant challenges arising from unpredictable price variations in the construction industry and their impact on project costs.

III. METHODOLOGY

This research aims to explore how the capacity of local contractors is affected by unexpected price fluctuations, and it is more detailed and exploratory. Research is based on case studies that help investigate problems and provide knowledge mainly to contractors and other stakeholders in the construction industry. According to the methodology, a flow chart research was done. (Refer to Fig.1)

According to the ICTAD Formula method for adjustments to contract price due to fluctuation in prices; the formula for contracts greater than 10 million is given in Equation (1). The calculation of price escalation for all six case studies was performed using the following formula

$$F = 0.966 \frac{V - V_{na}}{100} \sum_x P_x \frac{I_{xc} - I_{xb}}{I_{xb}} \quad (1)$$

Where:

F : Price adjustment for the period

V : Valuation of work done during the period concerned

V_{na} : Value of net non-adjustable element

P_x : Percentage cost contribution of input x

I_{xc} : Current index for input x

I_{xb} : Base index for input x

According to this equation, six parameters need to be found to solve it or find the "F" value.

Step 1: Valuation of the work done during period (V)

Valuation of the cumulative work done including 80% of the cost of material delivered to the site but not incorporated in permanent works and deducting the certified cumulative payment up to the previous bill. Equation (2)

$$V = (V_c + M_c) - (V_p + M_p) \quad (2)$$

where,

V_c : Cumulative value of work done during the period in question.

M_c : 80% of the invoiced value of material used for permanent works in the current valuation.

V_p : Cumulative value of work done up to the previous claim.

M_p : 80% of the invoiced value of material used for permanent works on the previous valuation.

Step 2: Excluding the non-adjustable element (V_{na})

The net Non- adjustable element for the current valuation is computed by deducting the cumulative non adjustable element of the previous bill from the current cumulative non adjustable element. Equation (3)

$$V_{na} = V_{nac} - V_{nap} \quad (3)$$

Where V_{nac} is the Cumulative Value of work certified under

items specified as nonadjustable element up to current claim, and V_{nap} is the Cumulative Value of work certified under items specified as nonadjustable element up to previous claim.

Step 3: Computation of first part of the Formula

$$0.966 \frac{V - V_{na}}{100} \quad (4)$$

Calculate the next part of the equation.

Step 4: P_x – Input Percentages

Input proportion of a particular input was calculated as the ratio between the cost of the input and the cost of all inputs. The contractor provides these input percentage values for the contract.

Step 5: I_{xb} – Base Indices

‘Base Indices’ shall be the indices for the input, prevailing for the calendar month, one month before the date set for the submission of the bid. These values are taken from the CIDA statistics bulletin publication.

Step 6: I_{xc} – Current Indices

The current index of a particular input shall be the index published by CIDA for that input for the month applicable. The contractor is supposed to submit the monthly statement for the payment.

For the first interim bill, the current indices shall be taken as the indices that prevail on the first month after the commencement of the contract.

For any other interim claim or the final claim, the current indices shall be taken as indices prevailing for the calendar month, one month after the previous valuation was done. These values were taken from CIDA statistics bulletin publication

Step 7: Computation of second part of the Formula

$$\sum P_x \frac{I_{xc} - I_{xb}}{I_{xb}} \quad (5)$$

Step 8: Computation of the total price fluctuation

Multiplying the total obtained in Step 3, Equation (4) and Step 7, Equation (5); and as in the case of any other payment made to the contractor, the amount computed as price adjustment shall be subject to VAT.

A. Data Collection

The target population for this research is local construction

contractors. Although price fluctuations are constant, no proper studies have been done on their relationship and impact

on the construction industry and especially on construction contractors.

Six case studies of construction projects are used as the research instrument in this investigation. These six case studies are taken from the North Western Provincial Engineering Department-Kuliyapitiya Division. This research work is designed in such a way that it has two parts. The first part deals with market price fluctuation and pricing issues, and the second part deals with compensation-related issues.

Unexpected price fluctuation is a problem that affects contractors of different grades and categories. But because higher-grade contractors take on larger projects, they are more vulnerable to the adverse effects of price fluctuation. Therefore, the study population included in this research work is local contractors of grade C2-C7.

IV. DATA ANALYSIS AND DISCUSSION

A. Market price Fluctuation Trend

Price fluctuation of construction inputs is unpredictable due to sociogeographical complexity. The price of construction materials fluctuates for a short period of time, but on a quarterly basis, it can be seen that it is consistently increasing at a lower rate. since most construction materials and raw materials are imported; The chain of continuous price changes was found to extend between these quarters. Meanwhile, the labourers have had to grow with the industry, because they have no opportunity to increase their demand.

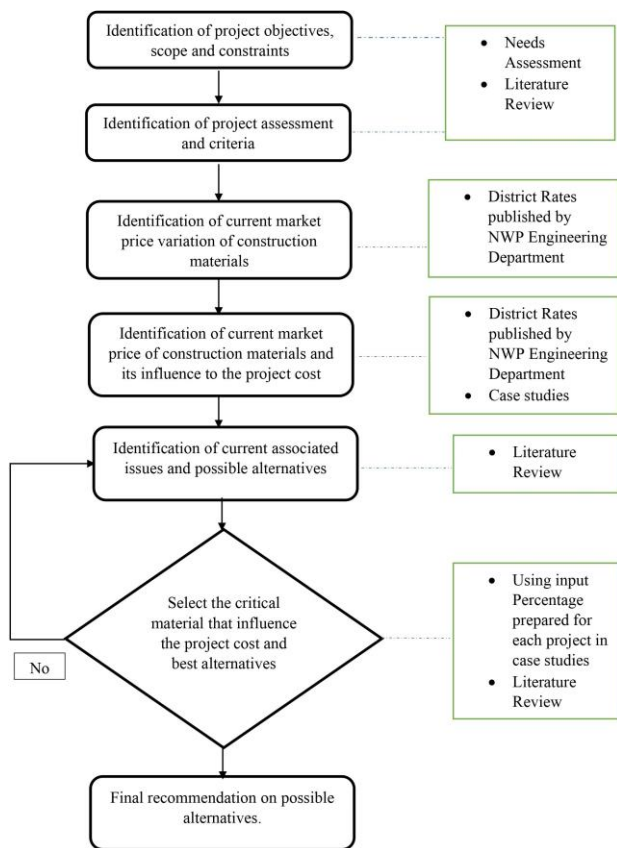


Fig. 1. Flow chart of Research Methodology

Since construction is a risky business, contractors must be careful in their bids. i.e., the contractor requires a detailed market survey of the construction inputs, to the preparation of the bid price. Pricing requires not only the market study, but also consideration of all other factors affecting prices such as price fluctuation and contingencies.

According to market surveys, the price variation of the labour from 2019 to 2022 is shown in TABLE I and Fig. 3,

the price variation of materials such as Cement, 6"-9" rubble, 1 1/2" metal, 1" metal, 1" metal, ABC, Quarry dust, Gravel and Sand which are directly linked with the construction is shown in TABLE II and Fig. 2. These Tables and Figures are merely used as an example to show the results of the market survey.

B. Case Studies

Six case studies were selected to illustrate the level and impact of price fluctuation on the six projects and the construction contractors. All the projects considered for the case study are building construction projects, and the contract amount is within 10-100million.

The study is conducted by collecting data from the projects contract amount, bid date, commencement date, details of the contractor, project basic price indices (input percentage), material requirements, progress reports, material delivery reports and causes of project time extensions. The study focusses on

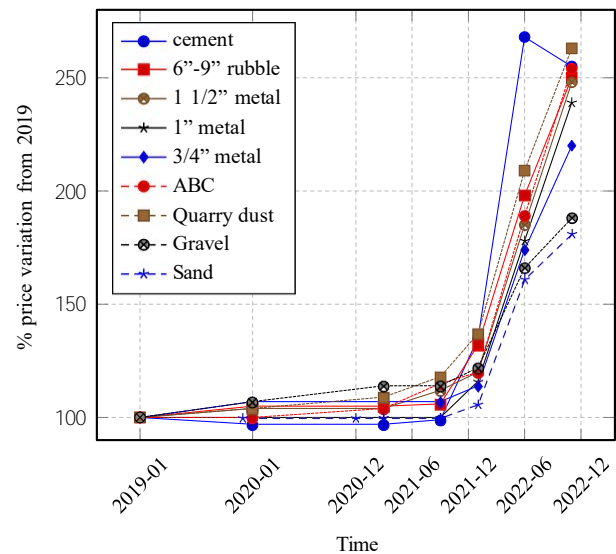


Fig. 2. % Price variation common construction materials compared to 2019

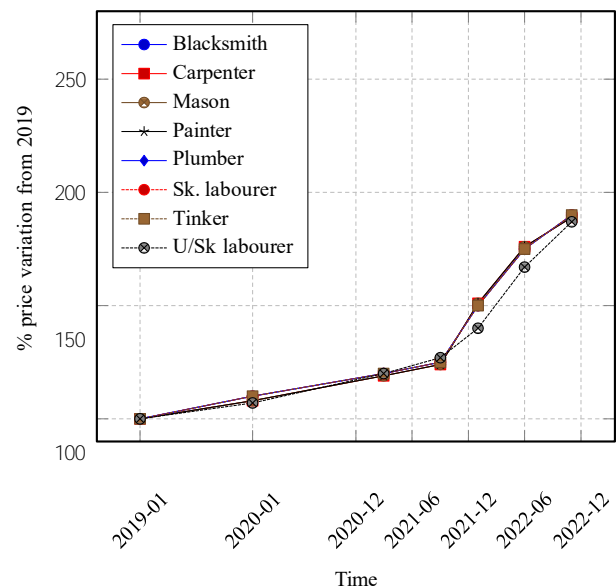


Fig. 3. Price variation graph of common construction materials in comparison to 2019

the planned and actual costs of the main inputs in construction projects, which are selected for the study. For building projects, the main inputs are material and labour. Therefore, data is collected from these documents to view the planned and actual cost of the projects for the main inputs of construction of the respective projects.

1) *Case study framework:* The framework of the case study is organized in four main steps.

- List all the main materials required for the project by input percentage, along with their base prices in pricing.
- Provide the actual purchase price of the materials.
- Analyse the compensation for the project.
- Study the price difference and how it contributes to the contractor's capacity and project performance.

TABLE I
PRICE VARIATION OF LABOUR IN COMPARISON WITH 2019

No	Item	Unit	2022 (3 rd part)	2022 (2 nd part)	2022 (1 st part)	2021 (2 nd part)	2021 (1 st part)	2020	2019
1	Blacksmith	Day	3,800.00	3,500.00	3,000.00	2,500.00	2,400.00	2,200.00	2,000.00
2	Carpenter	Day	3,500.00	3,250.00	2,800.00	2,300.00	2,200.00	2,000.00	1,850.00
3	Mason	Day	3,500.00	3,250.00	2,800.00	2,300.00	2,200.00	2,000.00	1,850.00
4	Painter	Day	3,500.00	3,250.00	2,800.00	2,300.00	2,200.00	2,000.00	1,850.00
5	Plumber	Day	3,800.00	3,500.00	3,000.00	2,500.00	2,400.00	2,200.00	2,000.00
6	Specials sk labourer	Day	3,800.00	3,500.00	3,000.00	2,500.00	2,400.00	2,200.00	2,000.00
7	Tinker	Day	3,800.00	3,500.00	3,000.00	2,500.00	2,400.00	2,200.00	2,000.00
8	U/Sk labourer	Day	2,800.00	2,500.00	2,100.00	1,900.00	1,800.00	1,600.00	1,500.00

TABLE II
PRICE VARIATION OF MATERIAL IN COMPARISON WITH 2019

No	Item	Unit	2022 (3 rd part)	2022 (2 nd part)	2022 (1 st part)	2021 (2 nd part)	2021 (1 st part)	2020	2019
1	Cement	Cwt	2,462.36	2,588.66	1,300.00	956.00	933.00	933.00	965.00
2	6"-9" rubble	Cu	9,779.00	7,742.00	5,165.00	4,138.00	4,114.00	4,114.00	3,914.00
3	1 1/2" metal	Cu	15,779.00	11,742.00	7,665.00	7,138.00	6,614.00	6,614.00	6,364.00
4	1" metal	Cu	15,779.00	11,742.00	7,665.00	6,638.00	6,614.00	6,614.00	6,614.00
5	3/4" metal	Cu	16,779.00	13,242.00	8,665.00	8,138.00	8,114.00	8,114.00	7,614.00
6	ABC	Cu	16,779.00	12,490.00	7,915.00	7,638.00	6,864.00	6,614.00	6,614.00
7	Quarry dust	Cu	14,779.00	11,742.00	7,665.00	6,638.00	6,114.00	5,864.00	5,614.00
8	Gravel	Cu	6,779.00	5,992.00	4,415.00	4,133.00	4,114.00	3,864.00	3,614.00
9	Sand	Cu	28,000.00	25,000.00	16,500.00	15,500.00	15,500.00	15,500.00	15,500.00

a) *Case study -01:* Construction of a three-story building with the primary Learning Resource Center & Junior Secondary Laboratory at Holy Angel's Girls' College, Kuliapitiya.

b) *Case study -02:* Construction of a 70 x 25 'two-story classroom building in Yayawaththa Mus K.V.

c) *Case study -03:* Construction of a three-storey 29.25x10.15m classroom building with ordinary-level science laboratory (FF) & library (SF) at Giri / Wildramashila Madya Maha Vidyalaya.

d) *Case study -04:* Repair of the building at the Giri / Wickramashila National School.

e) *Case study -05:* Construction of the new laboratory in the Bingiriya Divisional Hospital Bingiriya.

f) *Case study -06:* Construction of the Katupotha office building of MOH (Bihalpola).

According to TABLE III, it shows the result of case studies. Both contracts (case studies 1 and 2), which had a start date of 2019, have been extended to 2021. Additionally, the contract that started in 2020 must be completed in 2022. The Covid-19 pandemic situation, the lack of contract inputs and the increase in the price of contract inputs can be identified as the reason. Contractors have requested extensions for those projects and the reasons for them are,

- Scarcity of material due to COVID-19 pandemic
- Suspension of the site work due to Covid-19 pandemic
- Due to the difficulty of finding materials
- Due to the difficulty of finding materials
- Scarcity of tiles in the market
- Shortage of fuel
- Material cost increase

contracts concluded in the last months of 2022 (i.e. case study 4,5 and 6) have higher price fluctuations. It is up to 18%-26% compared to the contract amount. Although all the case studies are taken from the kuliapitiya area, entire country significantly suffered from the price escalation of the construction inputs between year 2019-2022.

With the free float of the rupee, the exchange rate of 1 US \$ is Rs.367.00 in December 2022. In December 2020 and December 2021, this was Rs.186.40 and Rs.203.00, respectively. As almost 70% of the construction materials in buildings and other engineering constructions are imported on an import basis, the impact of this would be at least another 60% increase in construction costs.

So this case studies could be applied for all over the country.

TABLE III
SUMMARY OF THE CASE STUDIES

Case study	Contact Duration	Commencement Date	Scheduled Completion Date	Actual Completion Date	Contract Amount (Rs.)	Total project cost (Rs.)	Price Increase (%)
1	365 days	11-Jun-2019	11-Jun-2020	25-Sep-2022	41,613,968.62	44,563,340.21	7.09%
2	365 days	2-Nov-2019	30-Apr-2020	20-Jun-2022	14,000,885.33	14,302,974.72	2.16%
3	365 days	22-Jan-2020	21-Jan-2021	21-Oct-2022	29,127,945.07	30,353,437.80	4.21%
4	365 days	26-Aug-2021	9-Dec-2021	21-Dec-2022	12,001,686.24	14,206,242.71	18.37%
5	365 days	18-Oct-2021	18-Apr-2022	18-Dec-2022	30,330,228.50	35,698,863.73	17.70%
6	365 days	14-Oct-2021	14-Apr-2022	25-Oct-2022	21,472,169.76	27,036,870.10	25.92%

V. CONCLUSIONS

According to this research it shows that price variation can occur at any time; but it is very difficult to predict the magnitude of the price fluctuation, the duration of the fluctuation, or whether it is an increase or decrease in price. Sometimes, even during a period of high price fluctuation, it is often difficult to predict whether the prevailing prices will rise or fall or remain fairly stable.

Price variation means increase or decrease in prices, but in this study it shows that almost all building materials show an increase in price and the prices of some construction inputs are rocketed; due to the contractor's planned construction cost, it will vary at the finishing stage of the project.

Although the construction inputs for civil engineering are quite large in number and type, the Sri Lankan government has allowed compensation for only a few types of materials. According to the ICTAD Bulletin of Statistics, only 55 items are mentioned.

These case studies revealed that contractors were unable to make as much profit as they expected from the projects. Due to insufficient profits, they have not been able to take steps to increase the capacity of the company.

This research shows that project delays are common as a result of material shortages, delaying receiving orders, and loss of working capital. Therefore, contractors try to reduce the quality of the project and materials to minimise their losses; and they try to use materials sparingly by minimising the materials they use.

VI. RECOMMENDATION

To address the challenges arising from unpredictable price fluctuations in the construction industry, it is recommended to enhance price fluctuation forecasting, diversify the compensation system, incorporate risk management strategies, allow flexible bidding mechanisms, promote contractual flexibility, foster collaborative supplier relationships, build contractors' capacity for financial resilience, streamline payment processes, prioritise quality over cost cutting, and advocate for regulatory reform to enable dynamic responses to price fluctuations.

ACKNOWLEDGEMENT

The author wishes to express their special thanks to Faculty of Engineering Technology, University of Vocational Technol-

ogy for providing necessary assistance in carrying out research work presented in this paper.

REFERENCES

- [1] "Why sri lanka construction services - edb." [Online]. Available: <https://www.srilankabusiness.com/construction-services/why-sri-lanka-construction-services.html>
- [2] "Annual report 2016 — central bank of sri lanka." [Online]. Available: <https://www.cbsl.gov.lk/en/publications/economic-and-financial-reports/annual-reports/annual-report-2016>
- [3] B. S. Lanka, "Department of census and statistics 'sankyana mandiraya' no.306/71, polduwa road," 2021. [Online]. Available: www.statistics.gov.lk
- [4] "Annual report 2019 — central bank of sri lanka." [Online]. Available: <https://www.cbsl.gov.lk/en/publications/economic-and-financial-reports/annual-reports/annual-report-2019>
- [5] "Annual report 2020 — central bank of sri lanka." [Online]. Available: <https://www.cbsl.gov.lk/en/publications/economic-and-financial-reports/annual-reports/annual-report-2020>
- [6] F. M. Department and A. D. Bank, "Price adjustment: Guidance note on procurement," 2023.
- [7] A. K. Mishra and B. R. Magar, "Implementability of municipal transport master plan of bandipur inner risk and safety view project operational analysis of projects in nepal view project implementability of municipal transport master plan of bandipur inner ring road, tanahun, nepal," *Nepal Article in International Journal of Scientific & Technology Research*, vol. 6, p. 8, 2017. [Online]. Available: www.ijstr.org
- [8] M. M. M. M. Perera, G. P. D. P. Senanayake, B. A. K. S. Perera, and V. Dissaratna, "Price fluctuations and the impact of the cida formula on the profits earned by the contractors of civil engineering construction projects implemented in sri lanka," *The Planning Research Journal*, vol. 08, 2021. [Online]. Available: <http://doi.org/10.4038/bhumi.v8i2.78>
- [9] J. A. B. Janardana, A. Samaraweera, and H. S. Jayasena, "Suitability of ictad formula and cida price indices to calculate the amount of price escalated in construction projects," vol. 9, pp. 505–515, 2021.
- [10] M. G. Mossa and A. Ababa, "Department of civil engineering assessment of price escalation and adjustment problems on federal road construction projects," 2013.
- [11] "Acknowledgement these rules are derived from price adjustment formulae for building contracts (series 2)-guide to application and procedure, prepared on behalf of the national consultative council standing committee on indices for building contracts," 2011. [Online]. Available: www.jctcontracts.com
- [12] S. C. Jayaweera, B. A. K. S. Perera, and S. J. A. R. S. Jayasinghe, "Applicability of ictad price fluctuation formula for government funded intelligent building projects," pp. 12–14, 2015.

Energy Management and Quantity Surveying Best Practices for Resilient Industries

Mitigation of Financial Risks Involved in the Budget Performance of Building Construction Projects.

K. H. S.U. Thilakarathna.
Department of Quantity Surveying
University of Vocational Technology
Ratmalana, Sri Lanka
sanjaniut@gmail.com

S. R. M. P. Seneviratne.
Department of Quantity Surveying
University of Vocational Technology
Ratmalana, Sri Lanka
srmpseneviratnaunivotec@gmail.com

Abstract— *The impact of financial risks involved in budget performance and the mitigation of those risks are important to achieving project success. The study focused on the impact of contractor's financial risks on budget performance and the mitigation of those risks in building construction projects. The sample is selected from Sri Lankan Colombo suburbs with high-rise buildings costing more than 100 million rupees. The research utilized quantitative and qualitative approaches, including a validated questionnaire survey and structured interviews. The review of the literature identified thirteen financial risk factors and examined four variables related to budget performance issues in these projects. The findings revealed that among the financial risk factors, unmanaged cash flows, inadequate financial management, bankruptcy, errors in estimating, liquidity risk, changes in government legislation, and the fluctuation of the inflation rate showed the highest impact on budget performance issues. In contrast, insurance risk had the lowest impact. Further, based on expert interviews, building an emergency fund, ensuring risk retention, and having a contingency plan were highly recommended methods for mitigating financial risks. Diversifying income sources and clear communication between project stakeholders were least preferred.*

Keywords—*Financial Risks; Budget Performance; Mitigation of Financial Risks; Building Construction Projects*

I. INTRODUCTION

The construction industry operates in a dynamic and challenging business environment, making construction projects highly susceptible to risks and uncertainties [1]. Compared to other sectors, construction projects face unique risks that can impede the achievement of their primary objectives [2]. Effective risk management is pivotal for project success, with a particular emphasis on financial risks [3, 4]. High-rise buildings, in particular, pose greater risks compared to other structures due to their complexity [5]. As Sri Lanka has experienced a surge in high-rise condominium projects, effective risk management is crucial for the country's development [6, 7, 8].

Financial risks are among the most significant risks in construction projects and are considered early in the investment process, potentially impacting project progress and the country's economy [9, 10]. Insufficient financing can lead to project implementation failures and bankruptcy situations [9]. However, despite the evident impact of financial risks on contractors in developing countries, research on addressing these risks remains limited [1].

In Sri Lanka, budget performance in building construction projects is a concern, often affected by financial risks such as cost overruns and delays, which can lead to reduced profitability and project failure [11, 12]. Contractors face challenges in determining appropriate risk management strategies based on the nature and potential outcomes of the risks [13].

While some studies exist on financial risks, there is a lack of research specifically focused on budget performance and mitigating financial risks in Sri Lankan building construction projects. This research gap highlights the need to develop strategies to mitigate financial risks and enhance budget performance. Therefore, this study aims to mitigate the financial risks involved in the budget performance of building construction projects in Sri Lanka. The study focused on high-rise building projects (contractor perspective, CIDA grades C1 and C2) in Sri Lanka with budgets exceeding one hundred million Sri Lankan rupees and constructed before 2019. The geographical scope is confined to Sri Lanka, aiming to provide insights and strategies for mitigating financial risks in the context of building construction projects.

II. AIM AND OBJECTIVES

This research aims to mitigate the financial risks involved in the budget performance of building construction projects in Sri Lanka.

The objectives of the study are as follows:

01. To identify the factors causing financial risks of building construction projects.
02. To examine issues related to the budget performance of building construction projects in Sri Lanka.
03. To examine the impact of financial risk factors on budget performance issues in building construction projects.
04. To suggest the most suitable strategies to mitigate the financial risks involved in building construction projects in Sri Lanka.

III. REVIEW OF LITERATURE

The construction industry plays a crucial role in urbanization as people strive to improve their living standards [14]. It is a significant sector of the economy that interacts with various fields of human activity [15].

This section consists of the following A-F subtopics:

A. Financial Risks

Financial risk in the construction industry refers to the potential loss of revenue and profit that may occur if a project fails, such as by exceeding the budget or missing the completion date [16]. These uncertainties and adverse events can significantly impact the financial aspects of construction projects [17, 18].

B. Financial Risk Factors

Extensive research in Sri Lanka has focused on financial risks in building construction projects and proposed strategies for risk mitigation. Jayawardena, C., et al., (2012) highlighted market condition changes and unexpected site conditions as critical risk factors, recommending contingency budgets and risk management plans [19]. Others identified bankruptcy, inflation rate fluctuations, interest rate fluctuations, exchange rate fluctuations, fuel price increases, insurance risk, currency exchange risk, liquidity risk, and changes in government legislation as affecting projects [20]. Perera, et al., (2020) emphasized errors in estimation as a major risk [21], while, Chan, et al., (2017) stressed accurate cost estimation [22]. Unmanaged cash flows can lead to liquidity issues and payment delays [23], affecting project progress. Contractors may face cash flow difficulties, leading to budget imbalances [24]. Factors like inaccurate cost estimation and monitoring contribute to cash flow problems [25]. Inadequate financing and financial planning were identified as risks [26, 27]. Dissanayake and Bandara (2015) highlighted effective budgeting and cost control as crucial for risk mitigation in construction projects [28].

C. The Project Budget

The project budget is the estimated or allocated amount of funds needed to complete a project from a contractor's perspective. It serves as the financial plan, encompassing expenses and revenues related to the project, including labor, materials, equipment, subcontractors, overhead, permits, insurance, contingencies, and a possible profit margin [29].

D. Budget Performance and Issues Related in Budget Performance

Budget performance in the construction industry refers to the actual costs compared to the original budget of a building project from the contractor's perspective. It involves cost control measures, tracking expenses, and analyzing any deviations from the planned budget [30, 31]. Project managers play a crucial role in overseeing and managing budget performance by collaborating closely with contractors, setting budget targets, and implementing cost-saving measures [32]. This collaborative approach fosters open communication, enabling informed decisions on financial management [33].

Numerous studies on budget performance in Sri Lankan building construction projects have highlighted common challenges and influencing factors. Seneviratne, et al., (2014) identified budget overruns in the majority of projects due to inadequate preparation, poor cost estimation, and scope changes [34]. Wijesinghe and Wijekoon (2013) pointed out that cost overruns and delays are common in the Sri Lankan construction industry and suggested that inadequate planning, poor contract management, and inadequate financial management are major contributing factors [35]. Gunawardena and Jayasuriya (2017) identified cost overruns, inadequate financing, and payment delays as major

contributors to financial risks [36]. Atapattu and Jayasinghe (2016) found a generally poor budget performance, with high percentages of projects experiencing cost overruns and delays [37]. Other studies emphasized the negative impact of cost overruns and delays on budget performance [38].

E. Impact of Financial Risk Factors on Budget Performance

Atapattu and Jayasinghe (2016) conducted a study on the impact of financial risks on budget performance in Sri Lankan construction projects [37]. The research identified cost overruns, inadequate financing, and payment delays as significant contributors to financial risks. To mitigate these risks, the study recommended effective project planning, budgeting, and the utilization of financial tools like cost-benefit analysis and sensitivity analysis.

F. Review of Literature Survey

1) Review of factors causing financial risks in building construction projects

The literature review accomplished the first objective. Among various risks, financial issues were found to pose a higher level of risk, directly affecting project progress.

The literature survey identified thirteen financial risk factors, including bankruptcy, inflation rate fluctuations, interest rate fluctuations, exchange rate fluctuations, fuel price increases, insurance risk, currency exchange risk, liquidity risk, inadequate financial management, market conditions, errors in estimating, unmanaged cash flows, and changes in government legislation.

2) Review of issues relating to the budget performance of building construction projects in Sri Lanka

The second objective was achieved through the literature review, which shed light on how contractors' budget performance is often evaluated by comparing actual costs to estimated costs.

The literature survey highlighted four significant budget performance issues in building construction projects in Sri Lanka: as cost overruns, inadequate project planning, inadequate contract management, and project delays.

IV. METHODOLOGY

Objectives 1 and 2: identify factors causing financial risks and examine issues relating to the budget performance of building construction projects in Sri Lanka, which were identified through a literature review. Objectives 3 and 4 examine the impact of financial risk factors on budget performance issues and suggest the most suitable strategies to mitigate the financial risks involved in building construction projects in Sri Lanka, which were identified through a questionnaire survey and expert interviews.

There are two basic research approaches: the quantitative approach and the qualitative approach [39]. Both quantitative and qualitative methods were used in this study.

The preliminary interviews were used to confirm and validate the literature findings, which supported the development of a successful interview guideline. The collected data through interviews was analyzed using quantitative and qualitative data analysis techniques, and those results were subjected to expert validation.

A. Preliminary Interviews

To validate the literature findings, build up a strong interview guideline, and to decide the most suitable data collection methods with suitable processes, preliminary interviews were conducted with thirty professionals engaged in the construction industry and having knowledge of the budget of high-rise building construction projects.

B. Structured Interviews

The interview method, which represents verbal stimuli and replies in terms of oral verbal responses, can be applied through personal interviews and, if possible, through telephone interviews [39]. However, for this research, structured interviews were used since it was needed to collect both structured information and details on how to mitigate the financial risks of interviewees.

Structured interviews were conducted with three professionals engaged in the construction industry and having knowledge of the budget of high-rise building construction projects. The respondents were interviewed one by one to gain their open thoughts on the strategies for mitigating the financial risks involved in building construction projects. Further, all the above question types were used in the interview guidelines to conduct the personal interviews in the name of gathering the most reliable data.

C. Data Analysis

The methods of data analysis depend on the way of collecting data and the purpose of the findings of the research [40]. In order to incorporate the literature findings and strengthen the interview guidelines, considering the opinions of professionals in the industry, thirty questionnaire surveys and three structured interviews were conducted to achieve the third and fourth objectives.

Likert Scale

A five-point Likert scale was used to understand the perception of practitioners: 1 for very low, 2 for low, 3 for medium, 4 for high, and 5 for very high [41].

The impact of financial risk factors on budget performance issues in building construction projects was calculated using the Relative Importance Index (RII).

The total questionnaire presentations were in the form of graphs, bar charts, and tables.

RII was calculated with the following expression: Where:

$$RII = \sum_{i=1}^5 \frac{w_i x_i}{AN} \quad (1)$$

RII = Relative Importance Index

w = weighting is given to each factor by respondents, and it ranges from 1 to 5.

x = frequency of its response given for each cause

A = highest weight (i.e., 5 in this case).

N = total number of respondents

V. PROFILE OF PARTICIPANTS

A. Details of Questionnaire Respondents

The details of the survey respondents' responses were mainly analyzed according to Table I.

TABLE I. CHARACTERISTICS OF QUESTIONNAIRE SURVEY PARTICIPANTS

Characteristics	No. of respondents	Percentage (%)
Rate of response		
Respondent	30	75%
Non-respondent	10	25%
Total	40	100%
Organization type		
Contractor	30	100%
Total	30	100%
Professional background		
Senior Quantity Surveyor	22	73%
Chartered Engineer	2	7%
Senior Engineer	6	20%
Total	30	100%
Working Experience		
6-10 years	6	20%
11-15 years	15	50%
16-20 years	5	17%
More than 20 years	4	13%
Total	30	100%

a) Experienced with financial risks in building construction projects in Sri Lanka.

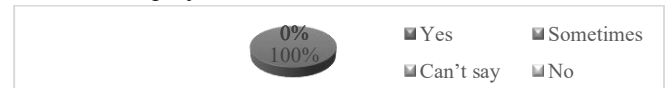


Fig. 1. Experienced with financial risks

According to the responses of professionals, figure 1 illustrates that 100% of respondents mentioned experiencing financial risks in high-rise building construction projects in Sri Lanka (which have a budget of more than 100 million rupees).

B. Details of Expert Interviews with Respondents

The details of expert interview responses from respondents were mainly analyzed according to Table II.

TABLE II. CHARACTERISTICS OF EXPERT INTERVIEW PARTICIPANTS

ID	Professional Background	Working Experience
Interviewee 1	Chartered Quantity Surveyors	more than 20 years
Interviewee 2	Chartered Quantity Surveyors	more than 20 years
Interviewee 3	Chartered Quantity Surveyors	more than 20 years

VI. RESULT AND DISCUSSION

The primary goal of this survey was to investigate the impact of financial risk factors on budget performance issues in building construction projects in Sri Lanka and to suggest suitable strategies for risk mitigation. To achieve this, a comprehensive literature review was conducted, which served as the basis for developing a questionnaire to gather data on the identified financial risk factors and budget performance issues. Additionally, structured interviews were employed to further enrich the analysis.

1) Impact of financial risk factors on budget performance issues in building construction projects

To address the third research objective, a comprehensive evaluation of the correlation between financial risk factors and budget performance variables was conducted via a questionnaire survey.

The literature review played a pivotal role in identifying and validating thirteen distinct financial risk factors, which were subsequently refined to seven significant factors through a questionnaire survey.

The validated questionnaire survey identified prominent financial risk factors, including unmanaged cash flows, inadequate financial management, bankruptcy, errors in estimating, liquidity risk, changes in government legislation, and the fluctuation of the inflation rate.

Concurrently, the literature review underscored significant budget performance concerns: cost overruns, inadequate project planning, inadequate contract management, and project delays.

a) Impact of financial risk factors on cost overruns in building construction projects in Sri Lanka:

As revealed by the findings presented in Table III, financial risk factors impact cost overruns in building construction projects in Sri Lanka. Table IV illustrates the rank of all factors of financial risk that have been investigated in this research from the contractor's perspective. In the results, 94% of respondents contributed to unmanaged cash flows, 90% of respondents contributed to changes in government legislation, and 89% of respondents contributed to bankruptcy, fluctuations in the inflation rate, and inadequate financial management. 87% of respondents contributed to the fluctuation of interest rates, the fluctuation of exchange rates, and currency exchange risk; 86% of respondents contributed to the rise in fuel prices and liquidity risk; 85% of respondents contributed to errors in estimating; 81% of respondents contributed to market conditions, and 73% of respondents contributed to the insurance risk contributing to cost overruns in Sri Lankan building construction projects.

TABLE III. IMPACT OF FINANCIAL RISK FACTORS ON COST OVERRUNS IN BUILDING CONSTRUCTION PROJECTS IN SRI LANKA

No	Factors causing financial risks	% of RII	Rank
1	Unmanaged cash flows	94%	1
2	Changes in government legislation	90%	2
3	Bankruptcy	89%	3
4	Fluctuation of inflation rate	89%	3
5	Inadequate financial management	89%	3
6	Fluctuation of interest rate	87%	4
7	Fluctuation of exchange rate	87%	4
8	Currency exchange risk	87%	4
9	Rise in fuel prices	86%	5
10	Liquidity Risk	86%	5
11	Errors in estimating	85%	6
12	Market conditions	81%	7
13	Insurance risk	73%	8

As revealed by the findings, the top three tiers of financial risk factors affecting cost overruns in building construction projects in Sri Lanka are identified as follows:

Unmanaged cash flows contribute to cost overruns in building construction projects in Sri Lanka.

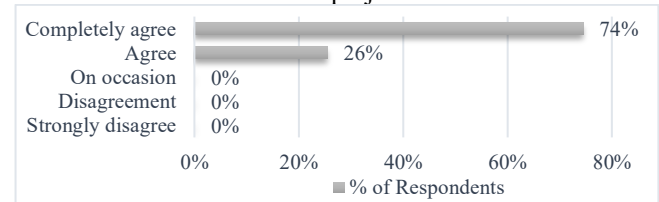


Fig. 2. Unmanaged cash flows contribute to cost overruns in building construction projects in Sri Lanka.

As illustrated in figure 2, 74% of respondents completely agree, and 26% of respondents agree with the statement that "unmanaged cash flows contribute to cost overruns in building construction projects in Sri Lanka."

Changes in government legislation contribute to cost overruns in building construction projects in Sri Lanka.

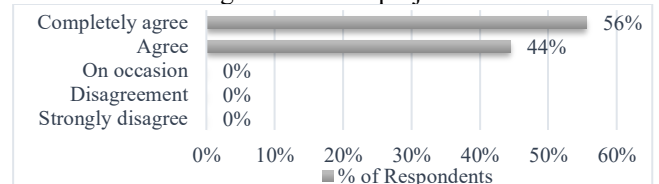


Fig. 3. Changes in government legislation contribute to cost overruns in building construction projects in Sri Lanka

As illustrated in figure 3, 56% of respondents completely agree, and 44% of respondents agree with the statement that "Changes in government legislation contribute to cost overruns in building construction projects in Sri Lanka."

Bankruptcy contributes to cost overruns in building construction projects in Sri Lanka.

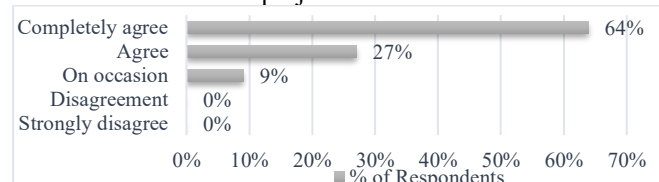


Fig. 4. Bankruptcy contributes to cost overruns in building construction projects in Sri Lanka.

As illustrated in figure 4, 64% of respondents completely agree, 27% of respondents agree, and 9% of respondents on occasion agree with the statement that "bankruptcy contributes to cost overruns in building construction projects in Sri Lanka."

The fluctuation of the inflation rate contributes to cost overruns in building construction projects in Sri Lanka.

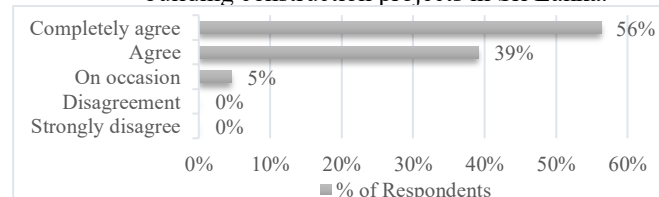


Fig. 5. Fluctuations in the inflation rate contribute to cost overruns in building construction projects in Sri Lanka.

As illustrated in figure 5, 56% of respondents completely agree, 56% of respondents agree, 39% of respondents agree, and 5% of respondents on occasion agree with the statement that "fluctuations in the inflation rate contribute to cost overruns in building construction projects in Sri Lanka."

Inadequate financial management contributes to cost overruns in building construction projects in Sri Lanka.

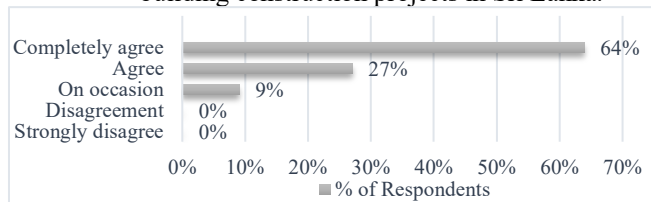


Fig. 6. Inadequate financial management contributes to cost overruns in building construction projects in Sri Lanka.

As illustrated in figure 6, 64% of respondents completely agree, 27% of respondents agree, and 9% of respondents on occasion agree with the statement that "inadequate financial management contributes to cost overruns in building construction projects in Sri Lanka."

b) Impact of financial risk factors on inadequate project planning in Sri Lankan building construction projects:

Financial risk factors have a significant impact on inadequate project planning in building construction projects in Sri Lanka, as revealed by the findings presented in Table IV. Table IV illustrates the rank of all factors of financial risk that have been investigated in this research from the contractor's perspective. The results indicate that 90% of respondents contributed to errors in estimating and unmanaged cash flows, and 87% of respondents contributed to inadequate financial management. 83% of respondents contributed to bankruptcy; 79% of respondents contributed to liquidity risk and market conditions; 77% of respondents contributed to the fluctuation of the inflation rate; 76% of respondents contributed to changes in government legislation; 75% of respondents contributed to the fluctuation of the exchange rate and currency exchange risk; 72% of respondents contributed to the rise in fuel prices; 67% of respondents contributed to the insurance risk; and 65% of respondents contributed to the fluctuation of the interest rate.

TABLE IV. IMPACT OF FINANCIAL RISK FACTORS ON INADEQUATE PROJECT PLANNING IN SRI LANKAN BUILDING CONSTRUCTION PROJECTS

No	Factors causing financial risks	% of RII	Rank
1	Errors in estimating	90%	1
2	Unmanaged cash flows	90%	1
3	Inadequate financial management	87%	2
4	Bankruptcy	83%	3
5	Liquidity Risk	79%	4
6	Market conditions	79%	4
7	Fluctuation of inflation rate	77%	5
8	Changes in government legislation	76%	6
9	Currency exchange risk	75%	7
10	Fluctuation of exchange rate	75%	7
11	Rise in fuel prices	72%	8
12	Insurance risk	67%	9
13	Fluctuation of interest rate	65%	10

As revealed by the findings, the top three tiers of financial risk factors that impact inadequate project planning in building construction projects in Sri Lanka are as follows:

Errors in estimating lead to inadequate project planning in Sri Lankan building construction projects.

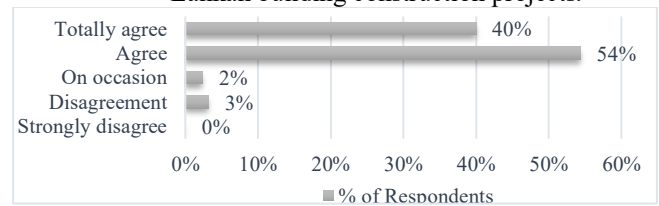


Fig. 7. Errors in estimating lead to inadequate project planning in Sri Lankan building construction projects.

As illustrated in figure 7, 40% of respondents totally agree, 54% of respondents agree, 2% of respondents on occasion, and 3% of respondents disagree with the statement that "Errors in estimating lead to inadequate project planning in building construction projects in Sri Lanka."

Unmanaged cash flows lead to inadequate project planning in Sri Lankan building construction projects.

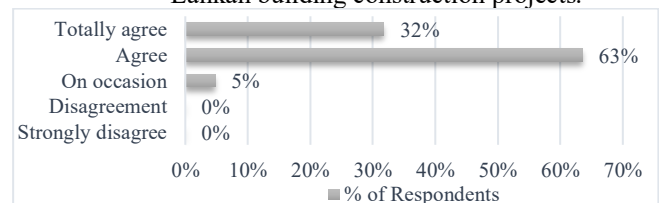
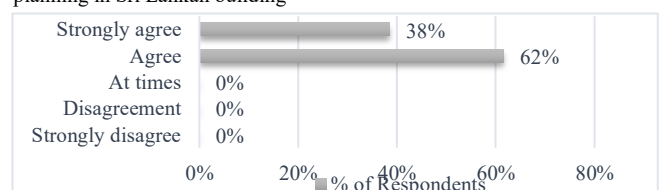


Fig. 8. Unmanaged cash flows lead to inadequate project planning in Sri Lankan building construction projects.

As illustrated in figure 8, 32% of respondents agree, 63% of respondents agree, and 5% of respondents on occasion agree with the statement that "unmanaged cash flows lead to inadequate contract management in building construction projects in Sri Lanka."

Inadequate financial management contributes to inadequate project planning in Sri Lankan building construction projects.

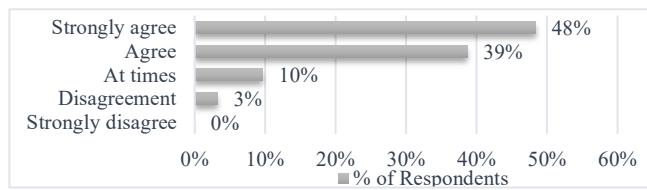
Fig. 9. Inadequate financial management contributes to inadequate project planning in Sri Lankan building



As illustrated in figure 9, 38% of respondents strongly agree, and 62% of respondents agree with the statement that "inadequate financial management contributes to inadequate project planning in building construction projects in Sri Lanka."

Bankruptcy contributes to inadequate project planning in Sri Lankan building construction projects.

Fig. 10. Bankruptcy contributes to inadequate project planning in Sri Lankan



building construction projects.

As illustrated in figure 10, 48% of respondents strongly agree, 39% of respondents agree, 10% of respondents at times disagree, and 3% of respondents disagree with the statement that "bankruptcy contributes to inadequate project planning in building construction projects in Sri Lanka."

c) Impact of financial risk factors on inadequate contract management in Sri Lankan building construction projects:

Table V illustrates the financial risk factors that impact inadequate contract management in building construction projects in Sri Lanka and ranks all factors of financial risk that have been investigated in this research from the contractor's perspective. 86% of respondents lead to inadequate financial management; 84% lead to unmanaged cash flows; 83% lead to errors in estimating and liquidity risk; and 82% of respondents lead to bankruptcy. 81% of respondents lead to the fluctuation of the inflation rate and changes in government legislation, 78% of respondents lead to the fluctuation of the exchange rate and currency exchange risk; 77% of respondents lead to market conditions; 75% of respondents lead to the rise in fuel prices; 72% of respondents contribute to the fluctuation of the interest rate; and 65% of respondents lead to the insurance risk.

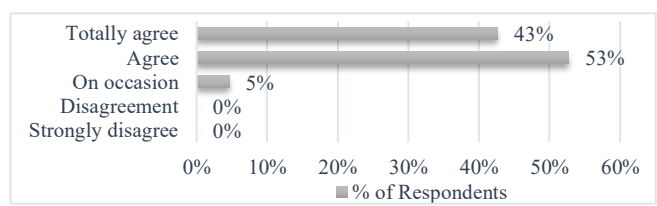
TABLE V. IMPACT OF FINANCIAL RISK FACTORS ON INADEQUATE CONTRACT MANAGEMENT IN SRI LANKAN BUILDING CONSTRUCTION PROJECTS

No	Factors causing financial risks	% of RII	Rank
1	Inadequate financial management	86%	1
2	Unmanaged cash flows	84%	2
3	Errors in estimating	83%	3
4	Liquidity Risk	83%	3
5	Bankruptcy	82%	4
6	Fluctuation of inflation rate	81%	5
7	Changes in government legislation	81%	5
8	Fluctuation of exchange rate	78%	6
9	Currency exchange risk	78%	6
10	Market conditions	77%	7
11	Rise in fuel prices	75%	8
12	Fluctuation of interest rate	72%	9
13	Insurance risk	65%	10

As revealed by the findings, the top three tiers of financial risk factors that impact inadequate contract management in building construction projects in Sri Lanka are as follows:

Inadequate financial management leads to inadequate contract management in Sri Lankan building construction projects.

Fig. 11. Inadequate financial management leads to inadequate contract

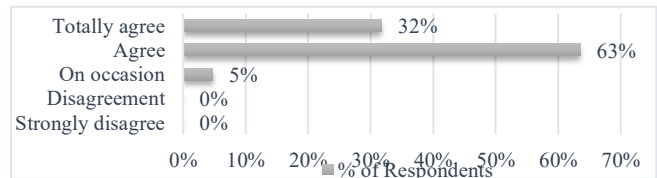


management in Sri Lankan building

As illustrated in figure 11, 43% of respondents agree, 53% of respondents agree, and 5% of respondents on occasion agree with the statement that "inadequate financial management leads to inadequate contract management in building construction projects in Sri Lanka."

Unmanaged cash flows lead to inadequate contract management in Sri Lankan building construction projects.

Fig. 12. Unmanaged cash flows lead to inadequate contract management in

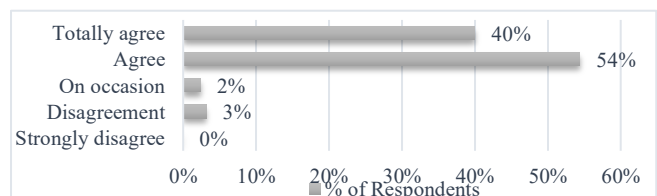


Sri Lankan building construction projects.

As illustrated in figure 12, 32% of respondents agree, 63% of respondents agree, and 5% of respondents on occasion agree with the statement that "unmanaged cash flows lead to inadequate contract management in building construction projects in Sri Lanka."

Errors in estimating lead to inadequate contract management in Sri Lankan building construction projects.

Fig. 13. Errors in estimating lead to inadequate contract management in Sri



Lankan building construction projects.

As illustrated in figure 13, 40% of respondents agree, 54% of respondents agree, 2% of respondents on occasion, and 3% of respondents disagree with the statement that "Errors in estimating lead to inadequate contract management in building construction projects in Sri Lanka."

Liquidity risks lead to inadequate contract management in Sri Lankan building construction projects.

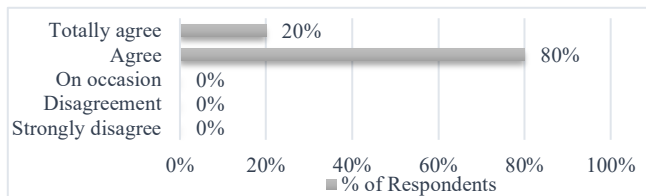


Fig. 14. Liquidity risks lead to inadequate contract management in Sri Lankan building construction projects.

As illustrated in figure 14, 20% of respondents totally agree, and 80% of respondents agree with the statement that "liquidity risk leads to inadequate contract management in building construction projects in Sri Lanka."

d) Impact of financial risk factors on project delays in Sri Lankan building construction:

The impact of financial risk factors on project delays in building construction projects in Sri Lanka is depicted in Table VI, which ranks all factors of financial risk that have been investigated in this research from the contractor's perspective. 94% of respondents contributed to bankruptcy, 93% contributed to inadequate financial management, 93% contributed to liquidity risk, and 93% contributed to unmanaged cash flows. 88% of respondents contributed to market conditions, 87% of respondents contributed to the fluctuation of the inflation rate, 85% of respondents contributed to the fluctuation of the exchange rate, 84% of respondents contributed to changes in government legislation, 82% of respondents contributed to currency exchange risk, 81% of respondents contributed to errors in estimating, and 78% of respondents contributed to the rise in fuel prices, 75% of respondents contributed to the fluctuation of interest rates, and 67% of respondents contributed to the insurance risk.

TABLE VI. IMPACT OF FINANCIAL RISK FACTORS ON PROJECT DELAYS IN SRI LANKAN BUILDING CONSTRUCTION

No	Factors causing financial risks	% of RII	Rank
1	Bankruptcy	94%	1
2	Inadequate financial management	93%	2
3	Unmanaged cash flows	89%	3
4	Liquidity Risk	89%	3
5	Market conditions	88%	4
6	Fluctuation of inflation rate	87%	5
7	Fluctuation of exchange rate	85%	6
8	Changes in government legislation	84%	7
9	Currency exchange risk	82%	8
10	Errors in estimating	81%	9
11	Rise in fuel prices	78%	10
12	Fluctuation of interest rate	75%	11
13	Insurance risk	67%	12

As revealed by the findings, the top three tiers of financial risk factors that impact project delays in building construction projects in Sri Lanka are as follows:

Bankruptcy contributes to project delays in Sri Lankan building construction.

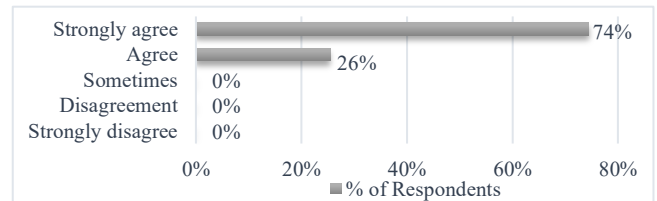


Fig. 15. Bankruptcy contributes to project delays in Sri Lankan building construction.

As illustrated in figure 15, 74% of respondents strongly agree, and 26% of respondents agree with the statement that "bankruptcy contributes to project delays in building construction projects in Sri Lanka."

Inadequate financial management contributes to project delays in Sri Lankan building construction.

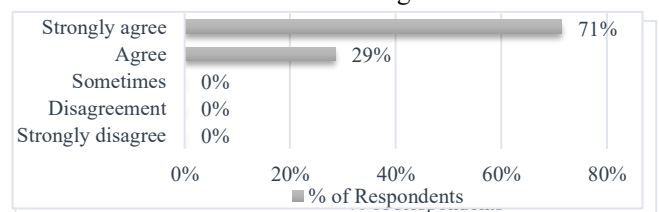


Fig. 16. Inadequate financial management contributes to project delays in Sri Lankan building construction.

As illustrated in figure 16, 71% of respondents strongly agree, and 29% of respondents agree with the statement that "inadequate financial management contributes to project delays in building construction projects in Sri Lanka."

Unmanaged cash flows contribute to project delays in Sri Lankan building construction.

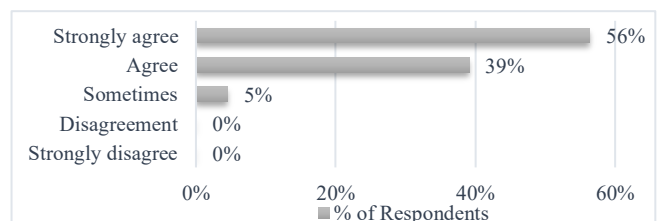


Fig. 17. Unmanaged cash flows contribute to project delays in Sri Lankan building construction.

As illustrated in figure 17, 56% of respondents strongly agree, 39% of respondents agree, and 5% of respondents sometimes agree with the statement that "unmanaged cash flows contribute to project delays in building construction projects in Sri Lanka." Liquidity risks contribute to project delays in Sri Lankan building construction.

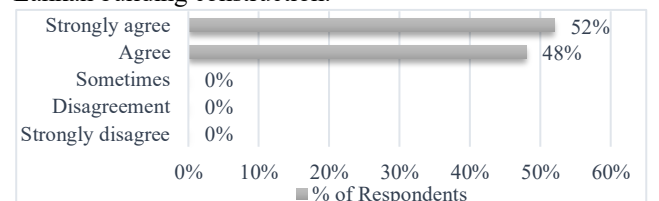


Fig. 18. Liquidity risks contribute to project delays in Sri Lankan building construction.

As illustrated in figure 16, 52% of respondents strongly agree, and 48% of respondents agree with the statement that "liquidity risks contribute to project delays in building construction projects in Sri Lanka."

2) Suggest the most suitable strategies to mitigate the financial risks involved in building construction projects in Sri Lanka.

As depicted in Table VII, the structured interviews yielded nine strategies that were suggested as effective for mitigating financial risks in building construction projects. These strategies include securing insurance policies, establishing an emergency fund, diversifying income sources, practising risk avoidance, implementing risk reduction measures, transferring risk, retaining the risk, developing a contingency plan, and promoting clear communication among all project stakeholders.

The study findings revealed a unanimous consensus among all respondents in favour of three key strategies: building an emergency fund, risk retention, and having a contingency plan. Additionally, two out of the three participants acknowledged the significance of securing insurance policies, risk avoidance, risk reduction, and risk transfer in mitigating financial risks. Moreover, one respondent emphasized the importance of diversifying income sources, adopting risk avoidance strategies, and fostering clear communication among all project stakeholders as effective measures to mitigate financial risks.

The identified strategies are vital for improving financial risk management in building construction projects in Sri Lanka. By employing these recommended measures, stakeholders can enhance their ability to respond to potential financial challenges, ultimately leading to more successful and financially stable construction projects.

TABLE VII. STRATEGIES FOR MITIGATING FINANCIAL RISKS INVOLVED IN BUILDING CONSTRUCTION PROJECTS IN SRI LANKA

No	Strategies to mitigate the financial risks	1st Respondent	2nd Respondent	3rd Respondent
1	Securing insurance policies	x	✓	✓
2	Building an emergency fund	✓	✓	✓
3	Diversifying income sources	x	✓	x
4	Risk avoidance	x	✓	x
5	Risk reduction	✓	✓	x
6	Risk transfer	✓	✓	x
7	Risk retention	✓	✓	✓
8	Have a contingency plan	✓	✓	✓
9	Clear communication between all parties involved in the project	x	✓	x

VII. CONCLUSION(S)/ IMPLICATIONS/ RECOMMENDATIONS & LIMITATIONS

This study exclusively focused on mitigating financial risks in building construction projects in Sri Lanka's Colombo suburbs, particularly for high-rise buildings costing more than 100 million rupees.

Among the risk factors, unmanaged cash flows, inadequate financial management, bankruptcy, errors in estimating, liquidity risk, changes in government legislation, and the fluctuation of the inflation rate showed the highest

impact on budget performance issues. In contrast, insurance risk had the lowest impact.

Based on expert interviews, building an emergency fund, ensuring risk retention, and having a contingency plan were highly recommended methods for mitigating financial risks. On the other hand, diversifying income sources and clear communication between project stakeholders were least preferred.

The study suggests implementing suitable strategies to mitigate financial risks in building construction projects in Sri Lanka. Additionally, it proposes a critical examination of the least preferred methods for further research to improve risk mitigation in the Sri Lankan construction industry.

REFERENCES

- [1] Iqbal, S.; Choudhry, R.; Holschemacher, K.; Ali, A.; Tamošaitienė, J. (2015). Risk management in construction projects, Technological and Economic Development of Economy.
- [2] Perera, B.A.K.S., Samarakkody, A.L. and Nandasena, S.R. (2020). Managing financial and economic risks associated with high-rise apartment building construction in Sri Lanka. *Journal of Financial Management of Property and Construction*, 25(1), pp.143–162.
- [3] Banaitienė, N.; Banaitis, A.; Norkus, A. (2011). Risk management in projects: peculiarities of Lithuanian construction companies, *International Journal of Strategic Property Management*.
- [4] Chen, J.; Hsu, S.; Luo, Y.; Skibniewski, M. (2012). Knowledge management for risk hedging by construction material suppliers, *Journal of Management in Engineering*.
- [5] Sakthiniveditha, V. and Pradeep, T. (2015), "A study on risk assessment in the construction of high-rise buildings", *International Journal of Science and Engineering Research (IJOSER)*.
- [6] Chougule, A. and Waghmare, A. (2015), "Risk management in high-rise building construction", *International Journal for Scientific Research and Development*, Vol. 3 No. 6, pp. 601-602.
- [7] Jayasundera, D. (2017), "Five trends in Sri Lanka's condo market", available at: <https://echelon.lk/home/five-trends-in-sri-lankas-condo-market/>.
- [8] Mayes, S. (2018), "Sri Lanka real estate market: 2018 predictions", available at: www.ft.lk/propertyconstruction/Sri-Lanka-real-estate-market-2018-predictions/10516649047.
- [9] Al-Joburi, K. I., Al-Aomar, R. & Bahri, M. E., (2012). Analyzing the Impact of Negative Cash Flow on Construction Performance in the Dubai Area. *Journal of Management In Engineering*, October, Volume 28, pp. 382-390.
- [10] Rahman, H. A., Wang, C., Takim, R. & Wong, S., (2011). Project Schedule Influenced by Financial Issues: Evidence in Construction Industry. *Scientific Research and Essays*, 4 January, Volume 6, pp. 205-212.
- [11] Chan, D. W. M., Lam, K. Y. K., & Tam, C. M. (2016). Cost overruns and delay in construction projects: A systematic review. *International Journal of Project Management*, 34(4), 586-604.
- [12] Haque, M. E., Khondker, B. H., & Hasan, M. Z. (2017). Determining the causes of cost overruns and time delays in construction projects in Bangladesh. *Journal of Financial Management of Property and Construction*, 22(3), 288-307.
- [13] Jayasudha, K. and Vidivelli, B. (2016), "Analysis of major risk in construction projects", *ARP Journal of Engineering and Applied Sciences*, Vol. 11 No. 11.
- [14] - Chavan, S., & Salunkhe, H. (2016). A Study on labour productivity in construction sites of Kodagu Region. *International Journal of Technical Research and Applications*, 4(3), 183-188. Retrieved from www.ijtra.com.
- [15] Hadiwattege, C., & Senaratne, S. (2012). A literature synthesis: is the construction industry low responsive to change and development? *World Construction Symposium 2012: Global Challenges in Construction Industry: 28-30 June 2012* (pp. 152-161). Colombo: Ceylon Institute of Builders - Sri Lanka.

- [16] Vavra, C. (2022). Mitigating financial risk in large construction projects. [online] Consulting-Specifying Engineer. Available at: <https://www.csemag.com/articles/mitigating-financial-risk-in-large-construction>.
- [17] Skitmore, M. (2011). Risk management in construction projects (3rd ed.). Routledge.
- [18] Al-Hammad, A. M. (2012). Identifying major risks in construction projects: A survey study. *International Journal of Business and Management*, 7(3), 79-91.
- [19] Jayawardena, C., Fernando, W., & Gnanarajah, S. (2012). Risk assessment of building construction projects in Sri Lanka. *Journal of Engineering, Design and Technology*, 10(2), 174-188.
- [20] Kolhatkar, M. J. and Dutta, A. B. (2013). Financial risks and construction projects. *International Journal of Application or Innovation in Engineering & Management (IJAIEM)*, ISSN 2319 – 4847.
- [21] Perera, B.A.K.S., Samarakkody, A.L. and Nandasena, S.R. (2020). Managing financial and economic risks associated with high-rise apartment building construction in Sri Lanka. *Journal of Financial Management of Property and Construction*, 25(1), pp.143–162.
- [22] Chan, D. W. M., Ho, D. C. K., & Tam, C. M. (2017). Factors affecting the accuracy of cost estimates in public works projects. *Journal of Construction Engineering and Management*, 143(6), 04017010.
- [23] Loo et al., 2014 - Loo, P. L., Ismail, S., & Jasman, Z. M. (2014). Cash flow management practices among construction firms in Malaysia. *Procedia-Social and Behavioral Sciences*, 129, 209-216.
- [24] Ndekugri et al., 2001 - Ndekugri, I., Jones, D., & Runeson, G. (2001). Payment delay and disruption in construction contracts. *Journal of Construction Engineering and Management*, 127(6), 494-501.
- [25] Hosseini, M. R., & Yavari, S. (2019). Factors affecting cash flow management in construction projects. *Journal of Construction Engineering and Management*, 145(5), 04019022.
- [26] Gunawardena, K. K. S. and Jayasuriya, K. B. (2016). "An analysis of the financial risk factors affecting construction projects in Sri Lanka".
- [27] Memon, A. H., Rahman, I. A., & Azis, A. A. (2011). Preliminary Study on Causative Factors Leading to Construction Cost Overrun. *International Journal of Sustainable Construction Engineering & Technology*, 2(1), 57-71. Retrieved from <http://penerbit.uthm.edu.my/ojs/index.php/IJSCET/article/view/49>.
- [28] Dissanayake, K. G. S. and Bandara, R. M. S. R. (2015). "Financial risk analysis of construction projects: A case study of Sri Lanka".
- [29] Project Management Institute (PMI): A Guide to the Project Management Body of Knowledge (PMBOK Guide).
- [30] Solakoglu, A. (2018). Construction Cost Control and Value Engineering. In R. M. McConathy (Ed.), *Construction Cost Estimating and Cost Control* (pp. 79-99). John Wiley & Sons.
- [31] Chan, D. W., & Chan, A. P. (2004). "Key performance indicators for measuring construction success." *Benchmarking: An International Journal*, 11(2), 203-221.
- [32] Kerzner, H., & Kerzner, H. R. (2017). Project management: a systems approach to planning, scheduling, and controlling. John Wiley & Sons.
- [33] Baloi, D., & Price, A. D. (2003). Modelling global risk factors affecting construction cost performance. *International Journal of Project Management*, 21(4), 261-269.
- [34] Seneviratne, S.M.R., Bandara, W.M.N.W., and Kumara, K.A.S.K. (2014). Budget performance of building construction projects in the Colombo District of Sri Lanka. *Journal of Management in Engineering*, Vol. 30, No. 4, pp. 04014028.
- [35] Wijesinghe, W.M.T.B., & Wijekoon, K.D.S. (2013). Project management in the construction industry of Sri Lanka: A review. *International Journal of Project Management*, 31(2), 238-248.
- [36] Gunawardena, K. K. S. and Jayasuriya, K. B. (2017). "The impact of financial risks on the budget performance of construction projects in Sri Lanka".
- [37] Atapattu, S., & Jayasinghe, S. (2016). Factors Influencing the Budget Performance of Building Construction Projects in Sri Lanka. *Journal of the Eastern Province of Sri Lanka*, 7, 23-34.
- [38] Goyal, R., & Arora, R. (2017). A study of cost overruns in building construction.
- [39] Kothari, C. R. (2004). *Research methodology : methods and techniques* (2nd ed.). New Delhi: New Age International. Retrieved from <https://books.google.lk/books?hl=en&lr=&id=hZ9wSHysQDYC&oi>.
- [40] Kumar, R. (2011). *Research methodology: A step by step guide for beginners* (8th ed.). India: Dorling Kindersley.
- [41] Likert, R. (1932), 'A Technique for Measuring Attitudes Archives of Psychology', 140 1 – 55.

The Impact of Challenges of Current Economic Crisis on the Performance of Sri Lankan Building Construction Projects.

G.A.S. Gunathilaka
Department of Quantity Surveying
University of Vocational
Technology
Sri Lanka
subodhani1991@gmail.com

U. Sivachelvy
Department of Management Studies
University of Vocational Technology
Sri Lanka
sivachelvy@uovt.ac.lk

S. R. M. P. Seneviratne
Department of Quantity Surveying
University of Vocational Technology
Sri Lanka
srmpseneviratnaunivotec@gmail
/

Abstract- Sri Lankan building construction projects face significant obstacles specifically, as a result of the economic crisis in the year 2019-2022. This research is conducted to identify the correlation between the critical challenges of the Economic Crisis of the construction sector of Sri Lanka (2019-2022), on project performance variables, and derive corrective measures to mitigate the impacts. The research focuses as objectives on identifying the critical challenges of a construction project, and further identifying the Project performance criteria for building construction projects. Research also identified the correlation between the most critical challenges of the Economic Crisis, with construction project performance. It also suggested corrective measures to mitigate the impacts. The mixed method was applied in the methodology. Data was analyzed using Excel and SPSS software. Among 21 critical challenges, 12 most preferred factors were identified over the ranking of factors by Relative Importance Index (RII)/ Further, the correlation between the ranged 12 critical challenges, with project performance variables: time, cost, and quality were identified. As per the findings, it was found that, considered three project performance indices: time, cost and quality. Key 12 performance metrics have impact positive and negative versions, on the current building construction performance.

Keywords:- construction, challenges, economic crisis, correlation, immediate attention

I. INTRODUCTION

The growth of the Sri Lankan economy is significantly influenced by the construction industry activities [1]. Any type of construction business is always at risk from unforeseen events [2]. Some actions and decisions are needed to mitigate and remove those challenges and protect the industry [3].

An "economic crisis" is any circumstance where financial assets or institutions experience an abrupt and significant decline in value [4]. The Sri Lankan economy has been in a state of economic crisis since

2018 and many issues are contributing to this crisis, such as trade imbalances, declining foreign exchange reserves, growing public debt, and the COVID-19 pandemic in 2020 [5]. The financial crisis-induced global downturn is affecting the real economy, and the construction industry is beginning to show signs of a financial crisis, primarily in the form of postponed investment and cancellation of contracts. Additionally, construction firms encounter financial challenges, and in some dire circumstances, even bankruptcy occurrences, [6]. The country's economy has been severely hampered by Sri Lanka's economic crisis, which has had a major impact on the construction industry [5]. The economic crisis caused a decrease in building projects, which led to job losses, especially for contractor businesses. Many workers were laid off, and others had their hours reduced [7]. The construction industry is vulnerable to collapse due to the ongoing economic crisis, as demonstrated by [8]. Therefore, it is important to identify the critical challenges that have arisen due to the economic crisis in order to uplift, protect, and identify premises. It also needs to take reactive measures to adapt to the current context of the construction industry for the future and the present. Yet, identifying the critical challenges of the current economic crisis on the performance of construction projects in Sri Lanka has not been revealed properly. Therefore, it is important to focus on identifying the challenges of the economic crisis on the performance of construction projects in Sri Lanka that require immediate attention and effective mechanisms to develop and sustain the construction sector in Sri Lanka.

II. AIMS AND OBJECTIVES

The objectives of the research are

- To identify the critical aspects of Project performance criteria for building construction projects.
- To identify the most critical challenges that are posed by the economic crisis on the building project performance in Sri Lanka.
- Identify the correlation between the challenges of the Economic Crisis that occurred in the year 2019-2022 on building construction project performance.
- To derive corrective measures to mitigate the impacts of the economic crisis on the building construction project performance of Sri Lanka.

III. LITERATURE REVIEW

A. *Project performance criteria for a construction project.*

The idea that a project's performance metrics time, cost, and quality are generally accepted [9]. Meeting a project's budget, schedule, workmanship standard, stakeholder satisfaction, technology transfer, and health and safety standards are varied criteria used to evaluate projects similarly [10]. According to Chan [11], several other important factors, including health and safety, environmental performance, user expectations and satisfaction, contractor satisfaction, and commercial value, also used to gauge a project's success.

B. *An overview of the economic crisis (2019-2022) in Sri Lanka*

In 2022 Sri Lanka's economy turn down to a significantly lower rate, as per the world economy [12]. As a result, there identified a shortage of daily necessities [12] [13] [14]. The roots of the noted economic crisis are understood as spread also over political and social spars [13]. The multi-faced crisis impacted households, businesses, and communities [15] [16].

1) *Challenges faced by the Sri Lankan building construction industry due to the Current crisis (2019- 2022).*

The economic crisis has impacted the Sri Lankan construction industry in several ways as other industries and created a hardship on construction project performance [15]. [17], pointed out that one of the major reasons for the downturn in construction performance was impacted by travel restrictions due to Covid 19. However, the multiple root causes of the Sri Lankan crisis (2019-2022) together impacted

negatively on the Sri Lankan Construction project performance, as discussed below.

a) *High inflation (Unprecedented cost escalations)*

The inflation of commodities results from excessive money printing by the Government during 2019-2022 [18]. According to [19], the price commodity inflation rate breached 50 percent in 2022. Also, construction material prices significantly increased.

b) *High foreign currency exchange rates*

The result of the noted economic mismanagement of the Sri Lankan government diminished the value of the rupee and significantly impacted foreign exchange rates [13] [19]. Researchers who studied Sri Lanka's crisis have identified that high foreign exchanges had limited essential imports to households as well as industrial use. Accordingly [17], the acceleration of the foreign exchange rates directly affected construction costs and performance.

a)c) *Restrictions on forward contracts of foreign exchange, import restrictions, and material shortage.*

[20] Posited as per the CBSL instructions of the licensed commercial banks for a period of three months maintain a refraining process for entering at forward contracts (foreign exchange) that will prevent excessive volatility of the market of foreign exchange. Import restrictions and limitations place mitigate the deduction of foreign reserves, further found with a significant effect on producers and the supply chain [17] on consumption goods, and capital goods [18].

The significant factor that contributed to the disruption of supply chains due to the global pandemic was travel restrictions imposed by the government, which impacted both labor and materials and significantly disrupted their supply chain channels [21].

However, [15] highlighted that 70% of Sri Lankan construction materials requirements depend on imports. Accordingly, during 2019- 2022 import restriction measures because of the negative foreign reserves in the country led to the raw material shortage in Sri Lanka. However, in general, a 40%-60% tax is based on imported contrition materials [22].

d) *Fuel and power crisis*

[15] Established that a fuel shortage causes stoppage of essential services.

e) *Significant project delays*

Nearly 90% of Sri Lanka's construction projects have been halted due to the impacts of the ongoing

crisis [23]. Due to the impacts of the Covid-19 and the economic crisis, some of the mega condominium development projects in Sri Lanka were halted [17].

f) Unprecedented payment delays

During the crisis, as clients are at significant risks such as losses, bankruptcy, high loan interest, and rental costs for office buildings and rented plants and machinery, there is the potential for claims and payment delays by clients [24]. Accordingly, [22] found that Sri Lankan contractors are struggling with high bank loan interest rates of 15%-25%, whereas other foreign contractors have 1%-3%, hence foreign contractors who engage with the national project but operate their financial accounts outside the country have more favorable situation than local contractors.

g) Government policy changes

According to [15], the Sri Lankan government and Central Bank (CBSL) have taken instant recovery strategies such as import restrictions, fuel, and power price increments. Further, the IMF recommended re-implementing and upgrading previous tax policies which were amended in 2019 (fiscal rules were suspended), the automatic fuel price mechanism, and lower price reform which was halted in 2019 [18].

II. METHODOLOGY

The research focuses on identifying the critical challenges of a construction project, identifying the Project performance criteria for building construction projects, to identifying the correlation between the two sets of variables. A mixed research design approach was carried out in the research. to identify critical challenges a question survey was carried out, and data collected from a non-random sample of 35 engineers, quantity surveyors, and project managers (C1, C2, C4 grade) contractors used in the survey. The most critical challenges which are posed by the economic crisis on the building project performance in Sri Lanka and responsive strategies were according to a 5-point Likert scale.

Data for critical challenges are analyzed using Excel software and the ranking of factors is calculated based on the Relative Importance Index (RII), to identify the most critical performance challenges.

$$RII \% = \sum a \times \frac{n}{N} \times \frac{100}{5} \quad (1)$$

Where is constant expressing the weighting given to each response, n is frequency of responses and N is total number in the responses. The most critical challenges that are posed by the economic crisis on the building project performance in Sri Lanka.

After identifying the most critical challenges selected over an RII evaluation, a secondary Google Survey questionnaire was carried out to identify the correlation between the identified most critical challenges and Project performance criteria (cost, time, and quality) on building construction project performance. Data was analyzed using SPSS software and calculated the correlation.

Finally, findings were validated over 05 semi-structured interviews conducted with Managing Directors and Chief Quantity surveyors to derive corrective measures to mitigate the impacts of the economic crisis on the building construction project performance.

III. DATA ANALYSIS AND RESEARCH FINDINGS

A. Project performance criteria: construction project.

The project's performance variables were identified as per the literature review. Accordingly, time, cost, and quality are generally accepted [9]. Meeting a project's budget, schedule, workmanship standard, stakeholder satisfaction, technology transfer, and health and safety standards are just a few of the varied criteria used to evaluate projects Similarly [25], According to [11] a number of other important factors, including health and safety, environmental performance, user expectations and satisfaction, contractor satisfaction, and commercial value, are also used to gauge a project's success

Figured out how to gauge project performance, cost, time, quality, client satisfaction, functionality health, and safety.

A. Identify the critical Challenges of the Economic crisis of Sri Lanka (Research Objective 1)

Based on the literature review and questionnaire survey findings critical challenges of highly impacted construction performance due to the economic crisis. It is indicated in TABLE I.

21 critical challenges have been recognized and will be taken into consideration for this research study are shown in TABLE I.

TABLE 1 . CRITICAL CHALLENGES OF THE CURRENT ECONOMIC CRISIS ON THE PERFORMANCE OF SRI LANKAN CONSTRUCTION PROJECTS

CRITICAL CHALLENGES OF CURRENT ECONOMIC CRISIS ON THE PERFORMANCE OF SRI LANKAN BUILDING CONSTRUCTION PROJECTS			
	Question	RII	Rank
	There is a relationship between the Government Policies and the performance of the construction projects		
1	Increasing Recovery action by banks will affect the Performance of Sri Lankan construction projects.	0.931	1
2	Changing government priorities for various sociological will the Performance of the Sri Lankan construction project	0.800	8
3	The performance of construction projects in Sri Lanka will be positively affected when the government stops importing materials from foreign markets	0.800	8
	There is no relationship between the Exchange Rates and the performance of the construction projects		
4	Changing Exchange Rates will not affect the Performance of Sri Lankan construction projects with local materials.	0.543	12
	There is a relationship between the Exchange Rates and the performance of the construction projects		
5	Changing Exchange Rates will affect the Performance of Sri Lankan construction projects with import materials.	0.863	5
6	Changing Exchange Rates will affect the Performance of Sri Lankan construction projects with Difficulties in importing raw materials to manufacture construction materials.	0.834	6
7	Fluctuation of the exchange rate will affect the Performance of Sri Lankan construction projects.	0.874	3
	There is a relationship between the socio- economic and the performance of the construction projects		
8	Shortage of construction materials will affect the Performance of Sri Lankan construction projects.	0.931	1
9	A shortage of Skilled laborers will affect the Performance of Sri Lankan construction projects.	0.874	3
10	Lack of initiatives will affect the Performance of Sri Lankan construction projects.	0.800	8
11	Lack of opportunities will affect the Performance of Sri Lankan construction projects.	0.800	8
12	Suspension of capital expenditure works will affect the Performance of the Sri Lankan construction projects.	0.800	8
13	Changing government priorities for various sociological will affect the Performance of Sri Lankan construction projects.	0.869	4

	Attitudes are an important concept in helping people to understand their social world. They help us to define how we perceive and think about others, as well as how we behave towards them. There is a relationship between the Attitudes and the performance of the construction projects		
14	People's attitudes related to material waste are directly or indirectly affected by the behavior of the construction and the performance of the construction projects.	0.754	10
15	Directly or indirectly affects people's attitudes towards the use of natural resources, and the performance of construction projects.	0.709	11
	There is a relationship between the Political situation and the performance of construction projects		
16	Political risks also arise from corruption, nepotism, and cronyism at all political levels. The performance of the building project in the country will be directly affected by political circumstances.	0.766	9
	There is a relationship between the Interest Rates and the performance of the construction projects		
17	Increasing Interest Rates will affect the Performance of Sri Lankan construction projects with supply chain issues and increased costs for building materials.	0.874	3
18	Lack of funds will affect the Performance of Sri Lankan construction projects, with project cash flow issues.	0.880	2
19	Inadequate investment plans will affect the Performance of Sri Lankan construction projects	0.817	7
20	Delays in payments for work done will affect the Performance of Sri Lankan construction projects	0.834	6
21	Unprecedented cost escalations will affect the Performance of Sri Lankan construction projects.	0.817	7

B. Identify the most critical Challenges of the Economic crisis of Sri Lanka (Research Objective 2)

Based on the literature review and questionnaire survey findings identify the critical challenges of highly impacted construction performance due to the economic crisis. To identify the most critical challenges of highly impacted construction performance due to the economic crisis, the Relative Important Index (RII) has been used for this research study. Based on the analysis 12 most preferred factors among 21 challenges have been identified. It is indicated in TABLE 2. According to TABLE 2, There are 12 most preferred factors among 21 factors that have been selected as the most critical challenges of economic crisis based on the RII values ranging.

TABLE II. THE MOST CRITICAL CHALLENGES OF THE CURRENT ECONOMIC CRISIS ON THE PERFORMANCE OF SRI LANKAN CONSTRUCTION PROJECTS

THE MOST CRITICAL CHALLENGES OF THE CURRENT ECONOMIC CRISIS ON THE PERFORMANCE OF SRI LANKAN BUILDING CONSTRUCTION PROJECTS			
No	Question	RII	Rank
1	There is a relationship between the Government Policies and the performance of the construction projects. Increasing Recovery action by banks will affect the Performance of Sri Lankan construction projects.	0.931	1
02	There is a relationship between the Socio-economic and the performance of the construction projects Shortage of construction materials will affect the Performance of Sri Lankan construction projects.	0.931	1
3	There is a relationship between the Interest Rates and the performance of the construction projects. Lack of funds will affect the Performance of Sri Lankan construction projects, with project cash flow issues.	0.880	2
4	There is a relationship between the Exchange Rates and the performance of the construction projects. Fluctuation of the exchange rate will affect the Performance of Sri Lankan construction projects.	0.874	3
5	There is a relationship between the socio-economic and the performance of the construction projects. Shortage of Skilled laborers will affect the Performance of Sri Lankan construction projects.	0.874	3
6	There is a relationship between the Interest Rates and the performance of the construction projects. Increasing Interest Rates will affect the Performance of Sri Lankan construction projects with supply chain issues and increased costs for building materials.	0.874	3
7	There is a relationship between the socio-economic and the performance of the construction projects.		

	Changing government priorities for various sociological will affect the Performance of Sri Lankan construction projects.	0.869	4
8	There is a relationship between the Exchange Rates and the performance of the construction projects. Changing Exchange Rates will affect the Performance of Sri Lankan construction projects with import materials.	0.863	5
9	Changing Exchange Rates will affect the Performance of Sri Lankan construction projects with Difficulties in importing raw materials to manufacture construction materials.	0.834	6
10	There is a relationship between the Interest Rates and the performance of the construction projects. Delays in payments for work done will affect the Performance of Sri Lankan construction projects.	0.834	6
11	There is a relationship between the Interest Rates and the performance of the construction projects. Inadequate investment plans will affect the Performance of Sri Lankan construction projects.	0.817	7
12	Unprecedented cost escalations will affect the Performance of Sri Lankan construction projects.	0.817	7

C. Analysis of research objective (3) - Correlation between the challenges of the economic crisis that occurred (2019-22) on project performance criteria of Sri Lankan building construction projects.

Findings are based on the data collected from the questionnaire and calculated correlation between the most critical challenges and cost time or quality variables.

1) *Identified challenges correlated with cost performance criterion in the construction project.*

TABLE III: Details of the identified challenges correlated with cost performance criterion

Identified challenges	Cost	
	Pearson Correlation	Sig. (2-tailed)
Increasing Recovery action by banks	-0.095	0.589
Shortage of construction materials	0.359*	0.034
Lack of funds with project cash flow issues	0.163	0.350
Fluctuation of the exchange rate	-0.181	0.299
Shortage of Skilled labors	-0.024	0.890
Increasing Interest Rates with supply chain issues and increased costs for building material	0.242	0.161
Changing government priorities for various sociological	0.148	0.397
Changing Exchange Rates with import materials	0.169	0.333
Changing of Exchange Rates with Difficulties in importing raw materials to manufacture construction materials.	-0.135	0.441
Delays in payments for work done	-0.004	0.983
Inadequate investment plans	0.273	0.113
Unprecedented cost escalations	0.327	0.055

According to TABLE 3 Shortage of construction materials, Lack of funds due to project cash flow issues, Increasing of Interest Rate with supply chain issues and increased costs for building materials, Changing government priorities for various sociological, Changing of Exchange Rates with import materials, Inadequate investment plans and Unprecedented cost escalations variable are positively correlated with the cost performance criterion of construction project. At the same time from those positively correlated 7 variables, only the Shortage of construction materials variable correlation significant value (.034) is statistically significant ($\text{sig} < 0.05$) and the rest of the 6 variables are not statistically significant. When considering the correlation of the 7 variable factors with the cost performance criterion, a positive value means changes in the challenge variable positively or negatively change the cost performance of the construction project. To improve the cost criterion performance of the construction projects, need to

improve the 7 most critical challenges identified by the correlation values.

2) *Identified challenges correlated with time performance criterion in the construction project.*

TABLE IV: DETAILS OF THE IDENTIFIED CHALLENGES CORRELATED WITH TIME PERFORMANCE CRITERION

Identified challenges	Time	
	Pearson Correlation	Sig. (2-tailed)
Increasing Recovery action by banks	-0.138	0.429
Shortage of construction materials	0.093	0.594
Lack of funds with project cash flow issues	0.048	0.784
Fluctuation of the exchange rate	0.110	0.529
Shortage of Skilled labors	0.030	0.865
Increasing Interest Rate with supply chain issues and increased costs for building material	0.002	0.992
Changing government priorities for various sociological	0.022	0.899
Changing of Exchange Rates with import materials	-0.160	0.359
Changing Exchange Rates with Difficulties in importing raw materials to manufacture construction materials.	-0.108	0.535
Delays in payments for work done	0.370*	0.028
Inadequate investment plans	0.197	0.256
Unprecedented cost escalations	-0.140	0.422

According to TABLE 4 Shortage of construction materials, Lack of funds with project cash flow issues, Fluctuation of the exchange rate, Shortage of Skilled laborers, Increasing of Interest Rate with supply chain issues and increased costs for building materials, Changing government priorities for various sociological, Delays in payments for work done and Inadequate investment plans variable are positively correlated with the time performance criterion of the construction project. At the same time from those positively correlated 8 variables, only delays in payments for work done variable correlation (.028) is statistically significant ($\text{sig} < 0.05$) and the rest of the 7 variables are not statistically significant. When considering the correlation of the 8 variable factors with the time performance criterion, a positive value means changes in the challenge variable positively or negatively change the time performance of the project. To improve the time criterion performance of the

construction projects, need to improve the 8 most critical challenges identified by the correlation values.

- 3) *Identified challenges correlated with quality performance criterion in the construction project.*

TABLE V: DETAILS OF THE IDENTIFIED CHALLENGES CORRELATED WITH QUALITY PERFORMANCE CRITERION

Identified challenges	Quality	
	Pearson Correlation	Sig. (2-tailed)
Increasing Recovery action by banks	0.056	0.748
Shortage of construction materials	-0.147	0.401
Lack of funds with project cash flow issues	-0.072	0.680
Fluctuation of the exchange rate	0.131	0.453
Shortage of Skilled labors	-0.226	0.191
Increasing Interest Rate with supply chain issues and increased costs for building material	-0.082	0.641
Changing government priorities for various sociological	0.205	0.239
Changing of Exchange Rates with import materials	0.082	0.640
Changing Exchange Rates with Difficulties in importing raw materials to manufacture construction materials.	-0.231	0.183
Delays in payments for work done	-0.106	0.544
Inadequate investment plans	0.169	0.331
Unprecedented cost escalations	0.169	0.331

According to TABLE 5 Increasing Recovery action by banks, Fluctuation of the exchange rate, changing government priorities for various sociological, Changing of Exchange Rates with import materials, inadequate investment plans, and Unprecedented cost escalations variable are positively correlated with the quality performance criterion of construction project. At the same time, for all those positively correlated 6 variables, correlation-significant values are not statistically significant because their values are more than > 0.05 . When considering the correlation of the 6 variable factors with the quality performance criterion, a positive value means changes in the challenge variable positively or negatively change the quality performance of the construction project. To improve

the quality criterion performance of the construction projects, need to improve the 6 most critical challenges identified by the correlation values.

D. Analysis of Research Objective - 4

It is very important to find out the effective mechanisms, to protect the construction industry and its performance immediately, which have ceased today due to the economic crisis according to the interviewees' answers based on industry experiences and openings from semi-structured interviews conducted with senior management professionals to validate the literature findings, reinforce the findings from the initial staff career questionnaire, and address the fourth objective is as follows;

- 1) *Immediate attention on increasing recovery action by the banks with Government policy changes.*
 - Maintain good relationships with banks
 - Prioritize cash flow management
 - Engage in dialogue with the government
 - Prioritize cost management
- 2) *Shortage of construction materials*
 - Find substitute material locally
 - Relax import control regulations.
 - Reducing the wastage of material
- 3) *Immediate focus on maintaining stability in finances.*
 - Develop a financial plan
 - Prioritize cost management
 - Maintain good relationships with stakeholders
- 4) *Positively dealing with exchange rate fluctuations*
 - Adopt a hedging strategy
 - Monitor exchange rates
- 5) *Prioritize retaining qualified laborers on-site right away.*
 - Encourage vocational training
 - Increase wages and benefits
 - Use technology and automation
 - Improve working conditions

- 6) *Immediate focus on supply chain difficulties and cost increases.*
 - Plan and budget carefully
 - Negotiate favorable contracts
 - Optimize supply chain management
 - Monitor interest rate changes
- 7) *Immediate attention on changing government priorities for various sociological.*
 - To address changing government priorities, it's important to build flexibility into construction projects.
 - Communication is key when government priorities change.
 - Focus on project outcomes.
 - Foster a culture of innovation
 - Emphasize risk management
- 8) *Immediate attention to the difficulties posed by importing raw materials for the production of construction materials and construction materials.*
 - Diversify suppliers
 - Invest in local manufacturing
 - Monitor exchange rates.
- 9) *Immediate attention to Delay in payments for work done.*
 - Establish clear payment terms Construction companies should establish clear payment terms with clients at the outset of the project.
 - Monitor cash flow
 - Consider legal options
- 10) *Immediate attention on inadequate investment plans.*
 - Develop a comprehensive investment plan.
 - Use project management tools
 - Prioritize value engineering
- 11) *Immediate attention on unprecedented cost escalations items or materials.*
 - Engage experienced professionals.
 - Use alternative materials.

- Get government assistance.

- 12) *Effective planning and design are crucial to mitigate cost escalations.*
 - In addition to the above, there are some other tips for overcoming cost escalation in construction projects.
 - Start planning early.
 - Build in the contingency fund

IV. CONCLUSION

The research emphasizes the important and crucial components of construction project performance criteria, the biggest challenges to project performance caused by the economic crisis, the correlation between the challenges posed by the 2019–2022 economic crisis, and derive corrective measures to mitigate the impacts of the economic crisis on the building construction project performance of Sri Lanka. The thorough literature review, questionnaire surveys, and semi-structured interviews with professionals in the construction industry all contributed to the research's accomplishment of its aim. The research findings indicate that in building construction projects, the most important components of the project performance criteria have been identified to be time, cost, and quality. There was no discernible difference in the RII value of the 21 identified construction challenges. It implies that none of these construction-related challenges are any less pressing given the current economic crisis. However, only 12 of the highest value points have been taken into consideration. The most important finding is that all identified challenges and the correlation between the three key performance metrics have an impact on the current building construction performance. This decision was made as a result of the fact that every response was either strongly agreeing or responding with a higher percentage of agreeing. According to the information gathered from the interviews, it is recommended that management level staff in the construction industry should take necessary measures to reduce the impact of the economic crisis on the success of building construction projects performance in Sri Lanka. These findings measures may have been mentioned above 5.5 under the analysis of research objective 4, derive corrective measures to mitigate the impacts of the economic crisis on the building construction project performance of Sri Lanka.

These measures may include working to change the contract provision about the payment system and price fluctuations method for all materials, not just a select few, utilizing local market options to reserve a spot for

the government's locally produced materials, and bargaining with foreign parties for credit facilities for materials. Even construction companies should assess and forecast their risk, and used to effective project management is essential for managing cost, they insist that a should be built a contingency fund to cover unexpected cost increases and obtain appropriate measures to stabilize the construction industry, including alterations to the procurement process. By implementing these strategies, the construction sector in Sri Lanka can be stabilized and sustainable growth can be attained.

V. RECOMMENDATIONS

The research can make the following recommendations for better building construction project performance in Sri Lanka during the current economic crisis. Shifting towards value engineering and leaning towards using local resources, The government should (ICTAD) incorporate price increases to account for inflation and high import taxes into the formula used to determine price escalations,

The construction industry is surrounded by many jobs and related lives and in an effort to protect it, the government provides loan relief to business owners who manage the sector. Many educated workers in the construction industry are emigrating because of the country's high unemployment rate. In order to prevent them from leaving the country, the government and organizations in the construction sector need to look into this. If not, they will benefit from free education in this nation and export its benefits to other nations. The government should give locally produced building materials a chance. This should be a relief for all local manufacturers who make those building materials, not just one, and the government should make sure that the raw materials are sold for a very fair price. Sri Lanka Should work with important financial institutions and partners to develop a new social security system, lower debts, ensure fair taxes, and fight corruption at the highest levels of the government challenge to the economic crisis.

VIII. REFERENCES

- [1]. Silva,Rajakaruna & Bandara, 2008. Challenges Faced By The Construction Industry In Sri Lanka: Perspective Of Clients And Contractors.
- [2]. Okema J.E (2000) 'Risk and Uncertainty Management of Projects: Challenges of Construction Industry', Challenges Facing the Construction Industry in Developing Countries, (1990).
- [3]. Bandara ,Nayanthara & Rajakaruna (2008). Challenges faced by the construction industry in Sri Lanka: perspective of clients and contractors.
- [4]. Gazi, M. A. I., Nahiduzzaman, M., Harymawan, I., Masud, A. A., & Dhar, B. K. (2022). Impact of COVID-19 on financial performance and profitability of banking sector in special reference to private commercial banks: empirical evidence from Bangladesh. Sustainability.
- [5]. Nistorescu & Ploscaru, 2010. Impact Of Economic And Financial Crisis In The Construction Industry.
- [6]. De Silva, S.S., Wijekoon, W.M.C.L.K. and Kalugala, C., 2023. Impact of economic crisis on employees of contractors' organisations in the Sri Lankan construction industry. In: Sandanayake, Y.G., Waidyasekara, 11th K.G.A.S., Ramachandra, T. and Ranadewa, K.A.T.O. (eds). Proceedings of the World Construction Symposium, 21-22 July 2023, Sri Lanka. [Online]. pp. 557-568. DOI: <https://doi.org/10.31705/WCS.2023.46>. Available from: <https://ciobwcs.com/papers/>
- [7]. Fadhil, G. A., & Burhan, A. M. (2021). Investigating the Effects of Economic Crisis on Construction Projects in Iraq. In E3S Web of Conferences (Vol. 318, p. 02005). EDP Sciences.
- [8]. Lanka News Wed. (2022, April 24). Sri Lanka's construction industry faces a threat of collapse. Lanka News Web. Retrieved from <https://lankanewsweb.net/archives/9610/sri-lankas-construction-industry-faces-a-threat-of-collapse/>
- [9]. Barkley, B. and Saylor, J. (1994) Customer-driven Project Management. New York: McGraw-Hill. Biazzo, S. and Bernardi, G. (2003) Process management practices and quality systems standards: Risks and opportunities of the new ISO 9001 certification. Business Process Management Journal 9 (2): 149 – 169.
- [10]. Kumaraswamy , M . M . and Thorpe , A . (1999) Systematizing construction project evaluations.Journal of Management in Engineering 12 (1) : 34 – 39.
- [11]. Chan , A.P.C . and Tam , C.M.(2000) Factors affecting the quality of building projects in Hong Kong . International Journal of Quality & Reliability Management 17 (4/5) : 423 – 441.
- [12].Kaur. S, (2022) 'Sri Lanka Crisis' Available at SSRN.
- [13]. Cooray, N.S. and Rankaduwa, W., 2022. Political Economy Perspectives on the Current Economic Crisis in Sri Lanka', Politics & International Relations Series.
- [14]. Devapriya, U. (2022) 'The crisis in Sri Lanka: economic and political dimensions', *Journal of Indo-Pacific Affairs*. Air University Press. Published August, 12.
- [15]. Parameswaran.A, Palliyaguru.R and Ranadewa.T, 2022. Emerging from the crisis: A new beginning for the construction Industry of Sri Lanka.
- [16]. Central Bank of Sri Lanka (2022), Annual Report 2021. Available at: <https://www.cbsl.gov.lk/en/publications/economic-and-financial-reports/annual-reports/annual-report-2021> (Accessed: 05 September 2022)., 2022. *Central Bank of Sri Lanka (2022), Annual Report 2021*, s.l.: s.n.
- [17]. Pathirana, L. P. D. S. (2020). Effect of COVID-19 and Strategic Response: A Review on Sri Lankan Construction Industry. SSRG International Journal of Economics and Management Studies, 7, 73-77. <https://doi.org/10.14445/23939125/IJEMS-V7I6P110>.
- [18]. International Monetary Fund. 2022. Global Financial Stability Report—Navigating the High-Inflation Environment. Washington, DC, October.
- [19]. Kataria, A. Manur, A. and Pradhan, S, 2022. Sri Lanka's Economic Crisis. Bangalore: takshashila institution..
- [20]. Bukhari S.S. & Bhat M, 2022. Economic Crisis in Sri-Lanka: A Politico-Economic Perspective.
- [21]. Perera, C. and Palliyaguru, R., 2022. Adapting the standard forms of contract to minimize the contractual effects of COVID-19 on construction projects.Proceedings of the 10th World Construction Symposium, 24-26 June 2022, Sri Lanka. [Online]. pp. 76-88. DOI: <https://doi.org/10.31705/WCS.2022.7>. Available from: <https://ciobwcs.com/2022-papers/>
- [22]. Mendis, A.P.K.D., Jayatunge, D.A.S.R., Disaratna, V. and Perera, B.A.K.S., 2022. Implementation of government policies in the construction industry: The case of Sri Lanka. *A| Z Itu Journal Of The Faculty Of Architecture*.

- [23]. Nilar, A. (2022, June 05). #OccupyGalleFace marks 58 days. Retrieved December 09, 2022, from News 1st: <https://www.newsfirst.lk/2022/06/05/occupygalleface-marks-58-days/>
- [24]. Vithana, N.D.I. Bandara, K.P.S.P.K. and Jayasooriya, S.D., 2020. Impact of Covid-19 pandemic to construction industry in Sri Lanka.
- [25]. Kumaraswamy, M. M. and Thorpe, A. (1999) Systematizing construction project evaluations. *Journal of Management in Engineering* 12 (1) : 34 – 39

A Review of Emission Filtering and Controlling Systems Applicable for Fossil Fuel-Based Electricity Generators

I. M. D. W. Hasakelum
Department of Mechanical &
Manufacturing Technology,
University of Vocational Technology,
Ratmalana, Sri Lanka.
wenusaradasun@gmail.com

A. M. S. Amandani
Department of Mechanical &
Manufacturing Technology,
University of Vocational Technology,
Ratmalana, Sri Lanka.
amandani917@gmail.com

S. V. R. Gamage
Department of Mechanical &
Manufacturing Technology,
University of Vocational Technology,
Ratmalana, Sri Lanka.
sasiri@uovt.ac.lk

Abstract— The increasing electricity demand has led to the widespread utilization of fossil fuel-based electricity generators, which, in turn, has raised concerns about their environmental impact due to emissions of pollutants. This paper presents a thorough review of emission filtering and controlling systems suited for fossil fuel-based electricity generators. The study encompasses various technologies aimed at mitigating the adverse effects of emissions, encompassing both emission filtering systems and advanced control strategies. Through an in-depth analysis of these systems, this paper aims to provide insights into their effectiveness, challenges, and prospects in the context of environmental sustainability and regulatory compliance.

Keywords— Emission filtering, Emission controlling Systems, Fossil fuel-based generators, Environmental impact.

I. INTRODUCTION

The increasing global demand for electricity has led to the widespread deployment of fossil fuel-based power generators, which are essential to the energy needs of modern societies. However, reliance on these fossil fuels has led to environmental problems, primarily arising from the emission of harmful pollutants during power generation. These emissions, which include nitrogen oxides (NO_x), sulfur dioxide (SO₂), carbon monoxide (CO) and particulate matter (PM), not only contribute to the deterioration of air quality but also contribute to the larger challenge of climate change [1].

TABLE I - presents a quantitative analysis of the emission output from diesel generators, offering a comprehensive insight into the magnitude of pollutants released into the atmosphere annually. By showcasing the actual emission figures in kilograms per year, this table underscores the tangible contribution of diesel generators to air pollution and their role in shaping environmental quality.

In response to these environmental challenges, there has been a major shift in the power generation industry, focusing on developing and implementing advanced emission filtering and control systems. These systems have to be designed with the objectives of reducing the adverse environmental impact of fossil fuel-based industrial electricity generation and ensuring a stable and reliable energy supply for society [2].

This review paper provides a wide-ranging exploration of the latest advances in emission filtering and control systems of internal combustion engines suited for fossil fuel-based power generators [3]. By looking at the various techniques available,[4] this study hopes to provide a comprehensive analysis of the methods employed to mitigate the adverse effects of emissions. From traditional methods of capturing

and removing emissions to cutting-edge control strategies driven by technology and innovation, this review aims to uncover the complexities of these systems and explain their effectiveness in achieving emissions reduction targets [5].

TABLE VIII. DIESEL GENERATOR POLLUTANT[6]

Pollutant	Emission (kg/yr.)
Carbon Dioxide (CO ₂)	156,152
Carbon Monoxide (CO)	385
Unburned Hydrocarbons	42.7
Particulate Matter	29.1
Sulfur Dioxide (SO ₂)	314
Nitrogen Oxides (NO _x)	3,439

Table II represents an overview of the intricacy of generator emissions and their far-reaching consequences on both human health and the environment.

II. EMISSION FILTERING SYSTEM

This section outlines various emission filtering systems applicable to fossil fuel-based electricity generators, including:

A. Flue Gas Desulfurization (FGD) Systems

The Flue Gas Desulfurization (FGD) system is designed to reduce the environmental impact of fossil fuel-based electricity generators. The combustion of fossil fuels releases sulfur dioxide (SO₂) into the atmosphere. SO₂ is a significant contributor to acid rain and respiratory diseases. FGD system is a key solution for minimizing SO₂ emissions [7].

• Mechanism and Components:

FGD systems use the principle of sulfur dioxide absorption, where flue gases with SO₂ are subjected to a series of processes that facilitate the removal of this noxious gas before it is released into the atmosphere. A central component within FGD systems is the absorber, where flue gases come into contact with a reagent, often composed of limestone (calcium carbonate) or lime (calcium oxide) [8]. Upon interaction with the reagent, SO₂ undergoes a series of chemical reactions that lead to its conversion into calcium sulfate (CaSO₄), commonly known as gypsum. This gypsum is then separated from the gas stream and can subsequently be used in various industrial applications, thereby offering an avenue for recycling the captured pollutant [9].

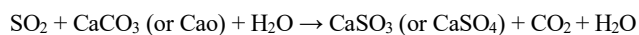
TABLE IX. ENVIRONMENTAL & HEALTH IMPACT OF GENERATOR EMISSION

Pollutant	Health Impact	Environmental Impact
Particulate Matter (PM)	-Respiratory issues and cardiovascular problems	-Air quality degradation. -Soil and water contamination.
Nitrogen Oxides (NOx)	-Aggravates respiratory conditions, -Impairs lung function, -Increases susceptibility to respiratory infections. -Can exacerbate heart diseases.	-Contributes to the formation of ground-level ozone (smog) -Contributes to eutrophication (excess nutrients) in water bodies. -Can lead to nitrogen deposition, affecting soil and ecosystems. -Can contribute to particulate matter formation.
Carbon Monoxide (CO)	-Reduces oxygen transport, leading to headaches, dizziness, and nausea. -It Impairs cognitive function and memory, -Aggravates cardiovascular conditions, leading to angina and heart attacks.	-Contributes to air pollution and smog. -Contributes to ground-level ozone formation. -Contributes to climate change as a greenhouse gas.
SOx	-Aggravates respiratory conditions (asthma, bronchitis). -Irritates eyes, nose, and throat. -Can lead to heart and lung problems. -Aggravates existing heart conditions.	-Contributes to acid rain, leading to soil and water acidity. -Harmful to aquatic ecosystems, causing damage to aquatic life, -Contributes to the formation of fine particulate matter (PM2.5). -Can damage plants and vegetation.

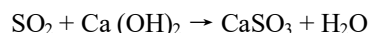
- Types of FGD Systems:

Several FGD technologies have been developed, each tailored to specific plant requirements and fuel types. Prominent among these are wet, dry, and semi-dry FGD systems:

1. **Wet FGD Systems:** These systems employ a wet scrubbing process where flue gases are brought into contact with a liquid absorbent, typically a slurry of limestone (CaCO_3) or lime (Cao) in water. The resultant chemical reactions lead to the formation of gypsum (CaSO_4) and calcium sulfite (CaSO_3). Wet FGD systems are highly efficient but require a significant amount of water and produce a liquid waste stream that necessitates proper management [10].



2. **Dry FGD Systems:** Dry FGD systems operate on a similar principle but use a dry absorbent, often in the form of hydrated lime (Ca(OH)_2) or sodium-based reagents(NaHCO_3). These systems are advantageous in terms of reduced water usage and waste generation. However, their efficiency may vary depending on factors like humidity levels [11, 12].



3. **Semi-Dry FGD Systems:** These systems combine elements of both wet and dry processes. Flue gases are contacted with a wet slurry, but subsequent drying steps remove excess water before the gases are released. This hybrid approach aims to strike a balance between efficiency and resource consumption [8, 12].

- Challenges and Advancements:

While FGD systems have demonstrated their efficacy in reducing SO_2 emissions, challenges persist. The procurement, transport, and disposal of reagents, as well as the management of generated waste, remain areas of concern. Additionally, the energy required for the operation of FGD systems can slightly

impact the overall efficiency of generators. Advancements in FGD technology focus on optimizing reagent utilization,

enhancing absorption rates, and improving the disposal and reuse of byproducts [13].

B. Selective Catalytic Reduction (SCR)

Selective Catalytic Reduction (SCR) is a pioneering emission reduction technology that holds the potential to significantly mitigate the impact of nitrogen oxide (NO_x) emissions from fossil fuel-based electricity generators. NO_x is a major contributor to air pollution and smog formation [14].

- Mechanism and Components

At the core of SCR systems lies a catalytic converter containing a catalyst, typically composed of metal oxides such as vanadium, titanium, or zeolite. Flue gases with NO_x are directed through the catalyst bed of the reducing agent, commonly an aqueous solution of ammonia (NH_3) or urea ($\text{CO(NH}_2\text{)}_2$). Upon contact with the catalyst, NO_x molecules undergo a chemical reaction facilitated by the reducing agent, resulting in the conversion of NO_x into harmless nitrogen (N_2) and water (H_2O) [15].

- Key Reactions:

The primary reactions within an SCR system involve the reduction of nitrogen oxides: [16, 17].

1. $\text{NO} + \text{NH}_3 \rightarrow \text{N}_2 + \text{H}_2\text{O}$: This reaction produces nitrogen gas and water vapor, effectively converting nitrogen oxides into benign substances.
2. $\text{NO}_2 + \text{NH}_3 \rightarrow \text{N}_2 + 2\text{H}_2\text{O}$: In the presence of nitrogen dioxide (NO_2), a similar reaction occurs, yielding nitrogen gas and water.

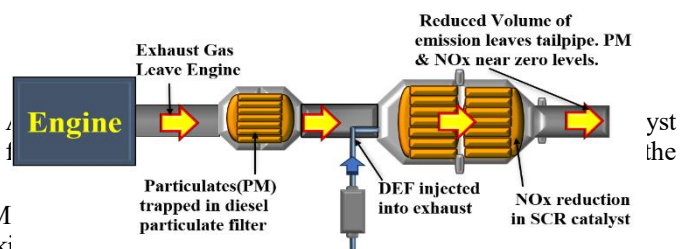


Fig. 1 – Selective Catalytic Reduction process

distribution and mixing of reducing agents. Furthermore, integration with other emission control systems, such as particulate matter removal technologies, is gaining attention to achieve comprehensive emission reductions.

C. Electrostatic Precipitators (ESP)

Electrostatic Precipitators (ESP) represent a significant innovation in emission control technology, serving as a potent tool for minimizing particulate matter (PM) emissions from fossil fuel-based electricity generators. As the combustion of fossil fuels generates a diverse array of particles, ranging from fine ash to soot, the ESP system is a possible solution to mitigate the environmental impacts of these emissions. [18].

- Principle of Operation:

The underlying principle of ESP technology lies in the utilization of electrostatic forces to capture and remove particulate matter from flue gases. ESPs consist of a series of collection plates, with alternating positive and negative charges. Flue gases containing PM pass through this arrangement, inducing an electrostatic charge on the particles. Charged particles are then drawn towards oppositely charged plates, resulting in their deposition on the plate surfaces. Over time, the accumulated particulate matter forms a layer, known as a "dust cake," which can be periodically removed through processes like rapping or mechanical shaking.

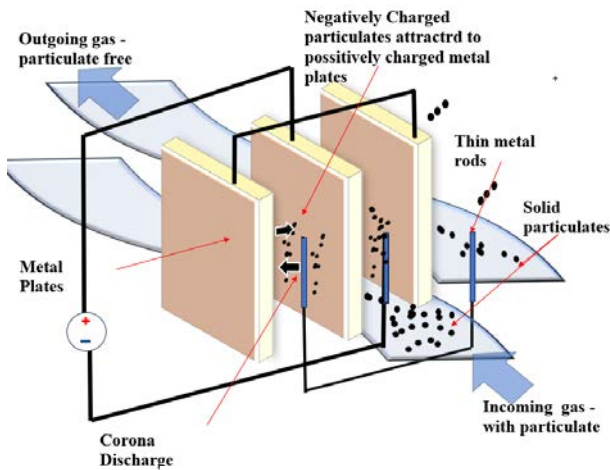


Fig. 2 – Electrostatic Precipitator [38]

- Considerations and Challenges:

1. Maintenance: Dust cake buildup on collection plates requires periodic cleaning, which can disrupt operation and impact efficiency.
2. Particle Resistivity: The electrical properties of particles, known as resistivity, can influence ESP performance. Highly resistive particles may require additional measures for effective removal.
3. Size Limitations: Large ESP systems may be required to handle high flow rates, making them space-intensive.

- Advancements and Future Trends:

Advancements in ESP technology aim to address limitations and improve performance. Enhanced electrode designs, utilization of advanced materials, and improvements in rapping and cleaning mechanisms are being explored to optimize efficiency and reduce maintenance requirements [19].

D. Fabric Filters (Baghouses)

Fabric filters, commonly referred to as baghouses, are suitable emission control systems that excel in the removal of PM and other pollutants from the exhaust gases of fossil fuel-based electricity generators. As the combustion of fossil fuels generates a diverse range of fine particles and pollutants, a fabric filter system is a good solution for minimizing the environmental impact of these emissions [20].

- Operational Mechanism:

Baghouses operate on the principle of mechanical filtration, employing a matrix of fabric filter bags to capture particulate matter as flue gases pass through. These bags, typically made from woven or felted materials, possess intricate porous structures that effectively trap particles larger than the pore size while allowing cleaned gases to pass through. As the flue gases laden with PM traverse the filter bags, the particles collide with the fabric's surface and adhere to it due to various mechanisms such as impaction, interception, and diffusion. Over time, the accumulation of captured particles on the filter surface forms a layer, known as the "dust cake," which further enhances the filtration efficiency.

- Considerations and Challenges:

While baghouses offer robust performance, they come with considerations:

1. Pressure Drop: As the dust cake accumulates, it causes an increase in pressure drop across the filter, which can impact the system's energy efficiency.
2. Maintenance: Regular maintenance involves periodic cleaning or replacement of filter bags to ensure optimal performance.
3. Temperature and Corrosion: The selection of appropriate filter materials is crucial, as high temperatures or corrosive gases can affect the fabric's integrity.

- Advancements and Innovations:

Advancements in baghouse technology are aimed at improving performance, reducing energy consumption, and extending the lifespan of filter media. Innovations include:

1. Pulse Jet Cleaning: Advanced cleaning mechanisms use pulses of compressed air to dislodge accumulated particles from the filter bags, reducing pressure drop.
2. Advanced Filter Media: Enhanced filter materials, coatings, and treatments are developed to withstand high temperatures, corrosive gases, and abrasive particles [21].
3. Hybrid Systems: Combining baghouses with other emission control technologies, such as scrubbers or electrostatic precipitators, can lead to comprehensive pollutant removal.

E. Carbon Capturing System

Carbon capture for generator emissions involves capturing carbon dioxide (CO₂) released during the operation of power generators. The mechanism typically includes three steps: capturing CO₂ from exhaust gases, transporting it to storage sites, and securely storing it underground.[22, 23].

- Considerations:
 1. Efficiency: Ensuring efficient capture without affecting generator performance.
 2. Cost: Balancing the expense of implementation against environmental benefits.
 3. Storage: Identifying suitable geological formations for safe and permanent storage.
 4. Regulations: Navigating legal and regulatory frameworks for storage and transport.
 5. Environmental Impact: Addressing potential risks, such as leakage from storage sites [4].
- Challenges:
 1. Energy Intensity: Carbon capture processes require energy, potentially reducing net emission reductions.
 2. Scale: Implementing at a large scale to make a significant impact on emissions.
 3. Cost: High upfront costs for technology setup and maintenance.
 4. Infrastructure: Developing pipelines for CO₂ transport and storage sites.
 5. Public Acceptance: Addressing concerns about long-term storage safety and environmental impacts.

Advancements and Innovations:

1. Solvent Improvements: Enhanced CO₂-absorbing solvents for more efficient capture.
2. Direct Air Capture (DAC): Technologies that capture CO₂ directly from the air, offering flexibility in location.
3. Carbon Mineralization: Converting CO₂ into stable minerals to ensure long-term storage.
4. Hybrid Systems: Integrating carbon capture with renewable energy sources to reduce emissions further.
5. Machine Learning: Optimizing capture processes through data-driven insights.

Table III represents a brief comparison of emission filtering systems for the technologies mentioned above.

III. EMISSION CONTROLLING STRATEGIES

This section highlights advanced control strategies and technologies to regulate emissions

A. Combustion Optimization

Optimizing combustion parameters is a method that can be applied for generators to mitigate emissions, particularly those utilizing fossil fuels. The combustion process within generators is a primary source of various pollutants, including nitrogen oxides (NO_x), carbon monoxide (CO), and particulate matter (PM). Through precise control and fine-tuning of combustion parameters, it is possible to achieve more efficient and cleaner combustion, leading to substantial reductions in emissions and improved energy efficiency [24].

- Key Combustion Parameters:

1. Air-Fuel Ratio: The ratio of air to fuel directly influences the completeness of combustion. A stoichiometric ratio (perfect balance) results in minimal CO emissions but can elevate NO_x levels. Leaner mixtures reduce NO_x but may increase CO emissions. Optimal tuning can strike a balance.
2. Combustion Temperature: Higher combustion temperatures can lead to increased NO_x emissions due to thermal nitrogen oxidation. Controlled cooling techniques can mitigate this effect.
3. Ignition Timing: Proper ignition timing ensures efficient combustion and minimizes the occurrence of incomplete combustion and the associated emissions of CO and unburned hydrocarbons (HC).
4. Burner Design: The geometry of burners and combustion chambers can influence combustion efficiency and emissions. Swirl, recirculation, and staged combustion techniques enhance combustion quality.

IV. CONCLUSION

Considering the growing demand for electricity and the associated environmental concerns stemming from emissions of pollutants, this review has extensively explored a range of emission filtering and control systems suitable for fossil fuel-based electricity generators. The utilization of these systems is vital for mitigating the adverse effects of emissions, meeting regulatory standards, and fostering environmental sustainability.

From the in-depth examination of emission filtering systems, including Flue Gas Desulfurization (FGD), Selective Catalytic Reduction (SCR), Electrostatic Precipitators (ESP), and Fabric Filters (Baghouses), it is evident that each technology presents unique advantages and challenges. These systems play crucial roles in reducing the release of harmful gases and particulate matter into the atmosphere, ultimately contributing to cleaner air quality and improved public health.

Furthermore, the exploration of advanced emission-controlling strategies, particularly combustion optimization, underscores the importance of addressing emissions at their source. By fine-tuning combustion parameters, employing cutting-edge technologies like Computational Fluid Dynamics (CFD), and implementing closed-loop control systems, power generators can significantly reduce emissions of NO_x, CO, and particulate matter, while concurrently enhancing fuel efficiency.

In conclusion, the field of emission filtering and controlling systems for fossil fuel-based electricity generators is advancing rapidly, driven by a global imperative to combat air pollution, climate change, and resource depletion. Through a multidimensional approach that combines effective emission filtering systems with innovative control strategies, the power generation industry can ensure a sustainable and responsible energy future while meeting the challenges of a changing environmental landscape. As new technologies continue to emerge and regulations become more stringent, ongoing research and development efforts will remain crucial for achieving comprehensive emissions reduction and ensuring a cleaner and healthier planet for future generations.

- Benefits of Combustion Optimization:
 1. Reduced NO_x Emissions: By controlling combustion parameters, generators can operate in conditions that promote lower NO_x formation rates, helping meet stringent emissions regulations.
 2. Improved Fuel Efficiency: Optimized combustion leads to better fuel utilization, maximizing energy output, and reducing fuel consumption.
 3. Minimized CO and HC Emissions: Fine-tuning parameters like air-fuel ratio and ignition timing ensure complete combustion, resulting in reduced emissions of carbon monoxide and hydrocarbons.
 4. Enhanced Particulate Matter Control: Efficient combustion minimizes the production of particulate matter, contributing to cleaner exhaust gases.
- Advanced Techniques:
 1. Computational Fluid Dynamics (CFD): CFD simulations model combustion processes, aiding in the assessment of various parameter combinations for optimal emission reduction [25].
 2. Closed-Loop Control Systems: Real-time sensors and control algorithms adjust combustion parameters dynamically to respond to changing load demands and fuel characteristics [26].
 3. Low-NO_x Burner Technology: Advanced burner designs create favorable conditions for combustion with lower NO_x production [27].
 4. Combustion Diagnostics: Monitoring equipment measures key combustion indicators, facilitating adjustments for emissions reduction [28].
- Challenges and Considerations:
 1. Trade-offs: Optimizing for one emission may inadvertently lead to an increase in another. Striking a balance is essential.
 2. System Complexity: Achieving optimal combustion may require sophisticated control systems and instrumentation

Aspect	FGD	TABLE III -FILTERING SYSTEM CATAGORIES SCR	ESP	Baghouse	Carbon Capturing Technology
Function	Remove sulfurdioxide	Reduce nitrogen oxides	Collect particulate matter	Collect particulate matter	Collect CO ₂
Pollutants Removed	SO ₂	NO _x	Particulate matter	Particulate matter	CO ₂
Process Type	Chemical absorption	Chemical absorption	Electrostatic attraction	Mechanical filtration	Post & pre- combustion Carbon capture
Efficiency	High for SO ₂	High for NO _x	Moderate to high	High	High for CO ₂
Applicability	Coalfired plants	Various combustionsources	Various combustion sources	Various combustion sources	Various combustion sources
Byproducts	Gypsum		Fly ash,	Collected particulates	CO ₂
Operating Cost	Moderate to high	Moderate to high	Low to moderate	Moderate to high	Moderate to high
Maintenance	Regular chemical	Catalyst replacement	Electrode cleaning	Filter replacement	Calibration & Sensor Check
Space Requirement	Moderate	Moderate	Low to moderate	Moderate to high	Moderate
Energy Consumption	Moderate	Moderate	Moderate to high	Moderate	Moderate to high
Installation Complexity	Complex	Moderate to complex	Moderate to complex	Moderate to complex	Moderate to complex
Start-up Time	Longer	Shorter	Short	Moderate	Short
Regulatory Compliance	Effective for SO ₂	Effective for NO _x	Effective for PM	Effective for PM	Effective for CO ₂
Environmental Impact	Generates wastestreams	Requires ammonia injection	Ozone generation possible	Generates waste streams	Depends on Storages
Flexibility	Limited	Limited	Limited	Moderate	Moderate
Advantages	High efficiency for SO ₂ removal.Effective regulatory compliance for SO ₂	High efficiency for NO _x reduction. Effective regulatory compliance for NO _x . Applicable to variouscombustion sources. Short start-up time. Limited maintenance.	Collects particulate matter., Effective regulatorycompliance for PM., Low tomoderate operating cost. Moderate space requirement. Continuous operation. Versatility. Moderate to high flexibility	High efficiency for particulate matter. Applicable to various combustion sources. Filter replacement is the main maintenance. High efficiency., Moderate flexibility.	Emission reduction Preservation of existing infrastructure Can be apply to various industrial process.
Disadvantages	Generates waste streams (gypsumproduction) Requires moderate space. Higher operatingcost. Complex installation and maintenance	Requires ammonia injection. Moderate to high operatingcost. Moderate energyconsumption. Moderate to complexinstallation. Limited flexibility.	Moderate to high energy consumption. Moderate to complex installation. Short start-up time. Requires regular electrodecleaning.	Generates waste streams (collected particulates). Moderate to high operating cost.Moderate to high space requirement. Moderate energy consumption., Moderate to complex installation. Limited flexibility.	High cost Energy intensive Environmental consents
References	[9]–[11], [13], [29], [30]	[14], [15], [31]–[33]	[18], [34], [35]	[20], [36]	[4], [22], [23], [37]

REFERENCES

- [1] "Just a moment..." Accessed: Aug. 07, 2023. [Online]. Available: https://www.nevadacountyca.gov/DocumentCenter/View/41584/43_Air-Quality-Greenhouse-Gas-Emissions-and-Energy
- [2] "The Dirty Footprint of the Broken Grid The Impacts of Fossil Fuel Back-up Generators in Developing Countries."
- [3] D. Dattatray M, D. Akshay P, S. Amit M, and K. Maruti D, "A Review on various NOx emission reduction techniques for C.I. Engine," International Research Journal of Engineering and Technology, 2017, [Online]. Available: www.irjet.net
- [4] S. D. Sharma and M. Azzi, "A critical review of existing strategies for emission control in the monoethanolamine-based carbon capture process and some recommendations for improved strategies," Fuel, vol. 121, pp. 178–188, Apr. 01, 2014, doi: 10.1016/j.fuel.2013.12.023.
- [5] P. N. D. Premadasa, C. M. M. R. S. Silva, D. P. Chandima, and J. P. Karunadasa, "A multi-objective optimization model for sizing an off-grid hybrid energy microgrid with optimal dispatching of a diesel generator," J Energy Storage, vol. 68, 2023, doi: 10.1016/j.est.2023.107621.
- [6] K. Okedu, R. Uhunmwangho, and N. Bassey, "Comparative Study of on and off Grid Tied Integrated Diesel/Solar (PV) Battery Generation System," International Journal of Engineering Technologies, IJET, vol. 1, no. 1, p. 19, Mar. 2015, doi: 10.19072/IJET.30671.
- [7] "Buy Flue Gas Desulfurization, Flue Gas Desulfurization Suppliers, Flue Gas Desulfurization Manufacturers, Flue Gas Desulfurization Factories." Accessed: Aug. 07, 2023. [Online]. Available: https://www.lonjing.com.cn/flue-gas-desulfurization_p118.html?gclid=Cj0KCQjwrMKmBhCJARIsAHuEAPSFPRj0jnLsB0kyfjhSRf3H5b_wUvv8W1yiMI_yFVC_3UzkW5oHY SKaAv6IEALw_wcB
- [8] D. Zhou et al., "Calcium sulfate whisker one-step preparation using semi-dry flue gas desulfurization ash and directional growth control," J Clean Prod, vol. 290, 2021, doi: 10.1016/j.jclepro.2020.125754.
- [9] Y. Li, W. Zuo, Y. Feng, H. Zhang, and Y. Dong, "Mechanism of SO₃/H₂SO₄ transformation and reduction in wet flue gas desulfurization systems," Fuel, vol. 307, 2022, doi: 10.1016/j.fuel.2021.121862.
- [10] L. Cui, J. Lu, X. Song, L. Tang, Y. Li, and Y. Dong, "Energy conservation and efficiency improvement by coupling wet flue gas desulfurization with condensation desulfurization," Fuel, vol. 285, 2021, doi: 10.1016/j.fuel.2020.119209.
- [11] Y. Chen et al., "Mechanisms of dry flue-gas desulfurization using natural manganese oxide ores," Korean Journal of Chemical Engineering, vol. 36, no. 7, 2019, doi: 10.1007/s11814-019-0274-2.
- [12] M. de Andrade Cruz, R. de P. V. de Castro, O. de Queiroz, F. Araújo, and J. L. de Medeiros, "Environmental performance of a solid waste monetization process applied to a coal-fired power plant with semi-dry flue gas desulfurization," Journal of Sustainable Development of Energy, Water and Environment Systems, vol. 7, no. 3, 2019, doi: 10.13044/j.sdewes.d6.0251.
- [13] T. Butalia, W. Wolfe, and P. Amaya, "The utilization of flue-gas desulfurization materials," Coal Combustion Products (CCPs): Characteristics, Utilization and Beneficiation, pp. 155–184, May 2017, doi: 10.1016/B978-0-08-100945-1.00006-X.
- [14] M. Casapu, A. Bernhard, D. Peitz, M. Mehring, M. Elsener, and O. Kröcher, "A Niobia-Ceria based multi-purpose catalyst for selective catalytic reduction of NOx, urea hydrolysis and soot oxidation in diesel exhaust," Appl Catal B, vol. 103, no. 1–2, pp. 79–84, Mar. 2011, doi: 10.1016/j.apcatb.2011.01.011.
- [15] Y. Zhang, X. Yue, T. Huang, K. Shen, and B. Lu, "In situ DRIFTS studies of NH₃-SCR mechanism over V₂O₅-CeO₂/TiO₂-ZrO₂ catalysts for selective catalytic reduction of NOx," Materials, vol. 11, no. 8, 2018, doi: 10.3390/ma11081307.
- [16] Z. Xue, X. Du, X. Wang, Y. Chen, Y. Yan, and J. Ran, "New Insights Into the Effect of H₂O on the 'Fast SCR' Reaction of V₂O₅/Ti Catalyst," Kung Cheng Je Wu Li Hsueh Pao/Journal of Engineering Thermophysics, vol. 43, no. 7, 2022.
- [17] I. Nova, C. Ciardelli, E. Tronconi, D. Chatterjee, and B. Bandl-Konrad, "NH₃-NO/NO₂ chemistry over V-based catalysts and its role in the mechanism of the Fast SCR reaction," Catal Today, vol. 114, no. 1, 2006, doi: 10.1016/j.cattod.2006.02.012.
- [18] "Electrostatic precipitator | Definition, Diagram, Application Of, & Uses | Britannica." Accessed: Aug. 07, 2023. [Online]. Available: <https://www.britannica.com/technology/electrostatic-precipitator>
- [19] I. Sretenovic, "New learnings and strategies for meeting future recovery boiler particulate emission limits with existing electrostatic precipitators," Tappi J, vol. 20, no. 6, 2021, doi: 10.32964/TJ20.6.405.
- [20] "FABRIC FILTERS Fabric Filters Air Pollution Control 1."
- [21] S. M. S. Rocha, L. G. M. Vieira, M. L. Aguiar, and J. J. R. Damasceno, "Fluid dynamics study of the influence of the direction of the gas flow in fabric filter," in Materials Science Forum, 2010, doi: 10.4028/www.scientific.net/MSF.660-661.520.
- [22] S. Das and J. Kumar, "Carbon Capture and Storage," Int J Sci Eng Res, vol. 7, no. 10, pp. 1385–1388, Oct. 2016, doi: 10.14299/IJSER.2016.10.006.
- [23] W. Sun, Y. Shao, L. Zhao, and Q. Wang, "Co-removal of CO₂ and particulate matter from industrial flue gas by connecting an ammonia scrubber and a granular bed filter," J Clean Prod, vol. 257, Jun. 2020, doi: 10.1016/j.jclepro.2020.120511.
- [24] Q. Li, Q. He, and Z. Liu, "Low NOx combustion optimization based on partial dimension opposition-based learning particle swarm optimization," Fuel, vol. 310, 2022, doi: 10.1016/j.fuel.2021.122352.
- [25] T. Li, Ø. Skreiberg, T. Løvås, and P. Glarborg, "Skeletal mechanisms for prediction of NOx emission in solid fuel combustion," Fuel, vol. 254, 2019, doi: 10.1016/j.fuel.2019.05.152.
- [26] T. Budenz, A. Denzinger, and H. U. Schnitzler, "Reduction of emission level in approach signals of greater mouse-eared bats (Myotis myotis): No evidence for a closed loop control system for intensity compensation," PLoS One, vol. 13, no. 3, 2018, doi: 10.1371/journal.pone.0194600.
- [27] "State-Of-The-Art & ACT-Gideon Ultra Low NOx Burner - ADVANCED COMBUSTION TECHNOLOGIES CO., LTD." Accessed: Aug. 07, 2023. [Online]. Available: https://www.act-gideon.com.tw/state-of-the-art?gclid=Cj0KCQjwrMKmBhCJARIsAHuEAPTWfLTpYTgUroEusvHAL_tltMXU7rXCjsnamGRAYj_1F0A85jCfl3ScaAvcZEALw_wcB
- [28] F. Peng, H. Liu, and W. Cai, "Combustion diagnostics of metal particles: a review," Meas Sci Technol, vol. 34, no. 4, 2023, doi: 10.1088/1361-6501/acb076.
- [29] R. K. Srivastava and W. Jozewicz, "Flue gas desulfurization: The state of the art," J Air Waste Manage Assoc, vol. 51, no. 12, 2001, doi: 10.1080/10473289.2001.10464387.
- [30] X. Li, J. Han, Y. Liu, Z. Dou, and T. an Zhang, "Summary of research progress on industrial flue gas desulfurization technology," Separation and Purification Technology, vol. 281, 2022, doi: 10.1016/j.seppur.2021.119849.
- [31] F. Gao et al., "A review on selective catalytic reduction of NOx by NH₃ over Mn-based catalysts at low temperatures: Catalysts, mechanisms, kinetics and DFT calculations," Catalysts, vol. 7, no. 7, 2017, doi: 10.3390/catal7070199.
- [32] W. Zhang, W. Gao, X. Zhang, Z. Li, and G. Lu, "Surface spintronics enhanced photo-catalytic hydrogen evolution: Mechanisms, challenges and future," Applied Surface Science, vol. 434, 2018, doi: 10.1016/j.apsusc.2017.10.228.

- [33] C. Li, L. Huangfu, J. Li, S. Gao, G. Xu, and J. Yu, "Recent advances in catalytic filters for integrated removal of dust and NO from flue gas: fundamentals and applications," *Resources Chemicals and Materials*, vol. 1, no. 3–4, pp. 275–289, Sep. 2022, doi: 10.1016/j.recem.2022.06.002.
- [34] Electrical 4 U, "Advantages and Disadvantages of Electrostatic Precipitator | Electrical4U," <https://www.electrical4u.com/>, 2020.
- [35] a Y. Z. *a Q. D. a X. D. a J. G. a P. D. and H. W. Lipeng Su, "An experimental study on the removal of submicron fly ash and black carbon in a gravitational wet scrubber with electrostatic enhancement," Feb. 2020.
- [36] G. D. Y. V. S. S. A. K. C. and Dr. M. V. K. N. Philomina, "Design and Fabrication of Soot Collector and Filtration of Soot," Oct. 2022.
- [37] M. Pasichnyk et al., "Membrane technology for challenging separations: Removal of CO₂, SO₂ and NO_x from flue and waste gases," *Sep Purif Technol*, p. 124436, Oct. 2023, doi: 10.1016/j.seppur.2023.124436.
- [38] "(PDF) Microplasmas: Environmental and Biological Applications." Accessed: Nov. 06, 2023. [Online]. Available: https://www.researchgate.net/publication/313428450_Microplasmas_Environmental_and_Biological_Applications

Guidelines to improve supply characteristics of Solar PV system components to improve sustainable supply chain practice

P. A. D. Madushan
Department of Quantity Surveyor
University of Vocational Technology
Sri Lanka.

S. R. M. P. Seneviratne
Department of Quantity Surveyor
University of Vocational Technology
Sri Lanka

Abstract- Sri Lanka has a considerable solar energy potential as, over two-thirds of the land mass attains a 4.0–4.5 kilowatt-hours per square meter per day (kWh/m²/day), as solar radiation in general. Yet, as per earlier research findings it was found out that, because of the lack of detailed market data in supply and demand statistics, it was difficult to develop a comprehensive solar PV-based energy supply chain in Sri Lanka. This research is conducted to find the frequency of correlated Performance characteristics related to the supply of Solar PV systems for buildings in Sri Lanka, to provide supply-side recommendations for improvement. Thus, the Literature review finds variables for supply components of a Solar PV system for buildings such as PV panels, Inverters, DC Cables, Surge Arresters, Mounting structures, Batteries, and Charge Controllers. Among the criteria of Solar PV system for residential buildings Cost, Efficiency and Durability was considered for performance evaluation. Accordingly, the frequency of correlations of each interpolated variable was identified. Further in the research strategies suggested for improving the supply characteristics of Solar PV system components to improve supply characteristics to the market.

Keywords:- supply components of a solar PV system, performance characteristics, effective mechanism

the usage of solar power in Sri Lanka is still in the primitive age. Sri Lankan Electricity Board established the Energy Unit in 1980, and the Sri Lankan government had not ventured to promote solar photovoltaics to electrify rural domestics [4]. Despite the government's aim to enhance the use of solar PV to reduce energy poverty, there is relatively less intent in the Sri Lankan community to use solar PV to meet the impending energy crisis in the world [5]. Therefore, introducing solar panels to the same consumer base will be a big challenge.

Electricity was identified as a strategic objective, and the development of renewable energy projects was identified as a part of this strategy. (Sustainable Energy Authority, 2017) [6]. Therefore, though introducing solar panels to the existing electricity users and suppliers is challenging, it becomes a must to address the upcoming energy crisis. Therefore, it is identified that finding a sufficient amount of supply and demand detailed market data is important to develop comprehensive proposals to

I. INTRODUCTION

Approximately 80% of global energy production depends on fossil fuels, and this proportion is estimated to decrease gradually [1]. Energy conservation and renewable energy are becoming increasingly important due to rising energy costs and urbanization [1]. The rapidly growing construction sector of Sri Lanka makes up 35% of the national energy consumption [2].

Electricity is an essential service for any country, and Sri Lankan industries rely on reliable, competitively priced, and sustainable power generation systems. However, the power generation sector in Sri Lanka is not living up to the industry, services, and public expectations. The surge in imports of generators after an announcement of power cuts occurred recently shows the level of trust people have in Ceylon Electricity Board (CEB) supply chain merely broken [3]. The mismanagement qualities performed by CEB and public unrest towards electricity provided an opportunity for opportunists to infiltrate the country [3].

It is a fact that Sri Lanka first used solar photovoltaic (PV) technology in 1970. However,

enhance the solar PV-based energy economy in Sri Lanka. This research is identified with supply-side data for improving the supply faces specifically at Solar PV system components to improve of supply characteristics of the market.

II. LITERATURE REVIEW

A. Current state of renewable energy in Sri Lanka

By the end of 2014, 98.4% of the households in Sri Lanka were electrified. The average per capita electricity consumption increased to 540 units from 519 units (kWh/person) in the previous year thus recording an increase of 21 units. The total electricity sales during the year increased from 10,621 GWh in the previous year to 11,063 GWh, a percentage increase of 4.2%. The average daily electricity consumption in the year was 30.3 GWh as against 29.1 GWh in 2013. The trend of using renewable energy sources has increased with time to a considerable

amount. Among the renewable energy sources, solar power is the most common method used in Sri Lanka. Meanwhile in solar energy, installed capacities in megawatts as well as the number of solar connections have increased. [7].

Due to the rapid consumption of conventional energy resources such as crude oil, coal, and natural gas, many initiatives taken all over the world have addressed the efficient use or replacement of the resources. Several renewable energy sources have been introduced and argued as alternatives to traditional sources to protect environmental resources and improve the quality of life. With the growing concerns about Green House Gas (GHG) emissions and consequent climate change, renewable energy sources have become more attractive options for power Generation around the world [8, 9].

B. Sri Lanka Energy Market

Sri Lanka's government expects a significant increase in renewable energy investment by the public and private sectors as it unveiled an ambitious plan to gain energy self-sufficiency in the next 15 years [9]. In regions of higher latitudes, the application of BIPV on the facades of modern buildings has become widespread [9].

The development of solar and rooftop solar power generation was based on the Government of Sri Lanka's strong policy initiative. In September 2016, the government announced "The Battle for Solar Energy" program, under which the government intended to increase solar photovoltaic generation capacity from the current level of about 61.4 megawatts (MW) to 200.0 MW by 2020 and 1,000.0 MW by 2025. [10]. The strong government commitment to creating a conducive business environment to enable rooftop PV system financing is the bedrock of this project design.

The present market condition in Sri Lanka is considerably favourable for rooftop solar system development. The government introduced net metering in July 2008 [11, 12]. Ceylon Electricity Board (CEB) currently has attractive rates of SLRs 22.0 per kWh for 7 years and SLRs 15.5 per kWh for the next 12 years [12]. There are more than 100 dedicated private sector renewable energy service companies to provide rooftop solar systems installation and maintenance. Both solar panels and inverters enjoy duty and tax exemptions. Both the Government of Sri Lanka and Lanka Electricity Company (LECO) have subsidized rooftop solar loan schemes at 6% and 8% annual interest rates (and a tenor of about 5–7 years) to catalyze market demand [12]. Both solar panels and inverters enjoy duty and tax exemptions. As a result, the rooftop solar power generation capacity expanded rapidly [11].

C. National Energy Policy 2006

Electricity was identified as a strategic objective, and the development of renewable energy projects was identified as a part of this strategy in the National Energy Policy 2006 [13]. Therefore, though introducing solar

panels to the existing electricity users is challenging, it becomes a must to address the upcoming energy crisis.

D. Market Analysis Factors for Sri Lanka

Among the three key variables to affect the market demand for Sri Lanka are the prevailing electricity tariff rates, and solar system costs for rooftops with financing incentives in higher priority [14].

III. OBJECTIVES

1. Identify components of a Solar PV system for buildings.
2. Identify Performance characteristics for a Solar PV system for residential buildings,
3. Identify the frequency of interrelated Performance characteristics for the supply of Solar PV systems for buildings in Sri Lanka
4. Develop a strategy for improving the Solar PV system of supply of market economy in Sri Lankan buildings,

IV. METHODOLOGY

Solar PV system components as well as the Performance characteristics for a Solar PV system were investigated through a literature survey.

A questionnaire survey was conducted among a focus group of Solar PV supply party engineers and technicians as a selected population of the construction sector of Sri Lanka, for a sample size of 33. Data was collected via a questionnaire based on a 5-point Likert scale. Data was analyzed with Microsoft Excel software to develop charts to display the results of objective 3 and to display the correlation between the impact of Performance characteristics for the supply of Solar PV systems for residential buildings. Objective 04 was covered with the results of the objective 03.

V. RESULTS AND DISCUSSION

A. Components of a Solar PV system for buildings.

The system consists of an array of photovoltaic (PV) panels, a solar charge controller (SCC), an Array battery as a storage unit, Inverters, a metering unit and a control panel to monitor system performance.

B. Performance Characteristics of a Solar PV system for buildings

Characteristics considered in evaluating a Solar PV system's performance for residential buildings are identified as Cost, Efficiency and Durability.

C. Frequencies of interrelated Performance characteristics for the supply of Solar PV systems for buildings in Sri Lanka

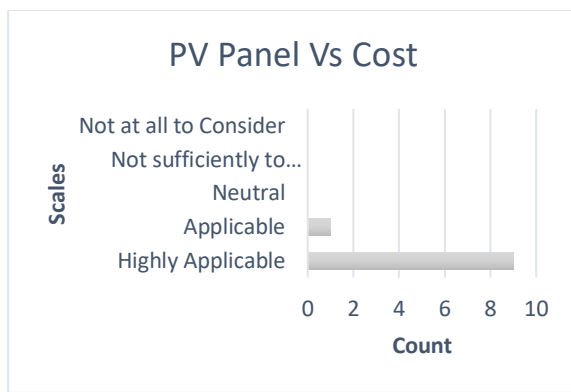


Fig. 1. PV Panel Vs Cost

For Cost as a factor to consider for buying Solar panels 85% of the commented cost is a highly applicable factor, 15% of commented cost is an applicable factor. Yet, No respondents are Neutral, Not sufficiently to consider or not at all to consider categories.

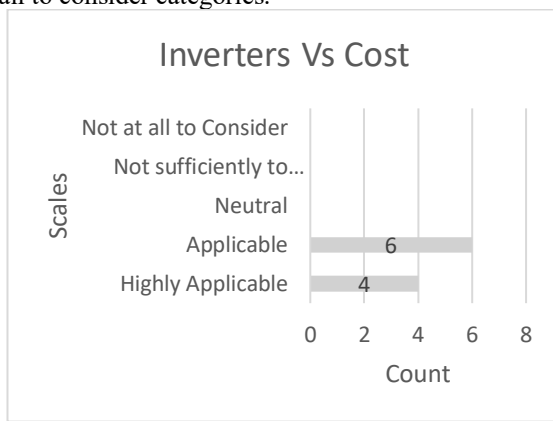


Fig. 2. Inverter Vs Cost

Accordingly, when occupying inverters 50% of the sample considered cost as an applicable factor, and 40% considered Cost as a highly applicable factor to consider for buying inverters. For Neutral, Not Sufficiently to consider or not at all to consider any respondents commented

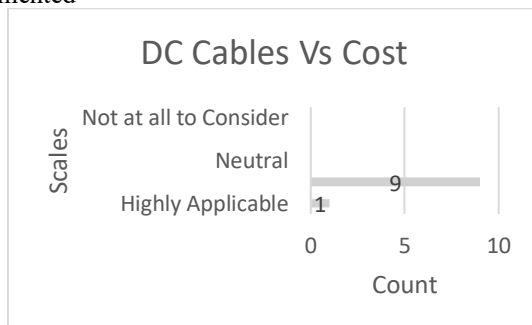


Fig.3. DC Cables Vs Cost

When considering Cost as a factor to consider in occupying DC cables 90% commented cost is an applicable factor, while 10% observed the cost as a highly applicable factor and, no respondents retorted or Neutral, Not Sufficiently to consider or not at all to consider groups.

Further, concerning DC Cables 90% of the sample considered cost as an applicable factor, and 10% considered Cost as a highly applicable feature to study for buying DC Cables. For Neutral, Not Sufficiently to

consider or not at all to consider no respondents commented.

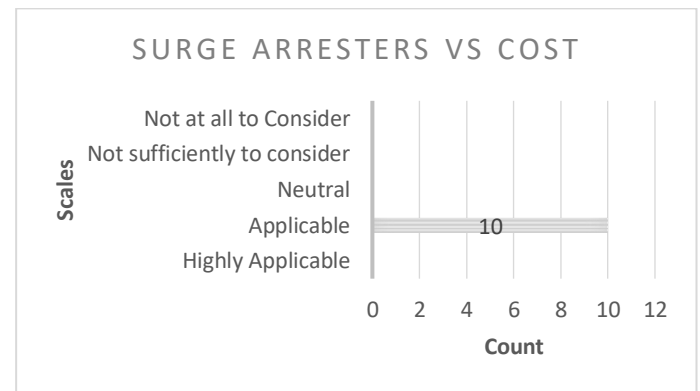


Fig. 4. Surge Arresters Vs Cost

For Cost to consider as a factor for buying Surge Arresters, a 100% commented cost is an applicable option, yet all other option categories were not considered in the answer.

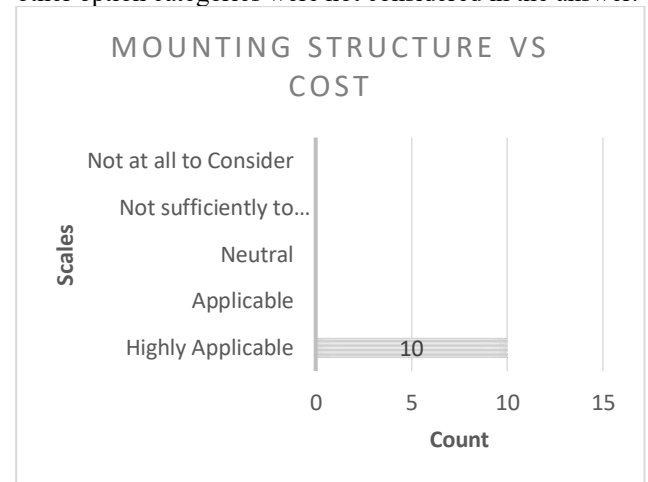


Fig. 5. Mounting Structure Vs Cost

When considering Cost as a factor for selecting mounting structures for installation, 100% of the sample (total) commented cost is a highly applicable option, and all other options not considered.

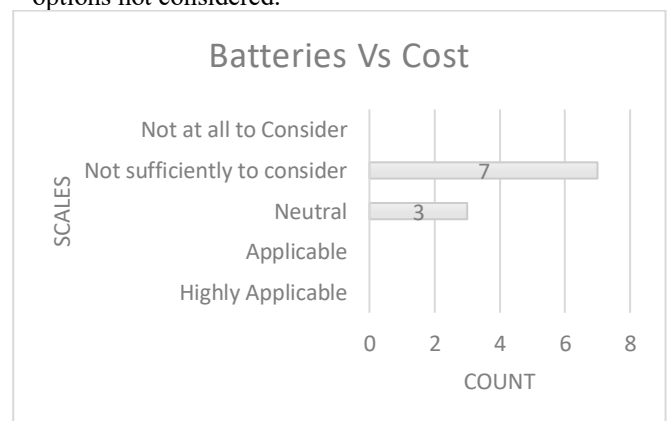


Fig. 6. Batteries Vs Cost

Considering the Cost as a factor of lodging Batteries as accessories of solar PV systems, 70% commented cost is not sufficiently considered as a factor, while 30% observed the

cost neural factor to consider. No respondents responded to other responses.

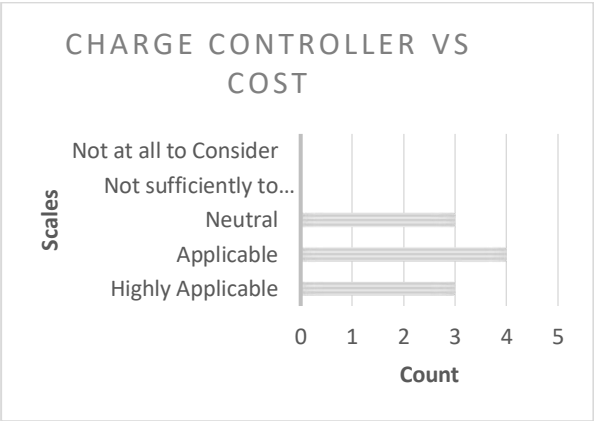


Fig. 7. Charge Controller Vs Cost

When occupying Charger controllers 40% of the sample considered cost as an applicable factor, and 30% consequently considered Cost as a highly applicable factor and also as a neutral factor to consider for buying Charger controllers Not Sufficiently to consider or not at all to consider no respondents commented.

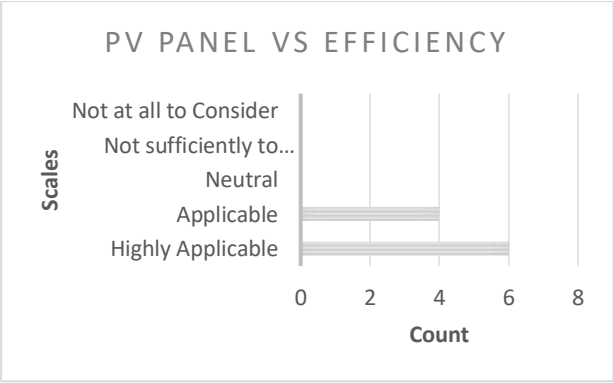


Fig. 8. PV Panel Vs Efficiency

Further, while concerning PV panels for efficiency, 60% of the sample considered efficiency as a highly applicable factor, and the rest of the 40% considered efficiency as an applicable feature to study for buying

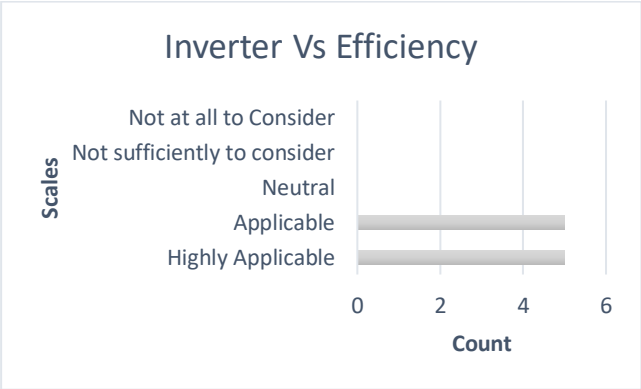


Fig. 9. Inverter Vs Efficiency

Considering inverters' efficiency, for highly applicable fund applicable responses 50% of the sample commented as efficiency to consider. For Neutral, Not Sufficiently to

consider or not at all to consider no respondents commented.

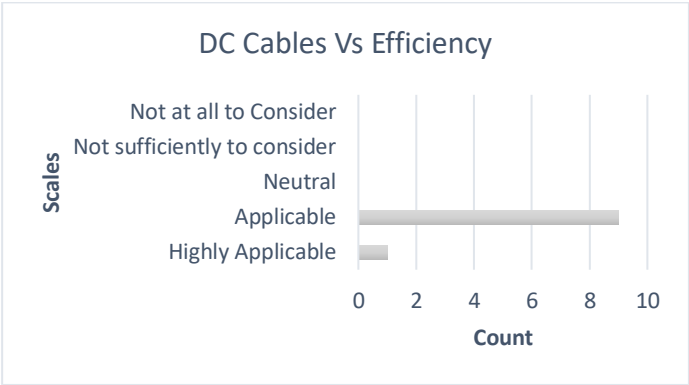


Fig. 10. DC Cables Vs Efficiency

Considering the efficiency as a factor of lodging DC cables as accessories for solar PV systems, 90% commented efficiency is applicable as a factor, while 10% observed efficiency as a highly applicable factor. No respondents responded to other responses.

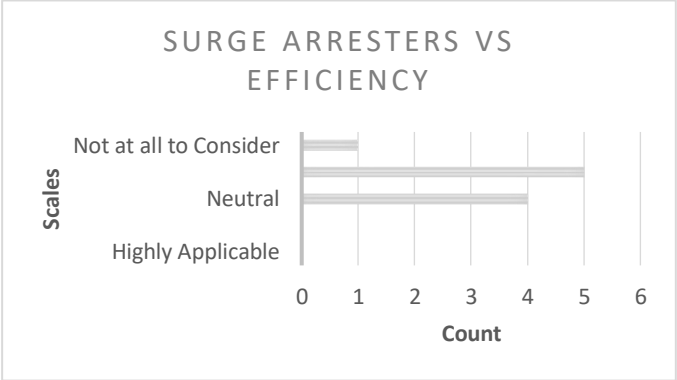


Fig. 11. Surge Arresters Vs Efficiency

Further, while considering Surge Arrestors for efficiency, 50% of the sample considered efficiency as not sufficient to consider, 40% responded in neutral consideration, and 10% think efficiency is not at all to consider. No respondents responded to other responses.

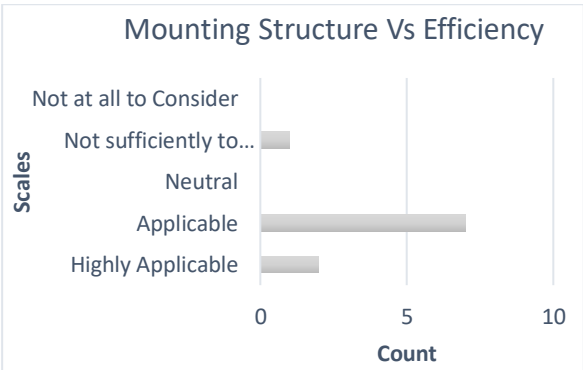


Fig. 12. Mounting Structure Vs Efficiency

For efficiency as a factor to consider for buying a Mounting structure 70% commented efficiency as an applicable factor, and 20% commented cost as a highly applicable factor. 10% commented on efficiency as a Factor Not Sufficiently to consider, No respondents were Neutral, or not at all to consider categories.

Considering the efficiency as a factor of lodging batteries as accessories for solar PV systems, 50% remarked efficiency is applicable as a factor, while 50% observed the efficiency as a highly applicable factor. No respondents responded to other responses.

Considering the efficiency as a factor of lodging DC cables as accessories for solar PV systems, 90% commented efficiency is applicable as a factor, while 10% observed efficiency as a highly applicable factor. No respondents retort to other responses

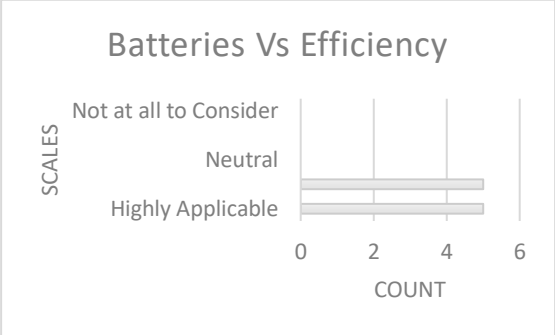


Fig. 13. Batteries Vs Efficiency

Considering the durability as a factor of Solar Panels as accessories for solar PV systems, 100% commented efficiency is highly applicable as a factor. Interestingly No respondents responded to other responses.

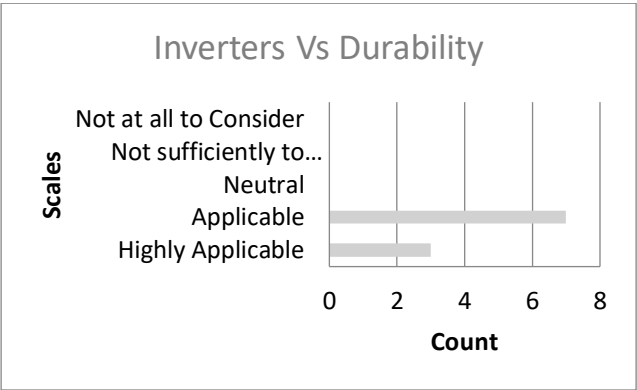


Fig. 14. Inverter Vs Efficiency

Accordingly, when occupying inverters 70% of the sample considered durability as an applicable factor, and 30% considered durability as a highly applicable factor to consider for buying inverters. For Neutral, Not Sufficiently to consider or not at all to consider no respondents commented.

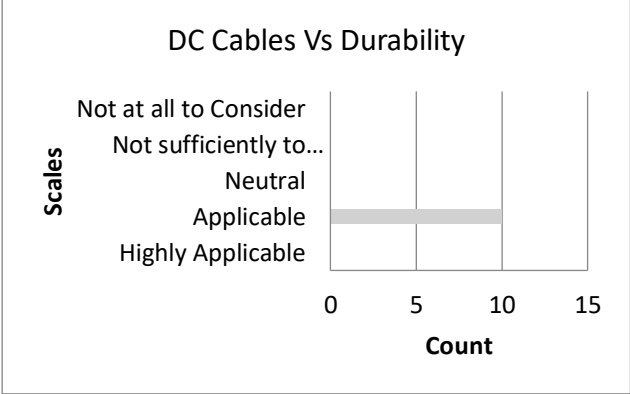


Fig. 15. DC Cables Vs Efficiency

For durability as a factor to consider for buying DC Cables, 100% commented on it as an applicable factor, Yet, No respondents other considered categories.

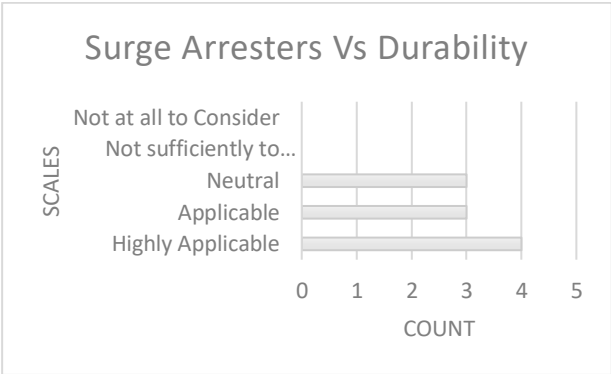
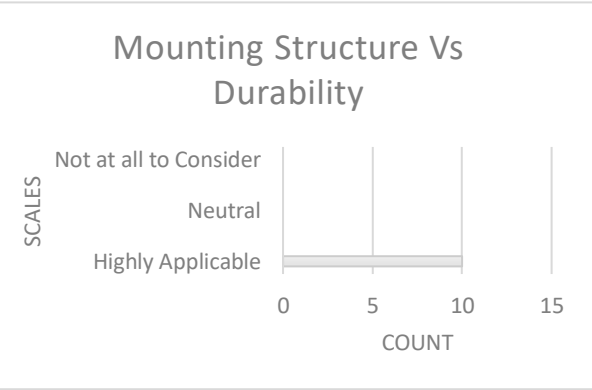


Fig. 16. Surge Arresters Vs Durability

Considering the durability as a factor of lodging surge arrestors as accessories for solar PV systems, 40% commented durability is highly applicable as a factor, while 30% observed durability as an applicable factor. 30% observed durability as a neutral factor to consider. No respondents responded to other responses.

Fig. 17. Mounting Structure Vs Durability



For durability as a factor to consider for buying a Mounting structure, 100% commented durability is a highly applicable factor. Yet, No respondents for other categories.

Considering the durability as a factor of Batteries for solar PV systems, 50% commented durability is highly applicable as a factor, while 30% observed the durability as an applicable factor. 30% observed durability as a neutral

factor to consider. No respondents responded to other responses.

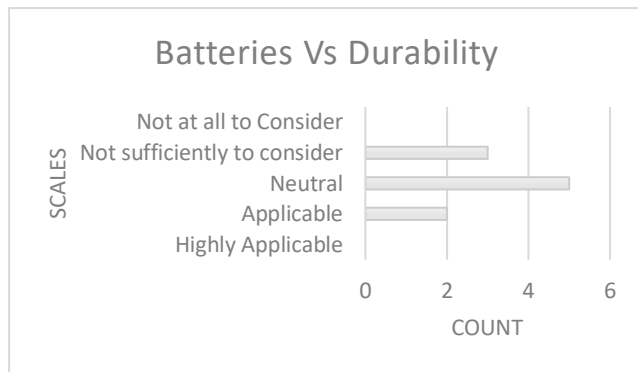


Fig. 18. Batteries Vs Durability

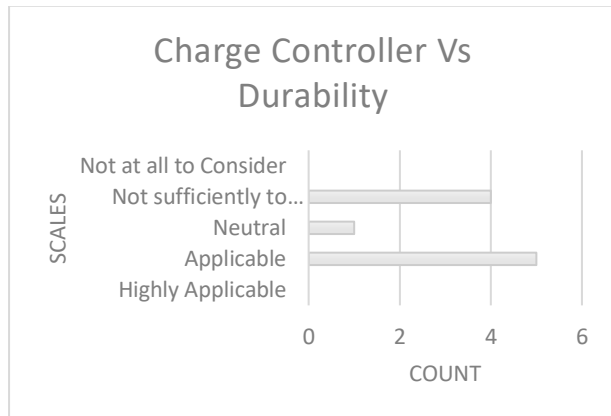


Fig. 19. Charge Controller Vs Durability

Considering the durability as a factor of accommodations of charger controllers as attachments of solar PV systems, 50% commented durability is an applicable factor, while 10% observed the durability neutral factor to consider. 40% commented durability is a factor not sufficiently to consider. No respondents responded to other responses.

D. Strategies for improving the Solar PV system of supply of market economy in Sri Lankan buildings

When considering the Cost as a performance characteristic, the Solar panels, DC Cables, Surge Arresters and Mounting cables are highly dependent on the Cost factor. As usual, Cost is preferred in all component selections.

Therefore, on the supply side of the market cost is to be considered in preparing strategies for market conditions.

For Efficiency as a performance characteristic, Only DC cables are considered high as a factor. Yet, all the components (instead of Surge Arresters) in general were in the selection of efficiency as an applicable factor. Therefore, for supply applications DC cables were to moderate with market conditions.

Durability as a performance characteristic for Solar PV components, PV Panels, DC Cables and Mounting

Structure responded to 100% option is a highly dependent factor.

Thus, for the supply side of the market for durability when preparing strategies for market conditions, the above factors need to be considered higher in priority.

VI. CONCLUSION

A. Cost as a function when selecting Components:

For PV panels, cost was preferred as a highly applicable option, whereas Neutral not sufficiently applied or not at all applied were not selected by any respondent. For Inverters selection cost was a moderate option as 60% preferred cost as applied. When Selecting DC Cables cost “Applicable” is the 90% highest option. For Surge Arresters all respondents selected “Applicable” as the option. Selecting Mounting Structures Cost Played “Highly applicable option. For selecting Batteries cost is not a highly considerable factor, more respondents prefer not a highly considered option.

Charge Controllers in considerations, applicable, highly applicable and neutral options are mostly preferred.

B. Efficiency as a function when selecting Components:

Selecting PV panels, Efficiency was preferred as a highly applicable option and applicable option, and Neutral not sufficiently applied or not at all applied were not selected by any respondent. For Inverters selection Efficiency was a moderate option as 50% preferred Efficiency as applied in Applicable and Highly applicable options. Selecting DC Cables Efficiency “Applicable” selected as the 90% highest option. The Surge Arresters are neutral, not sufficiently applied and not at all considered are the options. For Mounting Structures selection Efficiency played “applicable” for 70%. Batteries selection and efficiency is a considerable and highly considerable factor (50%).

Selecting Charge Controllers as considerations, applicable, and neutral are mostly preferred options.

C. Durability as a function when selecting Components:

While selecting PV panels, Durability was 100% preferred as a highly applicable option, whereas Neutral not sufficiently applied or not at all applied were not selected by any respondent. When selecting Inverters select Durability Applicable (70%) and Highly Applicable (30%). When Selecting DC Cables Durability “Applicable” is the 100% option, and no other options are selected by any occupant of the sample. For Surge Arresters Applicable” is 30%, Highly applicable 40%, and Neutral is 30%. Selecting Mounting Structures Durability Played 100% option. For selecting battery durability 50% selected Applicable option, 30% selected not applied, 20% is applicable.

Charge Controllers in consideration, 50% considered in applicable option, neutral 10% and 40% not applied.

REFERENCES

- [1] M.Shahbaz, M.Sbia, R. Nanthakumar, L.Afza, “ The Effect of Urbanization, Affluence and Trade Openness

- on Energy Consumption: A Time Series Analysis”, Institute of Information Technology Lahore, Pakistan, Free University of Brussels, University Malaysia Terengganu, COMSATS Institute of Information Technology Lahore, Pakistan , 2015
- [2] T. Mendis , K.N.K. Pathirana, and W.A.P.S Kumara, “Optimized building integrated photovoltaic systems for utilization on facades in the tropical climate” KDU 145 12 th International Research Conference of KDU, Proceedings of 12th International Research Conference, 2019
- [3] Sri Lankan Power Crisis and Future Energy Management, Institute of Engineers Sri Lanka, Energy Article .pdf, <https://iesl.lk/SLEN/47/upload/news/IESL>
- [4] L. Gunaratne ,”Solar photovoltaic in Sri Lanka: A short history”, First published: October, <https://doi.org/10.1002/pip.4670020406>, 1994
- [5] T. Fernando , B.N.F. Warnakulasooriya , K.P.L. Chandralal “Energy poverty and development of solar power as a sustainable energy source: a study based on customer perspectives of Sri Lanka”, 319 th International conference on business management (icbm 2022)
- [6] Paving the way towards an Energy Secure Sri Lanka, Sri lanka Sustainable Energy Authority, Sri Lanka, 11.08.2023,
- [7] <https://www.adb.org/sites>
- [8] U.C Bandara, “Factors Influencing Solar Energy Technology Adoption by Households in Western Province Sri Lanka”, 15th International Conference on Business Management 1032., Ceylon Electricity Board, Sri Lanka (ICBM 2018)
- [9] K.Mangla , S. Luthra, S. Jakhar , “A step to clean energy - Sustainability in energy system management in an emerging economy context”, Journal of Cleaner Production, Volume 242, 1 January 2020
- [10] <https://www.energy.gov.lk/en/soorya-bala-sangramaya>, 2021
- [11] <https://www.adb.org>
- [12] <https://www.ceb.lk/>
- [13] <https://www.energy.gov.lk>
- [14] <https://www.adb.org>

A Study on Lighting Technologies Used in Homes in Sri Lanka and its Impact on the Energy Demand of the Country

R.M.K.S.K. Ranaweera

Department of Building Services
Technology
University of Vocational Technology
Rathmalana, Sri Lanka
kalanarm97@gmail.com

W.M.C.A. Weerasekara

Department of Building Services
Technology
University of Vocational Technology
Rathmalana, Sri Lanka
chathurangaan75@gmail.com

N K L K. Pathum

Department of Building Services
Technology
University of Vocational Technology
Rathmalana, Sri Lanka
pathumkalpa12@gmail.com

P.M. Perera

Department of Building Services
Technology
University of Vocational Technology
Rathmalana, Sri Lanka
madhavikdy@gmail.com

Abstract— Lighting accounts for significant energy usage of household consumers. In Sri Lanka, morning and evening peak in the energy demand curve occurs mainly due to the household energy demand. The lighting technologies used in households will impact the energy consumed since the energy efficiency of different lighting technologies are different. This study investigates lighting technologies used by household consumers through a survey and the possibility of reducing the peak demand by changing the lighting to more energy efficient technologies is explored. The survey covers a sample of 1000 houses randomly selected and the results are extrapolated to the total number of houses in the country to arrive at national level data. The lighting technologies considered are incandescent, compact fluorescent lamps and light emitting diodes. Further, some other aspects regarding other characteristics of the household lighting systems are also investigated. The findings indicate that the majority of the households now use light emitting diode technology. However, the lighting load can be further reduced by converting the incandescent and compact fluorescent lamps used to light emitting diodes. This conversion can reduce the thermal energy usage for electricity generation at peak load situations which can immensely contribute to reduce the electricity generation cost and also reduce the carbon footprint of the power generation system of the country.

Keywords—lighting technologies, households, Sri Lanka, energy efficiency, peak demand

I. INTRODUCTION

Sri Lanka has faced a series of issues in terms of meeting its electricity demand in recent years and still, the issue is persistent. The recent economic situation of the country, unexpected weather changes and price escalations of other energy sources have worsened the issue. In such situations, demand side management strategies can be used to mitigate this issue to a certain level.

According to [1] household electricity consumption in the country has significantly increased in the last two decades due to two major reasons, expansion of rural electricity distribution programs and a dramatic increase of types of energy consuming equipment in use and the pattern of using those equipment. Electrification of households reached 100%

in 2017 Sri Lanka [2] and according to the [3] 24.7% of the annual electricity consumption in 2022 was accounted by the household customers.

Therefore, it is evident that household consumers play a major role in Sri Lankan energy demand and the demand management of household consumers is very important

Lighting is one of the main electricity consumption equipment in a household. According to [4] Lighting is a substantial component in household electricity consumption especially in the lower consumption (<90 kWh/month) category. Therefore, it is essential to investigate the type of lighting equipment that is used in the household in Sri Lanka and its impact on the energy demand of the country.

Traditionally incandescent bulbs were commonly used in households for lighting. However, with technological advancement consumers shifted to more energy efficient lighting technologies such as compact fluorescent lamps (CFL) and linear fluorescent lamps. These two technologies reduced the energy consumption by approximately 80%. Later LED (Light Emitting Diode) lighting was introduced and it is the most modern energy efficient lighting technology widely used in the world. At present LEDs reduce energy consumption by approximately 90% compared to incandescent lamps.

II. LITERATURE SURVEY & PROBLEM IDENTIFICATION

Previous research work done in this sector in Sri Lanka is very minimal. However, a comprehensive study has been carried out [4] in 2013. The researchers have found that the use of other technologies such as LED still low in the domestic sector. There is a market shift from FTL(Fluorescent Tube Lights) to CFL (Compact Fluorescent Lamps) because of the convenience of using CFLs. However, they have also noted that LED used in Sri Lanka is relatively new and rare. The reason is that good quality LED lamps are expensive and cheap lamps do not perform well at all.

One of the main objectives of this study is to find out the current situation of the lighting technologies used in the Sri

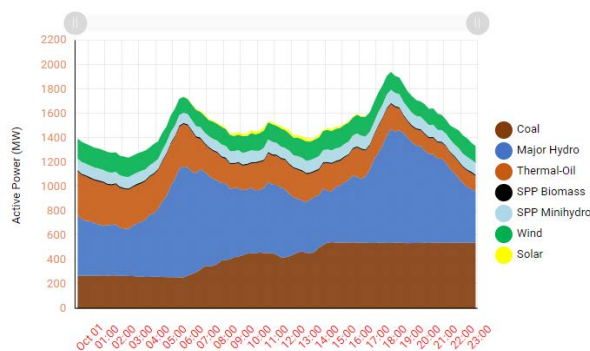


Fig. 19. Daily electricity load curve Source: CEB Load Curve October 1, 2022

Lankan households now since the 9 years have passed from the earlier study and it is observed at a glance that LEDs are more common in Households in the current context.

The major findings of this study [4] In the less 90 unit category, lighting loads peak during morning and evening times with incandescent dominating, closely followed by CFL load. In the 90 – 180 units category, lighting loads also peak in the morning and evening with equal contributions from incandescent and CFLs. Contribution from FTL was marginal. In the over 180 unit category, CFL is dominating the load as anticipated because of high tariffs. However, there is a relatively large component of filament lamps (IBs) used during peak hours. The presence of other technologies such as LED is not significant.

The lighting load of the household has a significant relationship with the peak load of the system.

Sri Lanka has a load curve with a steep peak in the late evening. From about 6:00 p.m., the load grows to about 2,500 MW by 7:30 p.m. and falls off after about 8:30 p.m. Therefore, the system requires substantial additional generation capacity only to meet the sharp night peak. [2]

The Fig 1 illustrates the daily energy demand of Sri Lanka. The nighttime peak that occurs from 6.00 pm to 8.30 pm is created by the lighting load since most of the households switch on the lights during this period. [4] also mentions the impact of residential lighting is highlighted in the CEB system load profile, the system peak is predominantly from lighting and hence, energy efficient lighting systems can make a major contribution to reducing the peak demand.

Due to these factors, the research gap exists to identify the lighting technologies used in Sri Lankan households and their impact on the peak electricity demand.

III. RESEARCH METHODOLOGY

The data collection for the research was carried out with primary and secondary data. Secondary data was collected from previous research and the data published by the Ceylon Electricity Board.

The primary research was collected through a survey. Two separate survey instruments were designed and applied, those are on-site surveys and questionnaire surveys. On site survey was done by researchers visiting randomly selected houses to collect the data. The questionnaire survey was done through

using Google Sheets and handouts survey and the data was input to the sheets by the residents of the houses. It was

TABLE X. DISTRIBUTION OF HOUSES IN CATEGORIES

Electricity usage (kWh) range	No of houses	Percentage from total
0-28	43	4%
28-56	128	13%
57-84	228	23%
85-112	384	38%
113-154	202	20%
154+	26	3%

TABLE XI. DISTRIBUTION OF HOUSES IN CATEGORIES

District	Total
Colombo	51
Kaluthara	7
Kandy	280
Matale	2
Galle	282
Mathara	5
Kurunagala	27
Anuradhapura	16
Polonnaruwa	273
Monaragala	44
Rathnapura	11
Kegalle	2

planned to select a sample of 1000 households for the survey and the actual number of households used for the survey was 1011. For each house, the consumption categories by type of technology used, location of use, wattage of each lamp and average hours of use per day were collected. The households were categorized according the electricity consumption, 1-28 kWh, 29-56 kWh, 57-84 kWh, 85-112 kWh, 113-154 kWh, and 154+ kWh. Information about the current situation of lighting in households was collected. and Table 1 indicates the distribution of samples over the categories of usage.

Initially, it was planned to select houses from all districts in the country equally, however, due to the corona pandemic and limitations regarding transport we could not conduct the survey to cover the whole country equally, hence the majority of the data collected in the districts of Kandy, Anuradhapura, Galle and Colombo. Table 1 indicates the distribution of samples in the districts and Table 2 indicates the distribution of samples over the categories of usage.

IV. RESULTS AND DISCUSSION

It was found out from the data that out of the light points that were considered for the survey 95.6% were LED, 2.92% were CFL, 1.43% were incandescent and 0.03% were fluorescent. This was a very different scenario from the findings [4] of 2013. The majority of the light points have been now converted to LED whereas earlier they were incandescent and CFL lamps.

However, a considerable number of points were using non LED technologies and it was important to calculate and obtain the effect on energy demand during the peak that can

be created by converting all these points to LED. A calculation was carried out for this purpose and the data that was collected for 1000 households was extrapolated for the total number of household customers in the country considering the data from [5].

TABLE XII. ESTIMATED ENERGY SAVING DURING PEAK TIME

Saving From Conversion	Morning Peak	Night Time Peak
Saving from converting incandescent lamps (MWh)	40.78	209.40
Saving from converting fluorescent lamps (MWh)	0.14	1.06
Saving from converting CFL lamps (MWh)	1.56	7.51

TABLE XIII. CORRELATED COLOUR TEMPERATURE DATA

Color of Lamp	Total Number of Bulbs	Percentage
Cool White	13799	97%
Warm White	467	3%
Total	14266	

The results of the calculation are given in Table 3. It was observed that considerable savings can be obtained during the peak time.

Further, the energy that was generated during the peak hours with thermal oil was calculated by analyzing the daily curve in Fig 1.

According to the calculation on the given day, the total energy that was generated with thermal oil during the night peak time is 665MWh. According to the data in Table III, if all incandescent lamps are converted to LED, 209.4 MWh energy can be saved on average during night peak. Since thermal oil is the most expensive energy source that is used to meet the additional demand, if the peak demand is reduced it can be utilized to reduce the energy produced using thermal oil. Hence on average, 31% of the energy produced by thermal oil can be saved from converting the incandescent bulbs remaining in the country to LED which is also a significant saving to the system since thermal oil generation is very expensive.

Data was collected regarding the correlated colour temperature of the lamps used by the households and the findings are tabulated in table 4. Although theoretically warm white light is recommended for most household areas, it was found that the majority of the users use cool white lamps.

Further data was also collected regarding whether luminaires are used in the households. It was observed luminaires were used only in 9% of the households and in all other cases bare lamps were used for lighting without any type of luminaire.

V. CONCLUSIONS AND FURTHER WORK

The major conclusion that can be arrived from the study is that the majority of the households in Sri Lanka now use energy efficient lighting technologies, CFL or LED. This is a

drastic change from the observations made in 2013 [4] This is a positive trend which needs to be further encouraged by the relevant authorities perhaps by providing subsidies for lower-income consumers.

It was observed through calculations that it is possible to reduce the usage of thermal oil from about 30% during the peak time if all the incandescent lamps that are still in use can be converted to LED. This indicates that there are still opportunities for improvement and the country can still try to reduce the peak load by using more energy-efficient lamp technology. As future work, a larger study needs to be carried out to generalize these data covering all the districts in the country.

REFERENCES

- [1] M. D. Lakmali, "Research on Electricity Consumption Pattern of Households," University of Moratuwa, 2016.
- [2] Asian Development Bank, "Sri Lanka Energy Sector Assessment, Strategy and Road Map," Asian Development Bank, 2019.
- [3] Ceylon Electricity Board, "Statistical Digest 2022," 2023.
- [4] International Institute for Energy Conservation and EnergySolve International (Pvt) Ltd, "Implementation of Energy Efficiency Policy Initiatives – Sri Lanka," Colombo, 2013.
- [5] Ceylon Electricity Board, "Statistical Digest 2021," 2022.

Energy management for the sustainability of Sri Lanka: Transition through green energy, Challenges & Future Prospects

D. S. B. Ratnayake
Industrial Engineering Training Institute
National Apprentice & Industrial Training Authority
Katubedda, Moratuwa, Sri Lanka
ratnayakeduminda394@gmail.com

Abstract— It is evident that the existence of mankind on earth is dependent on “energy”. However, human inclination to use non-renewable sources of energy such as fossil fuels exert considerable pressure on the environment and human health. This has made the countries to adopt the renewable sources of energy such as “green energy”. Thus, it has become a goal of modern governance to implement “green energy management” to achieve sustainable development. The author has adopted a qualitative approach as the methodology and objective is to elaborate on the applicability of the concept of “sustainable green energy” in the landmass of Sri Lanka, the challenges in implementation and the future aspects. The author has identified that the corporate sector must implement sustainable green energy strategies. However, this has several obstacles which are economical, educational and socio-cultural. The shortage of investments, technological support, data and the norms of the society are prominent impediments in the context of Sri Lanka. It is evident that the government and relevant authorities on energy are entrusted with the obligation to consider the prospects of green energy management by imposing laws and policies in setting targets, increasing the private sector interference in providing financial support, enhancing the institutional support in exploring the sources of green energy and the promoting common initiatives. The ultimate success is based on the manner in which Sri Lanka interacts with foreign nations. The conclusion of the paper has elaborated that, “green energy management” is an imperative component in the governance of Sri Lanka which can be developed by global collaboration.

Keywords— *energy, green energy management, sustainability, policies, strategies*

I. INTRODUCTION

“Energy” is considered a major component in human life and one of the essential basic needs. It is a key point in the context of economic, social and environmental dimensions of sustainable development [1]. The low security of the energy becomes directly influential to the overall economic framework of a country and the energy sources with maximum advantages should be utilized.

“Clean sources of energy that generate lower environmental impact in relation to conventional energy technology” are referred to as green energy.

Throughout the last decades, the concept of “green energy” emerged as a strategic sustainable energy formation process in the global arena. With the passage of time, the interest of the nation in green energy has increased.

It is apt to consider the context in Sri Lanka in this regard. There are different types of energy in Sri Lankan context among which “fossil-based energy” is of higher significance. In addition to this, Coal, petroleum, natural gas, etc. are also included under the same category and substantially influence the environment. Green energy has its significance as it prioritizes sustainable energy approaches due to the non-renewable nature and harmful nature of fossil energy for the environment [2]. Thus, a justification can be given for the transition through sustainable green energy strategies in the Sri Lankan context.

The paper consists of major parts under which current statutes of the energy consumption of Sri Lanka, Transition through sustainable energy, Challenges and future prospects are discussed.

The paper has three main objectives to deal with. This gives an idea of the transition through green energy strategies in Sri Lanka while reducing the negative environmental impacts of fossil energy. The second objective is the identification of the role of energy entrepreneurs in the implementation of sustainable green energy strategies in Sri Lanka. The third objective is directed at the understanding challenges and future prospects of green energy management in Sri Lanka.

II. LITERATURE REVIEW

Since the early twentieth century, Sri Lanka has progressed in the usage of renewable energy in the context of generation of local power and tea/plantation industries, hydropower generation can often be seen. Sri Lanka has faced the challenge of achieving environmental sustainability while meeting the demands of technological development. Sri Lanka is a country with a middle-income generation and self-sufficiency can be achieved by the use of renewable and other local indigenous resources. The maximum availability of solar energy and rainfall influence the plantations in Sri Lanka which becomes a key factor in the production of the high amount of biomass from a single unit of area. Sri Lanka has an optimistic hydropower

potential and its location near the equator provides a good opportunity to take the maximum benefit of solar power energy. The solar panels can be used to produce electricity. Sri Lanka being an island surrounded by ocean has the benefit of wind energy. However, in addition to the aforementioned sources, energy produced from waves, current energy from the ocean, geothermal energy and conversion of thermal energy from the Ocean are prominent [3]. It is achieved by positioning local economic strategies with the global trends by being an energy dependent nation in 2050 with a value of 100% [4]. Electricity generation can be done using renewable energy in the year 2050 and, it shall be a tremendous future goal of Sri Lankan energy [5]. Comprehensiveness of own energy sources and coherent energy transition policies with Long-term sustainability are imperative concerns in building up the indigenous capacities to overcome the failure of a country at the geopolitical battleground [6].

III. METHODOLOGY

The author of this paper has adopted a qualitative methodology and has undertaken a literature survey. The literature used in the paper is both national and international. The author has perused research papers and articles to enhance the quality of the study.

IV. RESULTS AND DISCUSSION

Transition through sustainable green energy

Sri Lanka is an island situated about 60 km from the Indian mainland and in the year 2022, it seems that 65,610 km² of area of the country. In the same year, Sri Lanka had a 22.2 million total population according to the Department of Census and Statistics, 2022. The gross domestic Production (GDP) in Sri Lanka in 2022 was 74.40 billion US dollars and the 0.003 percent of GDP value is shown for the world economy. Table 1 given below depicts statics on the energy supply of Sri Lanka.

TABLE 1 ENERGY SUPPLY AND USAGE PERCENTAGES
IN SRI LANKA (YEAR 2017) BY ASIAN
DEVELOPMENT BANK, 2019

Total Utilization of oil equivalent energy	12.8 million tons
Usage of Petroleum	43%
Usage of Biomass	37%
Usage of Coal	11%
Usage of Hydro based energy	6%
New energy with renewable nature	3%

Fossil fuel is a non-renewable energy source which results in issues pertaining to human health and the environment. These issues have arisen due to the excessive consumption of such fuel in both industrial and non-industrial sectors. The fossil-based technologies were used by the people as a tool in the governance of both domestic and international affairs. The excessive inclination towards fossil-based technologies necessitated the urgent and haste implementation of sustainable green energy strategies in domestic contexts. The main purpose of such a transition is to protect human beings from tolerable limits.

Green energy has tremendous advantages. One of the prominent advantages is that it is a source of energy which has the minimum environmental impact [7]. Green energy is favourable for the environment and is extracted as solar-based, hydro-based, biomass-based, wind-based, geothermal-based etc. This directs to the reduction of the negative results of fossil-originated energy and the overall harmful emission from the generation of electricity and suppresses the level of gases with the greenhouse effect. This creates a balance between environmental improvements and support in meeting the demand for clean energy in both industrial and non-industrial sectors.

There is an interrelationship between nature and society which supports gauging the sustainability of the environment and the progress of the utilization of green energy sources. The sustainable development can be reached with nature at a reasonable cost with minimum negative impacts on society. Comparatively, Green energy sources are preferable due to their sustainability. Contrarily, fossil fuels lack the elements of sustainability [8]. The green energy has become a catalyst to achieve sustainable technological development, and industrial development while exerting positivity on the living standards of the people. In Sri Lanka, everlasting and productive sustainable green energy approaches become supportive in promoting green energy origins and technologies.

B. Role of the energy entrepreneurs and sustainable green energy strategies in Sri Lanka

In the domestic arena, most of the companies face the challenge of sustainable energy management. Long-term strategic thinkers and energy entrepreneurs are closely knitted to the process. They perform the function of supporting organizations in choosing sustainable energy approaches. The in-depth knowledge and plenty of approaches granted by them lead to the ultimate decision-making on renewable energy.

It is axiomatic that the responsible authorities on energy should implement effective sustainable energy strategies by considering the needs of future generations. Sustainability is an outcome of sound and effective strategies. However, it is imperative to have clear strategies with coherence to use the appropriate energy in the achievement of goals.

The use of “green energy” is interwoven around different stakeholders including authorities of government, industries, clients, investors and bottom line of the financial sector, current & employees with future potential, non-governmental organisations, local community suppliers, etc. The main function of stakeholders of such categories is prominent as the main characters of the strategies and simultaneously have to analyze their choices. Thus, it necessitates the existence of effective sustainable energy management. The effective management is a collection of efforts namely the awareness about the target which should be set manner of structuring and financing the consumption

reduction efforts, the manner of dealing with the renewable energy generation approaches at on-site and cogeneration projects and the way of greening the remaining off-grid supply. Among all the ventures, the identification of the most pertinent sustainable energy generating technologies is of high significance. The initiation of technological areas with minimum environmental effects should be the main focus. Thus, the higher inclination towards solar panels established at on-site, windmills, biomass projects, cogeneration, and other renewable energy sources is remarkable.

The ultimate objective of using these sources is the achievement of the goals of sustainability with the nature of good rates-of-return on the implemented sustainability projects while ensuring the enhancement of security-of-supply (Ex: in a remote area) etc. Negotiating self-generation contracts is the main task of an energy entrepreneur. The calculations on the returns of investments are based on the more commercial approaches to self-generation projects. A good perception of costs and revenues will result in better forecasts, as the incline or decline of returns produced by the fluctuations of the available market should be noted. In this instance, the launching of projects excessively will result in the failure to deliver the expected rate of return. The reason behind the failure is the initial calculation based on over-optimistic forecasts of future energy costs or a lack of insight into cost components. The process of trading green commodities should be lawful and effected under a legally approved mechanism with better certification. The main purpose of certification is to grant the commodities a tradable nature. The improvement of return on investments can be achieved by planning and implementing a good approach for the trading of green-based commodities. The launch of sustainable green energy management can be swiftly attained by the adoption of green energy strategies such as trading green electricity.

C. Challenges

The green energy development in Sri Lanka is challenging and can be categorized under environmental, social and economic facets.

1) Economic Barriers

Under the economic facet, social cost and benefit analysis are of high significance. The deployment of energy of green origin is highly influenced by a shortage of investments to adopt green energy-related technologies, under-rated environmental shocks, cost for high investment in the country, fluctuation and under-rating of energy prices at the future, risks in the financial activities and various interrelated factors emerged with Corona Pandemic.

2) Barriers related to Informational and Awareness

Lack of thorough data on green energy sources has become a major problem. This issue has further been aggravated by the shortage of human resources and technical knowledge of the people. The formation of green

energy strategies with sustainable characteristics is impeded by the inadequacy of reliable data on wind and solar radiation. The successful execution of a green energy system needs competent human resources. However, in the domestic arena, there are several issues namely scarcity of opportunities to the training workforce with advanced technological knowledge, lack of specifics knowledge and minimum awareness of the academic institutions on the shifting from traditional energy technologies to modernized eco-friendly technologies etc.

3) Barriers emerging from Socio-Cultural aspects

The values and norms of the country have a direct connection with the socio-cultural barriers to launching green energy strategies. The society's perception and the subsequent acceptance of the establishment of green energy technologies impact the dispensation of resources. The ignorance and lack of concentration on the values and norms of the country influence the formation of these types of barriers. As the solutions, some strategies can be practiced (Ex: The indirect improvement of land extent for the agricultural development for both crop cultivation and animal husbandry while implementing the green energy strategies).

The Market structure is also a key component in the implementation of a successful green energy system within the country. Notably, there exist a small number of competitors within the energy industry. The system is highly centralized and consists of a minimum number of participating organizations. The process of production, distribution, and transmission is controlled by fewer organizations and such dominance makes it inconvenient for the compliance of a larger-scale green energy system. This necessitates the modification of market structure, and such a modification should be prioritized for the successful movement towards the renewable energy system [9].

D. Future Prospects

The authorities have an obligation to undertake the approaches to increase the green energy supply. Thus, they are responsible to supervise the matters of, institutional and technology-based support for green energy, publicizing and promoting the importance of green energy towards sustainability, strengthening and expanding the National and International Collaboration etc.

The preliminary step is to set objectives for green energy, and the next step is the implementation of targets via suitable policies. Such policies have the potential to provide strong market signs and realize the responsibility of the government in transition to the green energy.

Financial support is sprung from both government and private sectors. The private sector has the potential to increase new investments in encouraging green energy. Simultaneously, exploring the sources from which green energy can immensely be produced is highly significant. The second important factor is the institutional and

technical support which ensures the due extraction of green energy from the explored sources. It is imperative to have common initiatives which involve lowering the cost of worldwide green energy establishment. Further, the common initiatives should accelerate from the financial and technical parties and increase economies of scale while stimulating trade at domestic and international levels. The advantages of common initiatives can be further elaborated as collaboration with other countries to overcome the financial deficiency while incorporating relevant funding, and donation schemes. The negotiations with the partner countries and the formation of joint markets have the potential to reduce the costs of deployment.

It is axiomatic that the global collaboration of Sri Lanka with other countries creates a platform facilitating the sharing of technology-based knowledge and strengthens ideal practices for the expansion of green or renewable energy markets. This is not single-handedly applicable to Sri Lanka but to foreign countries as well.

V. CONCLUSION

The different types of energy in Sri Lanka bring different repercussions on the environment, economy and society of the country. The “fossil-based energy” including coal, petroleum, natural gas, etc. has a direct impact on the environment. “Green energy” is a significant type of energy and prioritizes sustainable energy approaches. It is preferred over the non-renewable sources of energy which cause harm and deterioration of the environment. Currently, the public concern has increased on the use of green energy and it is evident that there is a transition through green energy which can be justified under the conditions of Sri Lanka.

The companies established in Sri Lanka often confront the key challenge of sustainable energy management. Long-term strategic thinkers and energy entrepreneurs should support the decision making on the launch of renewable energy via different approaches. Green energy development of Sri Lanka is impeded by environmental, social and economic facets namely financial shortages, lack of information on awareness regarding green

energy and sociocultural obstacles. The elimination of problems and overcoming of such obstacles can be done through global collaboration with foreign nations while increasing the adequate supply of green energy, policy implementation, gaining the financial support of the relevant authorities, exploration of new sources of green energy, launching of the joint market strategies etc.

References

- [1] İ. Dinçer, “Environmental impacts of energy,” *Energy Policy*, vol. 27, no. 14, pp. 845–854, Dec. 1999, doi: 10.1016/s0301-4215(99)00068-3.
- [2] A. Midilli, İ. Dinçer, and M. Ay, “Green energy strategies for sustainable development,” *Energy Policy*, vol. 34, no. 18, pp. 3623–3633, Dec. 2006, doi: 10.1016/j.enpol.2005.08.003.
- [3] S. Sayanthan and N. Kannan, “Renewable energy resource of Sri Lanka! A review,” *International Journal of Environmental & Agriculture Research (IJOEAR)*, vol. 3, no. 4, pp. 80–85, Apr. 2017, [Online]. Available: https://ijoeear.com/assets/articles_menuscripts/file/IJOEAR-APR-2017-19.pdf
- [4] C. H. Dasanayaka, Y. S. Perera, and C. Abeykoon, “Investigating the effects of renewable energy utilization towards the economic growth of Sri Lanka: A structural equation modelling approach,” *Cleaner Engineering and Technology*, vol. 6, p. 100377, Feb. 2022, doi: 10.1016/j.clet.2021.100377.
- [5] S. Anjalee, “Potential renewable energy sources in Sri Lanka,” *ResearchGate*, Apr. 2023, [Online]. Available: https://www.researchgate.net/publication/370055760_Potential_Renewable_Energy_Sources_in_Sri_Lanka
- [6] Gz. M. Theiventhran, “Energy as a geopolitical battleground in Sri Lanka,” *Asian Geographer*, pp. 1–25, Jul. 2022, doi: 10.1080/10225706.2022.2098507.
- [7] Most. A. A. Rita, “Green path development and green regional restructuring for sustainable development,” 2020. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4014780
- [8] M. A. Rosen, “Energy Sustainability: A Pragmatic Approach and illustrations,” *Sustainability*, vol. 1, no. 1, pp. 55–80, Mar. 2009, doi: 10.3390/su1010055.
- [9] Most. A. Aktar, M. Harun, and Md. M. Alam, “Green energy and sustainable development,” in *Encyclopedia of the UN sustainable development goals*, 2020, pp. 1–11. doi: 10.1007/978-3-319-71057-0_47-1.

Analysing the Impact of Behavioural Changes on Residential Building Energy Consumption: A Case Study of Raddolugama National Housing Scheme

J.T.Lakmal

Department of Building Services
Technology
University of Vocational Technology
Rathmalana, Sri Lanka
rulztharu@gmail.com

G.M.S.R.G. Manawadu

Department of Building Services
Technology
University of Vocational Technology
Rathmalana, Sri Lanka
samanthamanawadu@gmail.com

K.A.D.R.S. Rathnasekara

Department of Building Services
Technology
University of Vocational Technology
Rathmalana, Sri Lanka
rajithrathnasekara@gmail.com

J.M.S.L.S. Ranasinghe

Department of Building Services
Technology
University of Vocational Technology
Rathmalana, Sri Lanka
sayururanasinghe@gmail.com

Abstract— Human behaviour stands as a pivotal determinant impacting household energy consumption. While a building's technical attributes wield significant influence, occupant behaviour remains crucial. Our study aims to explore the intricate interplay between energy use and occupant behaviour. Data was gathered through questionnaires and interviews, with 103 residents from the National Housing Scheme of Raddolugama participating. The questionnaire encompassed thirteen parameters, including comparisons like Hours Spent vs. Energy Costs, Total Energy vs. Family Income, and Total Energy vs. Family Size. The analysis utilized the Minitab software, facilitating the exploration of relationships between energy consumption and the mentioned parameters. The collected data was rigorously examined using the Minitab software.

Keywords: human behaviour, energy consumption, residential building, household energy use

I. INTRODUCTION

In recent years, the global necessity for sustainability has driven a heightened emphasis on energy-related research and analysis. Climate change is recognized as one of the most significant environmental challenges of our era, and according to Delzendeh and others this recognition has led to a surge in international, and national agreements and initiatives [1]. These include landmark agreements like the Kyoto Protocol, regional measures such as the European Emissions Trading Scheme and the European Directive on the Energy Performance of Buildings (EPBD), and national efforts like the United Kingdom's Climate Change Programme (UKCCP) and the Climate Change Levy (CCL). Residential buildings play a pivotal role in the global energy landscape, accounting for a substantial portion of energy consumption and greenhouse gas emissions [2]. Therefore, sophisticated software tools are used to analyse the energy consumption of buildings and strategies integrated to reduce energy consumption accordingly, it is identified that significant difference between calculated energy

consumption and actual energy consumption [3]. Paone and Bacher [4] state that human behaviour and occupancy preferences are crucial factors that contribute to the gap between predicted and actual energy consumption. The way occupants interact with their living spaces, appliances, and energy-consuming systems significantly influences the overall energy usage and efficiency but these factors have not been considered generally in design and pre-occupancy energy evaluations. Alterations in human behaviour hold the potential to augment the energy efficiency of buildings. While effecting enduring shifts in behaviour can prove challenging, recent years have witnessed the emergence of novel strategies to cultivate energy efficiency towards technological advancements in energy information measurement, storage, and presentation (such as smart meters, dashboards, and mobile applications) have become accessible. These technologies furnish consumers with data that enable informed decision-making in pursuit of energy-conscious choices. This intricate interplay between human behaviour and energy consumption underscores the importance of understanding behavioural dynamics for devising effective energy-saving strategies.

Over the years, research has indicated that while advancements in building technologies and energy-efficient designs contribute to energy conservation, the role of human behaviour cannot be underestimated [5]. Occupant behaviour impacts various facets of energy consumption, ranging from daily activities such as lighting, heating, and cooling to the utilization of electronic devices. A nuanced comprehension of these behavioural patterns is paramount in ensuring the effectiveness of energy management initiatives and sustainable building practices [5].

This study aims to identify the relationship between behavioural changes and energy consumption in residential buildings through a comprehensive case study. By analyzing real-world data and employing rigorous methodologies, this research endeavours to provide insights into the tangible

effects of behavioural interventions on energy use. Through a systematic investigation of behavioural patterns, energy consumption trends, and their mutual influence, this study seeks to inform policymakers, urban planners, and architects about the significance of incorporating behavioural considerations into energy-efficient building designs and policies.

II. METHODOLOGY

A. Selecting a Case study

Established in 1982 Raddolugama, National Housing Scheme (RNHS) is the largest housing scheme in South East Asia 1982 located at the Raddolugama semi-urban area closer to the Seeduwa in Gampaha District, Western Province. This housing scheme consists of 2022 no. dwelling units including 1696 nos. “B” type, 248 nos. “D” type and 78 nos. “F” type houses.

TABLE I. INITIAL DESIGN DETAILS OF HOUSING UNITS

House Type	No. of Housing Units	Facilities	Extent of Land
B (Single Story)	1696	Living, 02 Bed Rooms, Kitchen and Bathroom	4.5 p
D (Two Storied)	248	Living, 02 Bed Rooms, Kitchen and Bathroom	7.0 p
F (Two Storied)	78	Living, 02 Bed Rooms, Kitchen and Bathroom	8.0 p

Table I shows the initial development details of this housing scheme. The original blueprint of the housing scheme has undergone substantial transformations over time. Presently, these alterations have extended significantly, driven by the residents' individualized designs that align with their preferences and needs.

The housing scheme accommodates a diverse population encompassing various ethnicities, economic levels and different social parameters. Hence this house scheme was selected as a case for this study.

B. Sample and data collection

160 nos. of housing units were selected as a sample for this study using a simple random sample method. This sample included 130 nos. from “B” type, 24 nos. from “D” type and 6 nos. from “F” type housing units. Primary data were collected using a questionnaire survey from 80 nos. housing units and conducting structured interviews for other 80 housing units. A summary of the questionnaire categorization used for both the questionnaire survey and structured interview is given in Table II.

TABLE II. QUESTIONNAIRE CATEGORIZATION

Key Categories	Questions
Energy Consumption	Electricity Bill, Water Bill, Gas Consumption, Firewood Consumption
Building	building type, building area, number of rooms and bathrooms
Occupant Details	Name, age, sex, religion, race, education level, number of occupants, income, job, workplace address, occupancy schedules
Equipment Details	equipment used, number, of hours consumed per day and wattage

C. Data Analysing

Minitab software was used to find whether there is a relationship between energy consumption and the following parameters. Minitab is a software product that helps to analyse data. It provides a simple effective way to input the statistical data manipulate that data identify trends and patterns and then extrapolate answers to the current issues. Collected data was analyzed using this software as mentioned below in Table III Compared Parameters.

TABLE III. COMPARED PARAMETERS

Item No	Compare Parameters
1	Spend Hours Vs Cost of energy (Total Sample)
2	Total Energy Vs Total Income of Family (Type B,D,F Houses)
3	Total Energy Vs Total Income of Family (Type B House)
4	Total Energy Vs Total Income of Family (Type D House)
5	Total Energy Vs Total Income of Family (Type F House)
6	Total Energy Vs Number of Family Members (Total Sample)
7	Total Energy Vs Number of Family Members (Monthly Income Bellow Rs.50,000)
8	Total Energy Vs Number of Family Members (Monthly Income Between Rs.50,000 – 100,000)
9	Total Energy Vs Number of Family Members (Monthly Income Above Rs.100,000)
10	Cost of water bill Vs Number of Bathrooms
11	Total Wattage of Bulbs Vs Total Spend Hours of Family Members
12	Total Wattage of Appliances Per month Vs Total Spend Hours Per Month
13	Total Wattage of Appliances per Month Vs Number of Family Members

After the comparison of the above-mentioned parameters, ANOVA (one way) was used to identify the P-value from the analysis of variance and compare them.

III. RESULTS AND DISCUSSION

TABLE IV. SUMMARY

Item No	Description	P Value	Significant Difference Yes/No
1	Spend Hours vs cost of energy (Total Sample)	0.003	Yes
2	Total Energy Vs Total Income of Family (Type B, D, F Houses) Total Energy Vs Total Income of Family (Type B, D, F Houses)	0.008	Yes
3	Total Energy Vs Total Income of Family (Type B House)	0.023	Yes
4	Total Energy Vs Total Income of Family (Type D House)	0.516	No
5	Total Energy Vs Total Income of Family (Type F House) Total Energy Vs Total Income of Family (Type F House)	0.732	No
6	Total Energy Vs Number of Family Members (Total Sample)	0.000	Yes
7	Total Energy Vs Number of Family Members (Monthly Income Bellow Rs.50,000)	0.000	Yes
8	Total Energy Vs Number of Family Members (Monthly Income Between Rs.50,000 – 100,000)	0.020	Yes
9	Total Energy Vs Number of Family Members (Monthly Income Above Rs.100,000)	0.024	Yes
10	Cost of water bill Vs Number of Bathrooms	0.000	Yes
11	Total Wattage of Bulbs Vs Total Spend Hours of Family Members	0.939	No
12	Total Wattage of Appliances Per month VS Total Spend Hours per Month	0.001	Yes
13	Total Wattage of Appliances per Month vs Number of Family Members	0.002	Yes

In a series of one-way ANOVA tests, various factors were examined related to energy consumption and household attributes. Firstly, the analysis comparing the total spent hours on family members to the cost of energy revealed a significant difference among different family sizes (Total Sample), with a P-value of 0.003, indicating that the time spent by family members influences the energy cost. Similarly, when comparing total energy consumption to the total income of family members in Type B, D, and F houses, the ANOVA results showed a significant difference in the case of Type B and Type F houses with P-values of 0.023 and 0.008, respectively, while there was no significant difference for Type D houses (P-value > 0.05).

Moving forward, the analysis of total energy consumption and the number of family members (Total Sample) exhibited a significant difference, with a P-value of 0.000, indicating that the number of family members impacts energy consumption. This trend continued when examining the effect of the number of family members on energy consumption in households with monthly incomes below Rs. 50,000 (P-value of 0.000), between Rs. 50,000 and 100,000 (P-value of 0.020), and above Rs. 100,000 (P-value of 0.024). These results suggest that the number of family members plays a significant role in energy consumption across different income brackets.

Furthermore, in the context of cost analysis, a significant relationship was found between the cost of the water bill and the number of bathrooms in households, with a P-value of 0.000, demonstrating that the number of bathrooms impacts water bill costs.

Lastly, the analysis of the total wattage of appliances per month against total spent hours per month and the number of family members also displayed significant differences, with P-values of 0.001 and 0.002, respectively, indicating that both the time spent using appliances and the number of family members affect the energy consumption related to this study. These ANOVA tests provide valuable insights into the factors influencing energy and cost dynamics in different household scenarios.

IV. CONCLUSION

In conclusion, this research, grounded in rigorous numerical analysis, has yielded valuable insights that lead to a set of practical recommendations for optimizing energy consumption in a residential housing complex. These recommendations encompass a range of strategies, from judicious appliance usage to income-based energy management and family size considerations. Emphasis is placed on the adoption of energy-efficient appliances, time-based usage schedules, and consumer awareness initiatives. Architectural and design interventions, as well as environmentally conscious landscaping and the use of light-coloured paints, offer opportunities for energy savings and comfort improvement. The incorporation of sound and heat insulation materials can further enhance energy efficiency. By embracing these recommendations, residents, administrators, and policymakers can collectively embark on a path towards enhanced energy efficiency, reduced costs,

and a more sustainable residential environment. This study not only contributes to the energy conservation discourse but also provides a practical roadmap for informed decision-making, fostering a greener and more sustainable future for residential communities. In conclusion, this research, grounded in rigorous numerical analysis, has yielded valuable insights that lead to a set of practical recommendations for optimizing energy consumption in a residential housing complex. These recommendations encompass a range of strategies, from judicious appliance usage to income-based energy management and family size considerations. Emphasis is placed on the adoption of energy-efficient appliances, time-based usage schedules, and consumer awareness initiatives. Architectural and design interventions, as well as environmentally conscious landscaping and the use of light-colored paints, offer opportunities for energy savings and comfort improvement. The incorporation of sound and heat insulation materials can further enhance energy efficiency. By embracing these recommendations, residents, administrators, and policymakers can collectively embark on a path towards enhanced energy efficiency, reduced costs, and a more sustainable residential environment. This study not only contributes to the energy conservation discourse but also provides a practical roadmap for informed decision-making, fostering a greener and more sustainable future for residential communities.

REFERENCES

- [1] D. Elhem, W. Zong, L. Anjela and z. ying, "The Impacts on occupants behaviours on building analysis; A research review," *EISEVIER*, 2017.
- [2] M. A. Umbarek, S. K. Alghoul and E. I. Dekam, "Energy Consumption in Residential Buildings: Comparison between Three Different Building Styles," *Sustainable Development Research*, vol. 2, no. No.01, 2020.
- [3] R. Galvin, "Making the 'rebound effect' more useful for performance evaluation of thermal retrofits of existing homes: Defining the 'energy avings deficit' and the 'energy performance gap,'" *Energy and Buildings*, vol. 69, pp. 515 - 524, 2014.
- [4] A. Paone and J.-P. Bacher, "The Impact of Building Occupant Behaviour on Energy Efficiency and Methods to Influence It: A Review of the State of the Art," *Energies*, p. 953, 2018.
- [5] E. Delzendeh, S. Wu, A. Lee and Y. Shou, "The impact of occupants' behaviours on building energy analysis: A research Review," *Renewable and Sustainable Energy Reviews*, vol. 80, pp. 1061 - 1071, 2017.

Development of a Solar Photovoltaic System with Single-Axis Tracking

W M A Sampath
University of Vocational Technology

H G A Sampath
University of Vocational Technology
Sri Lanka

R L W Koggalage
University of Vocational Technology
koggalage@yahoo.com

K Y R Amaradewa
University of Vocational Technology
Sri Lanka

Abstract—As the global demand for renewable energy sources intensifies to mitigate climate change and reduce greenhouse gas emissions, the solar energy sector has garnered significant attention. The increasing demand for clean and sustainable energy sources has prompted the development of advanced solar photovoltaic (PV) systems. While solar installations have proliferated, the quest for optimizing energy generation remains a pertinent challenge. In this research paper, we present the design, development, and analysis of a solar photovoltaic system equipped with a single-axis tracking mechanism. This system aims to enhance the overall energy output of solar panels by optimizing their orientation to the sun throughout the day. The system outlined in this study integrates advanced controllers and sensors, which autonomously govern solar tracking, optimizing energy generation. Additionally, it incorporates an innovative water sprinkling mechanism to regulate panel temperature and cleanliness, further elevating energy output and system durability.

Keywords: *solar panel moving system, single axis solar tracking, photovoltaic solar tracking*

I. INTRODUCTION

Solar power, an increasingly vital facet of the global energy landscape, represents a compelling solution to meet burgeoning energy demands while mitigating the deleterious effects of greenhouse gas emissions. The utilization of solar panels has expanded significantly, yet the quest for enhancing their efficiency remains paramount. In pursuit of this objective, solar tracking systems have emerged as transformative technologies, offering the promise of optimizing energy generation.

This research paper delves into the realm of solar energy innovation, with a specific focus on the potential of single-axis solar panel tracking systems. In contrast to fixed solar panels, these systems offer a simpler and cost-effective approach to harnessing the sun's energy. By continually adjusting the tilt or azimuth along a single axis, these tracking systems have the capacity to dynamically align solar panels with the sun's movement, thus optimizing solar energy generation. The study's findings contribute valuable insights to improve the performance in the field of solar energy technology, offering practical implications for sustainable and cleaner energy solutions. There are mainly few sections to implement this control system. The first part of this paper introduces some important topics in solar tracking systems. The second section describes the system description of overall system design and implementation, which includes the control system, and some detailed features of the Solar Tracking System. Conclusion at

the end summarizes the achievements by applying the proposed system.

Photovoltaic Technology

Solar Cells are the best-known technique for producing electrical power through Silicon Cells swaddle in photovoltaic modules. To elucidate the photovoltaic solar panel more easily, photons from sunlight energies electrons in an upper state of energy and coming to the lower state to release one electron so that it can generate electricity. The term photovoltaic defines the general unbiased working condition of a photodiode in which current through the appliance is due to the transduced light energy [7]. Solar cells generate direct current electricity from light, which can be used to recharge a battery for electric devices [2].

1.1 solar potential in the Sri Lanka

Sri Lanka, with its tropical location and abundant sunshine, is uniquely poised to harness the power of the sun for energy generation. The island nation experiences consistently high solar irradiance levels throughout the year, presenting a significant opportunity for solar energy development. On a global scale, solar energy has emerged as a dynamic force in the transition to sustainable power sources. Countries worldwide are tapping into this boundless resource to reduce carbon footprints and mitigate climate change. The sun, once considered an inexhaustible source of life, is now also the wellspring of clean, renewable energy for our future

2.1 Solar Tracking System

A solar tracking system is designed to dynamically adjust the position of solar panels, aligning them with the sun's path as it moves across the sky during the day.

Solar tracking systems come in two primary types: single-axis and dual-axis (figure 1). Single-axis systems track the sun's movement along one axis (typically east-west), while dual-axis systems can track both the sun's elevation and azimuth.

By continuously following the sun, solar tracking systems maximize the amount of sunlight that reaches the solar panels, resulting in increased energy generation compared to fixed panels.

Solar tracking systems are more complex and require additional components (such as sensors, motors, and control

systems) to move the panels. As a result, they tend to be more expensive to install and maintain than fixed solar panels.

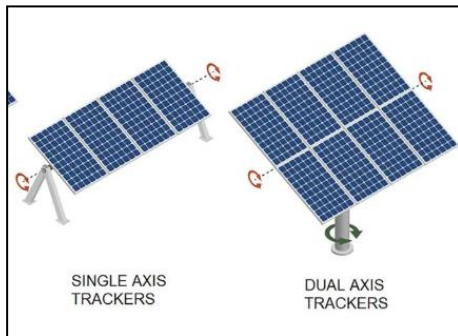


figure 1- single-axis and dual-axis

2.2 Fixed Solar Panels:

Fixed solar panels are stationary and remain in a fixed position, with a predetermined tilt and azimuth angle relative to the ground or roof (figure 2).



Figure 2-fixed solar

Unlike solar tracking systems, fixed panels do not adjust their position throughout the day to follow the sun's movement. They remain static, with a fixed orientation. Fixed panels are simpler, have lower installation costs, and require less maintenance since they don't have moving parts or tracking mechanisms.

However, fixed panels are less efficient than solar tracking systems because they cannot maintain an optimal angle to the sun at all times. Their energy generation is limited to the amount of sunlight they receive at their fixed tilt. Solar tracking systems are most beneficial in locations with significant variations in sun position throughout the day, such as areas far from the equator and regions with distinct seasonal changes.

Fixed solar panels are more suitable in locations with relatively consistent and predictable sun angles year-round, especially in areas closer to the equator.

The choice between a solar tracking system and fixed panels depends on factors like the site's latitude, available space, budget, and desired energy output.

In summary, solar tracking systems offer improved energy generation by continuously following the sun's path, while fixed solar panels remain static and have lower installation and maintenance costs. The decision to use either system depends on specific site conditions and project requirements.

II. LITERATURE REVIEW.

Within the renewable energy sector, solar tracking systems have garnered considerable interest for their capacity to amplify solar energy generation. These systems achieve this by continuously aligning solar panels to track the sun's trajectory throughout the day. This literature review embarks on an exploration of the existing body of research dedicated to single-axis solar panel tracking systems. Our focus is centred on delineating the strengths, limitations, and performance attributes of these systems in contrast to traditional fixed solar panels.

Imam Abadi proposes a single-axis solar tracking system implemented with a fuzzy logic controller [1]. The study aims to enhance the efficiency of solar panels by dynamically adjusting their tilt angle based on solar radiation levels. Results indicate that the fuzzy logic-based control strategy effectively improves energy output compared to fixed solar panels.

In A Review Paper on Solar Tracking System for Photovoltaic Power Plant [2]. This review paper provides an overview of solar tracking systems in photovoltaic power plants. It discusses various tracking approaches, including single-axis and dual-axis systems, while highlighting their respective advantages and challenges. The paper emphasizes the importance of choosing an appropriate tracking technology based on site-specific factors to optimize energy generation.

From Rajan k. solar tracking system- a review article in international journal of sustainable engineering [3] This review article discusses solar tracking technologies with a focus on their applications and benefits in solar energy systems. The study presents a comprehensive overview of various solar tracking methods, including single-axis tracking. It covers key design considerations, performance metrics, and potential cost savings through energy optimization. Dhanabal et al. [4] compared the efficiencies of static panels and tracking systems of single axis and dual axis fixed mount. The readings are taken from morning 8 AM to evening 6 PM for fixed panel, single axis tracker and dual axis tracker for every one hour. The results says the efficiency of the single axis tracking system over that of the static panel is calculated to be 32.17% and dual axis tracking

system over that of the static panel is calculated to be 81.68%.

Tiberiu tudorache et al [5] compared the solar tracking PV panel with a fixed PV panel in terms of electric energy output and efficiency. The proposed device automatically searches the optimum PV panel position with respect to the sun by means of a DC motor controlled by an intelligent drive unit that receives input signals from dedicated light intensity sensors. The solar tracking PV panel produced more energy than fixed one with about 57.55%.

Anusha et al. [6] compared the fixed PV panel and single axis solar tracking based on real time clock(RTC) using ARM processor. The experiment is conducted using both fixed and tracking system for 6 days. The results show that the solar tracking system increased the efficiency around 40% and energy received from the sun is improved from 9.00AM to 6.00 PM.

Figure 3-design

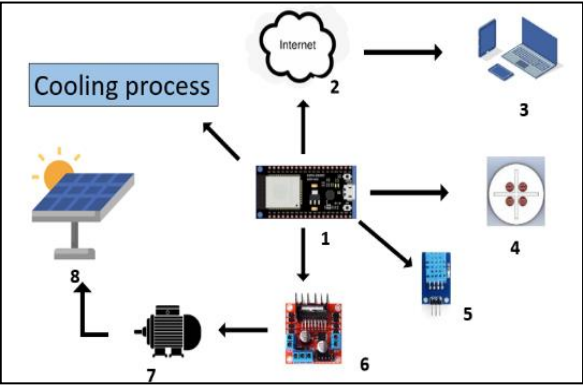
III. METHODOLOGY

4.1System Overview and design

The single-axis solar tracker system is a harmonious fusion of hardware components and software control mechanisms. At its core, the ESP32 takes on the pivotal role of central controller, orchestrating interactions with an array of sensors and actuators. In this intricate symphony of technology, the ESP32 processes inputs derived from the Light-Dependent Resistor (LDR) to meticulously track the sun's radiant path. It then meticulously guides the DC motor to manipulate the solar panel's orientation. Additionally, the ESP32 exercises precise command over the temperature-driven water sprinkler system via a relay.

- 1. ESP32
- 2. Internet
- 3. Monitoring device
- 4. LDR
- 5. Temperature sensor
- 6. Motor controller
- 7. Motor

8. Solar panel



4.2Component Roles:

ESP32 Controller (figure 4): In its key role, it acts as the brain of the system. It gathers data from sensors, processes it, and sends instructions to the motor and relay.

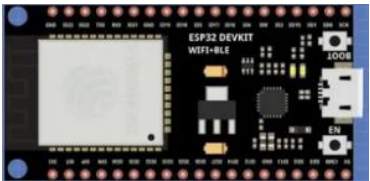


Figure 4-ESP32

Specifications

- * 448 KByte ROM
- * 520 KByte SRAM
- * 16 KByte SRAM in RTC
- * Power supply: 2.2 V to 3.6 V

LDR (Light Dependent Resistor) (figure5): Detects sunlight intensity and provides analogue input to the ESP32.



Figure 5-LDR

DC Motor: Adjusts the solar panel's angle to follow the sun's movement across the sky.

Temperature Sensor (figure 6): It keeps an eye on the temperature of the solar panel, and when it gets too hot, the system turns on the water sprinklers to cool it down.



Figure 6-temperature sensor

Relay: Controls the activation and deactivation of the water sprinkler system based on temperature readings.

4.3 Communication and Interaction:

The LDR constantly checks how bright the sunlight is and tells the ESP32. The ESP32 then figures out where the solar panel should move to get the best generating and tells the DC motor how to turn. While that's happening, the temperature sensor tells the ESP32 how hot things are. The ESP32 decides if the solar panel needs cooling and turns on or off the water sprinklers accordingly.

4.4 Sunlight Detection:

Utilization of the LDR: The LDR serves as a light sensor when properly positioned on the solar panel. Its resistance varies with light intensity, allowing it to detect levels of sunshine.

Figure 7 - circuit diagram Process and Frequency of Data

Collection: The LDR continually generates analogue voltage values proportional to light intensity. The ESP32 receives these numbers at regular intervals, often every few seconds, ensuring accurate real-time tracking.

LDR Data Processing: The ESP32 translates the LDR's analogue voltage to a digital value. The digitized values are then mapped to the sun's location using a calibration technique. The ESP32 identifies the direction in which the solar panel should be adjusted to face the sun by comparing repeated measurements.

4.5 Motor Control Algorithm:

Algorithm for Movement Calculation: Using LDR data, the algorithm computes the difference between the present solar panel orientation and the intended orientation. It determines the required motor movement by taking into account aspects such as the time of day, current position, and desired tracking precision.

Motor Control Logic: The ESP32 sends pulse-width modulation (PWM) signals to the DC motor. PWM signals regulate the speed and direction of the motor, allowing for exact changes. The ESP32 changes the

PWM duty cycle based on the predicted movement, providing progressive and precise solar panel relocation.

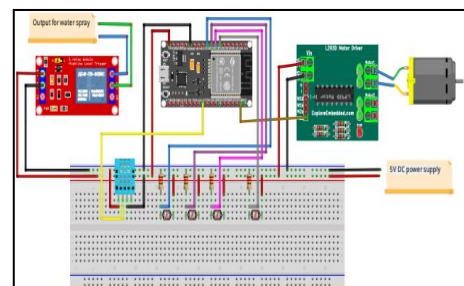
Smooth Movement Considerations: The algorithm may include acceleration and deceleration characteristics to prevent sudden or jerky motions. This contributes to smooth transitions and reduces unneeded stress on mechanical components.

Implementation and Results

A single-axis solar panel structure was set up to allow angle adjustments by rotating the top structure along the middle axis. This ensured all panels faced the sun at the same angle. A controller circuit, was assembled to manage the system. Sensor inputs were connected to the controller, and output signals were generated to control the motors. In our testing, the system successfully directed the solar panels. This resulted in a significant increase in monthly power generation, approximately 35%-40%, within the first month of implementation compared to the fixed configuration..

Results of the cooling effects using water sprinkles yet to be explored.

- Circuit diagram:



IV. RESULTS

Results were obtained from a similar capacity fixed solar panel and single axis solar panel tracker system.

Table 1-collected data

Day	Fixed Panel	single-Axis
1	24.53 KW	44.74 KW
2	23.62 KW	42.58 KW
3	22.54 KW	40.65 KW
4	23.91 KW	43.54 KW
5	20.78 KW	38.63 KW
6	22.21 KW	40.34 KW
7	23.49 KW	43.18 KW

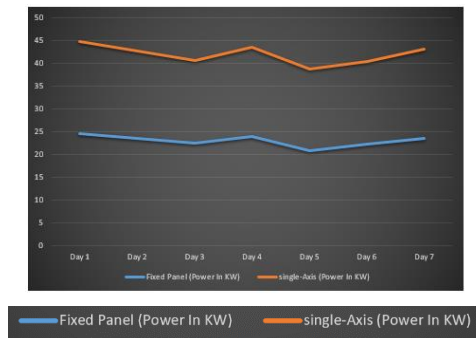


Figure 8-comparison of the data

There is a significant increase in energy generation of single-axis solar tracking system compared to the similar capacity fixed system. On average it is about 40 per cent increase of the efficiency.

- Existing System



Figure 9 – Solar Panel Structure

This is the exist system of the solar panel

V. CONCLUSIONS

In this study, we designed and implemented an automated solar tracking system. The research has unequivocally demonstrated

the effectiveness of single-axis solar panel tracking in optimizing solar energy generation. This tracking system consistently outperforms fixed solar panels, leading to a significant increase in energy production. The insights from this study have profound implications for sustainable energy solutions, highlighting the potential of solar tracking technology to enhance photovoltaic efficiency. While the benefits are clear, further research is warranted to explore advanced control algorithms, integration with energy storage, and cost-effectiveness analysis. Continued innovation in this field can contribute to a more sustainable and eco-friendly energy future. As solar energy remains pivotal in global energy transitions, the findings from this study can offer valuable guidance to decision-makers, solar developers, and researchers in leveraging solar tracking systems and advancing renewable energy adoption worldwide.

REFERENCES

- [1] Imam Abadi, Adi Soeprijanto, Ali Musyafa. "Design Of Single Axis Solar Tracking System At Photovoltaic Panel Using Fuzzy Logic Controller". Sepuluh Nopember Institute of Technology Surabaya · November 2014.
- [2] Bhagwan Deen Verma, Prof. (Dr.) Mukesh Pandey and Asst. Prof. Anurag Gour."A Review Paper on Solar Tracking System for Photovoltaic Power Plant" International Journal of Engineering Research & Technology (IJERT) Vol. 9 Issue 02, February-2020.
- [3] krishna, sunitha; st.peters university, mechanical K, Rajan; DR.M.G.R university, Mechanical. "Solar Tracking System-A review, January 2016.
- [4] Dhanabal.R., Bharathi.V., Ranjitha.R., Ponni.A., Deepthi.S., and Mageshkannan.P. "Comparison of efficiencies of solar tracker systems with static panel single axis tracking system and dual axis tracking system with fixed mount." 2013.
- [5] Tiberiu tudorache., Constantin daniel oancea., and Lliviu kreindler. "Performance evaluation of a solar tracking PV panel." 2012.
- [6] Anusha.K., Chandra.S., and Mohan Reddy "Design and development of real time clock based efficient solar tracking system." 2013.
- [7] A. A. Radwan and Y. A. R. I. Mohamed, "Grid-Connected WindSolar Cogeneration Using Back-to-Back Voltage-Source Converters," IEEE Trans. Sustain. Energy, vol. 11, no. 1, 2020.

Design and Development of Foot Step Power Generation System

W.M.R.P Bandara

*Department of Electrical and Electronics Technology
University of Vocational Technology
Sri Lanka*

W.L Shyamalee

*Department of Electrical and Electronics Technology
University of Vocational Technology
Sri Lanka*

H.G.E.Chandramal

*Department of Electrical and Electronics Technology
University of Vocational Technology
Sri Lanka*

M.Barathy

*Department of Electrical and Electronics Technology
University of Vocational Technology
Sri Lanka
barathy@uovt.ac.lk*

Abstract-Energy is an important requirement in our daily life. The resources we use are limited and many of them considerably lead to environmental pollution. Therefore, there is a need to find a way to establish methods to get the maximum use of natural resources to generate energy. The project aims to generate electrical energy by harnessing the force and vibration of the earth's surface when people walk. We designed a method for generating and storing energy using a piezoelectric plate. We wanted to find a solution using our energy source. This is a non-traditional innovative solution. Our source holds the model in place and uses the same vibration generated by humans to generate energy. It generates electrical energy that can be used to apply street lamps and phone charger points. This saves energy due to its survival and is easy to use even in the event of a power outage.

Keywords: *Environmental Pollution, Natural Resources, Piezoelectric and vibration*

I INTRODUCTION

There is a huge demand for energy in the world today. People employ various strategies to meet this demand. Energy is the workforce. Electricity is a widely used energy source. Human consumption has been high since industrialization. It is important to provide a simple supply of consumption. Precaution must be taken in the production of energy sources that minimize the negative impact on the environment as well as increase energy. There are two ways to generate energy such as renewable energy and non-renewable energy. At present non-renewable energy is becoming available and due to this, the energy is facing an energy crisis. Due to this, the focus is on renewable energy. Renewable energy sources are either renewable sources or crystals. These are solar energy, wind energy, geothermal energy, and hydropower as well as different energy sources. Renewable energy sources are often referred to as green energy and pure energy sources. There are differences in these categories as well. Renewable sources

are recyclable, and energy sources that do not emit pollutants to the environment are referred to as pure energy sources, and green energy sources are energy sources derived from natural sources.[2]

In our project, we use the energy generated by human walking to produce energy. There is no environmental damage from this. Renewable and clean energy is produced. The average person travels about 3000 - 5000 steps a day. These vibrational times travel over a surface and receive vibrational energy, both magnetic and electrostatic, and piezoelectric. Vibration energy is converted into electrical energy.

This project is a kind of attempt to do that. In this project, the human footstep becomes the main energy generation source. The strain of the human step is generating electricity from the usage of the piezoelectric transducer. We arranged 15 piezoelectric traducers in this project and all are connected parallels.

The modern world needs more renewable, Sustainable energy generation methods.

So the objective of this research is

To introduce an emerging eco-friendly energy production system using piezoelectric technology. which is one of the sustainable energy-producing methods then it will lead to a reduced amount of pollution marking fossil fuel utilization in our country

II BACKGROUND

It is important to identify an innovative eco-friendly power generation system in the face of the current energy crisis in the world as well as in our country. A footstep power generation system is a good solution for this. This is a unique energy source that has been identified and identified.

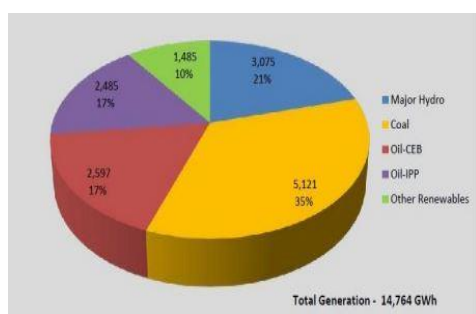
This is a successful solution to the energy crisis that we have introduced with low cost and innovation to suit our country. But many problems can be solved successfully in this project. In this, the vibration time travels through a surface and receives vibrational energy from both magnetic electrostatic and piezoelectric components. Vibration energy is converted into electrical energy. Electricity can be generated without a complex mechanical structure. In this project, we use this method the electrical energy received from a piezoelectric converter is usually powered by a very light, loaded, and generated AC catalyst. This is because it requires the development of an interface that converts to DC. It uses a full wave bridge rectifier to convert AC to DC, which is stored in a capacitor before the waveform is filtered.[5]

In the modern world electricity generation is such an important thing. Ecofriendly renewable methods are even more important. That's why these kinds of projects are invaluable for the modern world. This system can generate constant electric energy when a lot of motions happening around. It means, need to apply this project to busy places where people are moving rapidly. The system provides a lot of benefits. Ecofriendly Ness, easy to apply, are a few of them. But the most important thing is the energy source. The

system uses energy sources that are available freely and most of the time wasting. That is the mechanical stress of human footsteps. Energy supply and power generation are important for sustainability, longevity as well and economic growth in a country in the modern world. Often gratifying electricity necessities take up a full-size element of a nation's finances and it is due to the fact of the irrefutable fact that no industry, profession, or company can feature except the required energy.

Out of the various forms of energy available for use in the modern world, electricity has by far become the preferred choice to fulfill most energy needs in households and industries. This is because electricity can be produced, transferred over very long distances, and then converted to the desired form of energy with minimum wastage and high conversion and transmission efficiencies. So for any individual in the field of energy, power, and engineering in Sri Lanka, knowledge of electricity generation will be a basic requirement for success in the field. Therefore, in this report, understanding will be gained on the past, present, and future of electrical energy generation in Sri Lanka.[1]

The total electricity generation in Sri Lanka for the year 2017 was 14,764 GWh, an increase of 4.9 % from 2016. Here it



can be observed that in 2017 major hydropower constituted less than a quarter of the generation.

Fig.1: Electricity Generation Statistics in Sri Lanka in 2017

II. METHODOLOGY

It is possible to generate electricity without a complex mechanical structure. The piezoelectric effect we use has two modes of energy conversion, the direct piezoelectric effect, and the opposite piezoelectric effect. When a shock or mechanical stress is applied to a piezoelectric, the converter deforms and produces electric charges. The inverse piezoelectric effect converts electrical energy into mechanical energy, whereas the piezoelectric transformation is distorted. The piezoelectric converter is subjected to an electric field. The operation of collecting the vibration energy begins with obtaining the mechanical vibration energy and conversion of AC and generating AC (AC) conversion voltage Current (DC) voltage. Using the piezoelectric effect, waste energy generation can be used electrical. Energy by converting mechanical energy from the foot can be used as piezoelectric materials Mechanical energy, usually ambient vibration, is the mechanism of conversion to potential electrical energy Stored and used to power other devices. Electrical energy from a piezoelectric converter the vibration system is generally very light, loaded, and powered by the generated AC excitation. For this, it is necessary to develop an interface that converts to DC. A full wave bridge rectifier is used to convert AC to DC, it is then stored in a capacitor before filtering the waveform. The project can be used to generate energy. The electricity generated by this can be used as a street light and phone charger point.[3]

That whole unit, we call it piezoelectric tile. This piezoelectric tile has a top layer and a bottom layer. The bottom layer is the place where all the piezo transducers are placed. The upper layer is the platform that transmits the strain of a human step into the piezoelectric transducer when someone steps on it. After that generated energy goes through a rectification and filtering process.

That filtered DC voltage is going to the DC-to-DC converter. After that, the battery is charged using the regulated voltage. Also, a voltage sensor is used to detect generated voltage from piezoelectric tile. The microcontroller is used to show the generated voltage and battery level in the LCD. When talking about the output of the project, there is direct DC output from the battery. Also with the usage of an inverter, provide AC output as well.

When pressure is applied to this piezoelectric plate, it produces a potential gap. When we tested with a certain amount of pressure, we were able to observe that a potential gap was produced on the pressure applied from 0 to 30 V by one plate. The image below shows, the generated voltage of one piezo transducer. One piezo plate can produce up to a maximum of 30V according to applied pressure.



Figure 02: Piezoelectric transducer Parallel connection

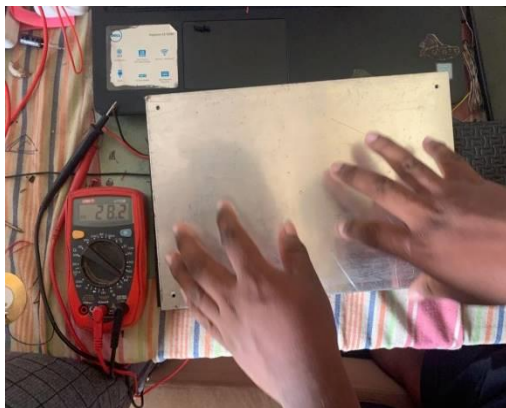


Figure 03: Illustration of the final product

III.RESULTS AND DISCUSSION

The initial stage of the project faced a bit of difficulty. Especially when finding components like piezoelectric transducers had faced difficulties. We found the quality of that component available in the local market is not that good. Also, when had been designed it was too difficult to obtain results. But put more effort and finally got the results that had to be wanted. This project is a very innovative one. It was unexpected to generate electricity from human footsteps. But this effort shows it is a possible thing. Especially in Sri Lanka if the government implements this project, it will be a great thing for the economy because this is a low-cost energy generation system.

IV.CONCLUSION

The footstep power generation system is a low-cost power generation, method, using human footstep as the main energy source. The backbone of this project is a piezoelectric material. The piezoelectric material has a piezoelectric effect. With that property, it can convert mechanical stress into electrical energy. We used a Piezoelectric transducer for this project which has all those properties and can generate electricity.

REFERENCES

- [1] Mohd Asry, A., Mustafa, F., Sim, S., Ishak, M. and Mohamad, A., 2019. [online] Available at: <https://www.researchgate.net/publication/339802422_Study_on_footstep_power_generation_using_piezoelectric_tile> [Accessed 6 August 2020].
- [2] D, M., M, E., Sunitha. N, S. and C, V., 2022. [online] researchgate. Available at: <https://www.researchgate.net/publication/308120087_Footstep_Power_production_using_Piezoelectric_Sensors> [Accessed 6 August 2022].
- [3] Kamboj, A., Haque, A., Kumar, A., Sharma, V. and Kumar, A., 2017. Kamboj 2017 | PDF | Piezoelectricity | Energy Harvesting. [online] Scribd. Available at: <<https://www.scribd.com/document/510119528/kamboj-2017>> [Accessed 6 August 2020].
- [4] Ramakrishnan, K. and Chockalingam, S., 2020. Redirecting. [online] Doi.org. Available at: <<https://doi.org/10.1016/j.matpr.2020.08.474>> [Accessed 6 August 2020].
- [5] Ali, A., Khan, U., Ahmad, M. and Aziz, A., 2022. Footstep Power Generation Using Piezoelectric Sensor. [online] Eudl. eu. Available at: <<https://eudl.eu/doi/10.4108/eai.27-2-2020.2303209>> [Accessed 6 August 2022].
- [6] Najini, H. and Muthukumaraswamy1, S., 2022. [online] <https://www.hindawi.com>. Available at: <<https://www.hindawi.com/journals/jre/2017/9643858/>> [Accessed 6 August 2022].
- [7] Et. al., D., 2022. A Novel Method for Electricity Generation from Footsteps Using piezoelectric transducers.[online]Available at: <<https://www.turcomat.org/index.php/turkbilmat/article/view/1089>> [Accessed 1 August 2022].

IMPROVING THE VIABILITY ASSESSMENT PROCESS OF UNSOLICITED DEVELOPMENT PROJECTS IN SRI LANKA

L.P.S.P.K. Loku Pathirage
Department of Quantity Surveying
University of Vocational Technology
Ratmalana, Sri Lanka
lpampathpriyantha@gmail.com

Roshani Palliyaguru
Department of Quantity Surveying
University of Vocational Technology
Ratmalana, Sri Lanka
rpalliyaguru@uovt.ac.lk
(<https://orcid.org/0000-0002-9786-4969>)

Abstract - A trend concept used by many governments in the modern world to achieve infrastructure development goals with the contribution of private sector capital and technical know-how is unsolicited development projects. Sri Lanka has been associating with unsolicited projects during the last two decades, targeting infrastructure development needs, but the lack of transparency in the process has created a paradox among the public. To achieve the aims of this research, a literature survey was conducted to understand the features and potentials identified by others on unsolicited projects, along with a desk study to compare the weaknesses and strengths of the procurement processes and the guidelines followed by the Sri Lankan authorities at present with similar arrangements practiced by Philippines, South Korea, and South Africa. Moreover, survey interviews were conducted to identify the existing problematic issues in connection with unsolicited projects and to collect suggestions for amendments to be introduced to the prevailing guidelines for overcoming those issues. Finally, to overcome those issues, it is recommended to introduce a few reforms to the existing system based on four policies.

Key words- accountability, solicitation, transparency, viability.

INTRODUCTION

The development of infrastructure plays a significant role in the development of any economy, and implementing development projects as Unsolicited Projects (USPs) has been globally recommended as an innovative and alternative procurement method for achieving infrastructure development goals [1]. USPs are projects that come as proposals from the private sector and are invested in and implemented by the private sector to develop infrastructure facilities with or without the invitation of the government [2]. In a situation where human capital and/or financial resources are scarce when deploying infrastructure development programme, USPs would be substitutes for achieving development objectives [3]. Sri Lanka also prefers to accept USPs as one of the financing models suitable for fulfilling infrastructure needs [4]. When a USP concept is initiated by the private sector, the government should verify that the proposed project is in line with aspects

of the government's infrastructure development strategy, policies, and development goals [5]. To achieve success through an investment, a project should be able to deliver at least its minimum level of expectations at the end. That means the project is in line with its primary objectives. The "Public-Private Partnership Legal Resource Centre", attached to the World Bank, has pointed out in their report published in 2022 that implementing a project as a USP would make sense only if the project itself is viable, and "Viability" of a project can be considered under several dimensions, such as Economic Viability, Technical Viability, Legal Viability, Social Viability, Cultural Viability and Environmental Viability [5].

Many researchers have attempted to improve the operation of a USP by identifying key features such as project performance, risk factors, pros and cons, etc. Therefore, the aim of this research paper is to identify the requirements and procedures that have to be addressed when dealing with the USPs to improve their viability while achieving value for money. The objectives of this research were to: 1. explore the necessity of unsolicited development projects and the procedures and processes that are involved in the viability assessment of those projects; 2. identify the failures observed in unsolicited development projects and the causes of those failures; 3. investigate the strengths and weaknesses of existing provisions and procedures available for assessing the viability of unsolicited development projects; and 4. determine the provisions and procedures that need to be incorporated into a future potential guideline for unsolicited development projects to improve their viability.

LITERATURE REVIEW

o *Necessity of USPs*

Most governments around the world, especially in developing countries, are struggling to develop and maintain their infrastructure requirements due to a lack of capital requirements and technical capacities [6], and many governments around the world are trying to invite unsolicited proposals to find solutions through creative solutions of the private sector to the problems arising in the acquisition of infrastructure needs as alternative procurement methods [2]. Through USPs, a government

could get the benefits of the knowledge, ideas, and capital requirements of the private sector to achieve their development targets and also obtain assistance to uplift the established knowledge related to industry. Except for those benefits, the World Bank's "Public-Private Infrastructure Advisory Facility" exposed that the following benefits can also be entertained through USPs, and USPs help to [7]:

- avoid lengthy competitive processes in order to implement projects early.
- address the government's inability to plan and fund necessary infrastructure development.
- tap into the private sector's innovations and knowledge to identify value-for-money project solutions.

○ *Sri Lanka and USPs*

Research shows that USPs have played an important role in the development of infrastructure in Sri Lanka [8]. For example, a study carried out by "Verité Research" (2021) on 50 high-value loans obtained by the Government of Sri Lanka to finance infrastructure during 2005–2018 has revealed that about 27% of funds secured through loans have been originated as USPs for financing large infrastructure projects [8]. By granting these loans, they have also imposed tight conditions and restricted the bidding to contractors from the lender's country of origin [8]. As this report pointed out, Sri Lanka has also entertained bids that have been originated as USPs from the contractors of the lender's country when the projects have been funded through bilaterally tied loans at higher interest rates. As the cost of such financing rises, it is more important than ever that the policy framework within which these investments take place ensure maximum returns on investment and benefit the country as a whole [8].

○ *Features of USPs*

USPs are defined as projects for which the project proposals are initiated by the private sector, aiming at business prospects, and submitted to the government or relevant authority without any request for or invitation to bid [9]. The "Public-Private Partnership Legal Resource Centre" of the World Bank (2022) states that the following features can be observed in USPs [5]:

- USP allows governments to identify and prioritize projects and generate innovative solutions to infrastructure challenges.
- The USP process allows the private sector to propose project concepts that are in line with a government's development strategies while developing commercially viable project solutions.
- When governments do not have the technical and financial resources to develop preliminary feasibility studies, a well-designed USP process can request that the USP proponent conduct a feasibility study as part of the USP submission.
- Unsolicited proposals do not arise as a part of the government's planning process. This raises the question of whether the proposed service is sufficiently integrated with other sector plans to

ensure that demand and benefits are robust to changing circumstances and priorities.

- Due to the absence of a transparent or competitive procurement process, dealing with a project proponent based on a USP may cause distress and undermine the legitimacy and public support for the USP program.
- In a government planning process, government agencies are responsible for identifying infrastructure plans and projects that directly respond to the identified social and economic needs. However, a private entity's primary motivation for coming up with a project idea is to advance its own interests without needing to align with those of the government or society. Accordingly, it is the responsibility of the government to ensure that the proposed USP project is structured to meet social needs while ensuring transparency and accountability.

○ *Requirements for Effective Evaluation of USP Proposals*

As pointed out in the "World Bank's PPIAF Report in 2012", there are only a very few projects that have been implemented as USPs and also given viability for public money, and most projects are found to be financially weak, facing high risks, and having failed to give precious value for time and public money [7]. The report further exposed that the majority of USP projects studied, particularly those that were directly negotiated, were charged with corruption allegations. Stakeholders often perceive USPs as being associated with corruption, regardless of whether or not the accusations have been confirmed [7]. Moreover, USPs are somewhat more complex than traditional Engineering, Procurement and Construction (EPC) contract models. Even when there are abilities to mitigate the risks through a special mechanism, the scale of complexity of the USP system has increased the opportunities for hiding wrongdoings [10]. Further the shape of the USPs provide relatively higher corruption opportunities [11]. Although, the Sri Lanka has a framework for procurement processes for both public sector infrastructure (issued in 2006) and private sector infrastructure (issued in 1998), that has failed to meet the expectations of a procurement guideline [12]. A report published by the Sri Lankan Chapter of Transparency International" recommends that Sri Lanka needs to take the necessary actions to establish a framework to enable accountability and transparency when dealing with public money. Sri Lanka has to refine its regulations and policies to suit the shifting international financing environment and optimize the return on its infrastructure investments [13].

○ *Provisions Already Available for Evaluation of USPs in Sri Lanka*

Generally, all government procurement works in Sri Lanka have to be carried out in accordance with the National Procurement Guidelines, and the USPs have been addressed by "Supplement 23" to the "Procurement Guidelines 2006 (for Goods and Works)" facilitating the reference to the "Part II of the Guidelines for Government Tender Procedure 1998" (GGTP). Accordingly, if a government body receives a USP proposal, the relevant line ministry

must publicly advertise and call for proposals for the project, indicating the requirements under the competitive bidding procedure. Then the party that made the unsolicited proposal will have the opportunity to amend their original proposal to match the needs and objectives identified by the relevant government body. Further, the above guidelines emphasized that no decision should be taken solely based on an unsolicited proposal without conducting a publicly advertised invitation for proposals. However, a provision has been added to the Guidelines, allowing permission to deviate from the above process through a Cabinet Approval under urgent or exceptional circumstances, even though a clear definition is not provided for this so-called "urgency" or "exceptional circumstances".

Furthermore, if approval has been granted to execute the project, overall supervision of the USP process is to be carried out by the "Bureau of Infrastructure Investment (BII)" of the "Board of Investment of Sri Lanka (BOI)", under the supervision of the Ministry of Finance. However, in 2017, this authority was transferred to a newly established institution under the Ministry of Finance called the "National Agency for Public Private Partnerships (NAPPP)". The scope of this agency was to provide all facilitative works for PPP investors. Accordingly, NAPPP had drafted a wide-ranging guideline for USPs, considering the best practices around the world. However, this institution was called off in 2020 before finalizing the new guideline. Meanwhile, on 26th December 2016, the Department of Public Finance published the "30th Supplement to the Procurement Guidelines 2006", amending Reference 237 of Part II of the GGTP and introducing the "Swiss Challenge Procedure" for USPs. However, based on a Cabinet decision taken in August 2018, the Public Finance Department issued another Circular on 25th September 2019, abolishing the "Swiss Challenge Procedure", and citing an "impractical procedure for evaluation of project proposals".

METHODOLOGY

Firstly, a comprehensive literature review was carried out to identify the research gap by referring to journals, books, articles, conference proceedings, reports, etc., and also to clarify the aim and objectives of the research.

Secondly, a desk study was conducted to identify the viability assessment strategies adopted by other countries for USPs and then to select the most appropriate strategies ones that could be introduced to improve Sri Lanka's practice.

Due to practical difficulties in collecting information about past projects and also the cold-shouldering situation to expose the information by personnel who have been involved with USPs, in this research, it was decided to conduct semi-structured survey interviews over case study interviews in order to gather information from industry experts. Accordingly, survey interviews were carried out on a semi-structured basis with industry experts who have through knowledge of USPs, and the collected data were analysed using software based system to derive findings to achieve the objectives of the study.

DESK STUDY

The objectives of the desk study are to identify the existing provisions of currently available Procurement Guidelines on USPs in Sri Lanka and to identify and compare the strategies that have been used by other countries during the approval and evaluation process of USP proposals. Through the desk study, a detailed comparison of practicing guidelines relevant to USPs in the Philippines, South Korea, South Africa, and Sri Lanka was carried out. It should be emphasized that in selecting those guidelines, special attention was paid to selecting internationally recognized guidelines, and that these three guidelines use three different internationally recognized mechanisms in evaluating the financial viability of USPs. Accordingly, the major steps which need to be followed when submitting for approval and the major steps of the USPs approval systems have been studied and then the observed similarities and deviations in those guidelines were summarized in Table 1 below:

Table 1: Summary of the Desk Study

		Philippines	South Korea	South Africa	Sri Lanka
USPs for Governments' key identified projects		Not Allowed	Allowed		
USPs for new project proposals		Allowed			
Viability Assessment Method	a. Technical-related	Provisions available for conducting a detailed assessment to verify requirements			
	b. Social-related				
	c. Environmental-related				
	d. Financial-related	Swiss Challenge System	Bonus System	Best and Final Offer System	No any method
Approval Process		Every USPs shall qualify through a detailed evaluation procedure and then solicited through a Competitive Bidding Process		USPs shall qualify through a feasibility Assessment or through a direction of the Cabinet	

When examining the guidelines used in the Philippines, infrastructure projects identified as having major importance are not allowed to be procured as USPs. But the other three guidelines, including Sri Lanka, do not maintain such restrictions. It is evident that all the countries have provided adequate provisions for the feasibility assessment

process (except financial viability), and as far as financial feasibility assessments are concerned, all three countries except Sri Lanka use three different mechanisms

that are recognized globally. Accordingly, in those three countries, all USP proposals must confirm financial viability through a competitive bidding process, and if there are additional requirements, a new feasibility assessment must also be conducted before granting approval for the project. But in the Sri Lankan system, there are no provisions provided for evaluating the financial viability of USPs.

From the findings of the desk study, it was revealed that the viability assessment systems in Philippines, South Korea, and South Africa are more equipped with suitable mechanisms to improve transparency and accountability. Similar mechanisms could be introduced to fill the gaps identified through this research in the procurement system of USPs that is currently being adopted by Sri Lanka, such as:

- a. To improve the transparency of the system, the project proposal has to be solicited through a suitable competitive bidding process.
- b. To improve the accountability of the system, restrictions have to be imposed on projects that have been identified and considered strategically important before implementing them as a USP.
- c. Other optional routes or opportunities that can affect the transparency of the procurement system of a USP have to be removed from the procurement system. For example, the authoritative power that is being kept by the Cabinet to award a contract directly seems questionable. Most importantly, none of the procurement systems that were considered for the desk study were found to entertain this kind of authority.

SURVEY INTERVIEWS

o Details of Interviewees

Six industry experts who have experience with USPs and government tender procedures were interviewed to gather their views about the USPs and their comments on the practicing procedures in Sri Lanka, of whom the details are presented in Table 2:

Table 2: Details of Interviewees

Interviewee	Designation	Field	Experience
EI-1	Procurement Specialist	Engineering	over 28 years
EI-2	Project Manager	Engineering	over 25 years
EI-3	Deputy General Manager	Quantity Surveying	over 20 years
EI-4	Director (Research)	Economist	over 20 years
EI-5	Researcher	Economist	over 05 years
EI-6	Manager (Investment)	Investment	over 20 years

DATA ANALYSIS OF SURVEYING INTERVIEWS AND DISCUSSION

o Necessity of Unsolicited Construction Projects

Through the literature review, it was revealed that the viability of the USPs should be considered under economic, technical, social, and legal aspects. Hence, the necessity of USPs could also be considered under those aspects, and the

opinions of the experts too were categorized under above criteria as presented in Table 3 below.

Table 3: Necessity of Unsolicited Construction Projects

	EI-1	EI-2	EI-3	EI-4	EI-5	EI-6
1. Economic-Related Solution for lack of funds	X	X	X	X	X	
Incentive for new business investments				X	X	X
2. Technical-Related Helps introduce new technical knowledge	X	X	X		X	
Fails to introduce new technical knowledge				X		
3. Social-Related Helps create new job opportunities				X	X	X
Opportunity for infrastructure development				X	X	
4. Legal-Related Helps avoid lengthy procurement process	X					

The survey results indicate that USPs can address issues related to economic, technical, social, and legal aspects while attempting to achieve infrastructure development goals. When considering the "economic aspect", the opinions of the majority of experts were that USPs would help overcome financial constraints when capital requirements for infrastructure projects are secured through such proposals. It was further found from the analysis of interviews that a USP would be the most suitable solution for a development project that may get delayed in implementation either due to insufficient funds or a lack of technical capacity, and through the USPs, the private sector would get the self-motivation to invest in infrastructure development projects, bypassing traditional procurement and business models.

With the involvement of the private sector as well as foreign investments, there is an opportunity to mix with the new technologies practiced in the modern world. However, there was a consensus among the interviewees that "USPs have failed to introduce new technical knowledge". This was a new finding derived from interviews that was not recognized in the literature review. As such, this opinion could be considered an open argument for future research. The opinions of the experts about the "social factor" were that since the private sector directly invests the capital requirement for the infrastructure development projects, it will help create new job opportunities that did not exist

earlier due to the lack of supply of capital. And of course, USPs may be helpful in avoiding the lengthy process of acquiring infrastructure facilities, in the opinion of one of the interviewees.

○ Failures Encountered in USPs

Through the literature review, it was revealed that the viability of the USPs should be considered under economic, technical, social, and legal aspects. Hence, the failures of USPs can also considered under those areas, and thus the opinions of the experts too, as tabulated in Table 4 below:

Table 4: Failures Encountered in USPs

Type of Failure	EI-1	EI-2	EI-3	EI-4	EI-5	EI-6
1. Economic-related	X	X	X	X	X	
2. Technical-related	X	X	X	X	X	
3. Social-related				X	X	
4. Environmental-related		X	X			
5. Legal-related		X	X			

According to the experts, most projects implemented in Sri Lanka as USPs have been economically and technically unsuccessful. As pointed out by them as an example, the Colombo Lotus Tower Project does not show any economic success and still cannot be used as a telecommunication tower, which had been the prime objective of this project. Another expert pointed out that, as a result of the construction of Colombo Port City, the seawater flow pattern around the west coast of the island has been disturbed, affecting certain coastal areas in the south-western parts of the island. He further states that the recent incident of sand piling observed in coastal areas of Mount Lavinia could also have been due to this project. He also emphasized that, according to legal experts, projects such as Hambantota Port and Colombo Port City would create serious legal issues once they start fully functioning as a result of not having a proper legal framework when dealing in such a heavy investment arena.

Another two experts pointed out that the ongoing Attanagalla Water Supply Project has commenced even before the project cost has been properly determined. Even today, most of the main roads around the Attanagalla area have already been damaged due to this project, and several fatal accidents have also been reported. If they have been designed and implemented in this manner, it will cause economic, technical, and social issues in the future.

After analysing the data from the survey interviews and literature review, it can be observed that most USPs implemented in Sri Lanka have experienced mainly economic and technical failures, but some failures can also be observed under social, environmental, and legal aspects.

○ Causes of Failures

As observed from the literature review, the "Sri Lankan Chapter of Transparency International" has pointed out, and it was confirmed during the survey interviews, that the main reasons for failures of USPs in Sri Lanka were due to a lack of transparency and poor decisions taken by authorities on

implementing USPs. It is also noted that a lack of competition has prevented opportunities for assessing the financial viability process. Lack of proper technical assessments and feasibility studies (on other factors such as environmental and social factors) may also have led to the failure of USPs in Sri Lanka. Table 5 shows the distribution of the opinions of interviewees on the causes of failures.

Table 5: Causes of Failures

Causes of Failure	EI-1	EI-2	EI-3	EI-4	EI-5	EI-6
1. Due to less competitiveness	X	X	X	X	X	
2. Less transparency in procurement process	X	X	X	X	X	X
3. Not having a proper technical evaluation	X	X				
4. Not having proper feasibility studies	X	X	X	X	X	
5. Poor decisions taken by Authorities	X	X	X			

○ Strengths and weakness of the existing provisions and procedures for granting approval for USPs.

○

As far as the strengths and weaknesses of existing provisions and procedures for granting approval for USPs concerned, the experts who were involved with the survey interviews pointed out that some areas of the existing guidelines are very weak when compared with the other guidelines in the world which are using for USPs ; those weaknesses are listed in Table 6 below:

Table 6: Weaknesses of the existing provisions and procedures

Weakness	Experts Interviewed					
	EI-1	EI-2	EI-3	EI-4	EI-5	EI-6
1. Less transparency	X	X	X	X	X	
2. Poor accountability	X	X	X	X	X	X
3. Low fairness	X	X				
4. Low openness	X	X	X	X	X	
5. Less competition	X	X	X	X	X	

Strengths of existing provisions and procedures in the existing guidelines include the potential to introduce some of the mechanisms into the Sri Lankan procurement system by introducing a few amendments to these guidelines, such as follow-up competitive bidding procedures to fill the gaps identified by this research. It was also observed that in none of the procurement guidelines of the Philippines, South

Korea, South Africa had there been any reference to empowering the Cabinet or any other authority to grant approval for a USP directly, bypassing the general procedure, and Sri Lanka is the only country that entertains such authority.

- *Improvements needed for a future potential guideline to strengthen the viability assessment procedure of USPs and the areas that need to be opened for USPs*

According to the results derived from the survey interviews, most of the experts' opinion was that, as a prime requirement, necessary actions must be taken to improve the transparency of the entire approval process of USPs, and special attention should be paid to obtaining a competitive bid price for USP proposals through the introduction of suitable arrangements such as the "Swiss Challenge System" or "Bonus System".

Further, a few of the experts proposed to publish all the information related to USPs to the public and to get the final approval for USPs through a parliamentary process in order to improve the transparency of the USP approval procedure.

Further, experts pointed out the importance of establishing a new independent body to handle USPs and introducing suitable arrangements to share both risks and rewards among the investor and the government, like in a public-private partnership project, and some experts had an opinion that the government should not go for USPs by using public money. Accordingly, those opinions were identified and categorized as factors that can be used to improve the accountability of the USP approval procedure. Additionally, some of the experts had the opinion that the government should not allow the implementation of infrastructure development projects for the key projects that were identified as strategically important as the Philippine system, and a few of them had the opinion that the government should not restrict the opportunities for USPs. Accordingly, all the outcomes under this heading are summarized in Table 6 below.

Table 3: Procedures that need to be followed in a future potential guideline to strengthen the viability assessment procedure of USPs and the areas that need to be opened for USPs.

Proposal	Experts Interviewed					
	EI-1	EI-2	EI-3	EI-4	EI-5	EI-6
1. Areas where improvements needed for the procurement processes of USPs						
Transparency of the USP approval procedure. ○ USP proposals should be attested through a competitive bidding process	X	X	X	X	X	
○ All information related to USPs to be published to the public					X	
○ Final approval for USPs should be obtained through a parliamentary process					X	
Accountability of the USP approving procedure. ○ Establish a new independent body to handle USPs	X			X		
○ Both risks and rewards should be distributed among the investor and the Government.		X			X	
○ Government should not go for USPs, if they use public money				X	X	
The areas which need to be open for USPs						
a. USPs should be allowed for projects that are identified as key government projects				X	X	
b. USPs should not be allowed for projects that are identified as key government projects	X	X	X			X
c. USPs should be allowed for new and innovative projects	X	X	X	X	X	X

CONCLUSIONS AND RECOMMENDATIONS

○ Conclusion

This research reveals that a USP would be the most suitable solution for a development project, which may get delayed in implementation either due to insufficient funds or a lack of technical capacity. USPs would also assist economic development by creating direct and indirect job opportunities. Nevertheless, it was revealed that most of the

projects that were implemented as USPs in Sri Lanka encountered either financial or technical-related failures, and a few encountered social, environmental, or legal-related failures as well. The main cause of financial failures was the improper financial evaluation process adopted at the initial stages. The reasons for technical, environmental, social, and legal failures could be attributed to the poor attention paid to those aspects during the feasibility assessment stages and also to the low transparency of the entire procurement process of USPs.

The government of Sri Lanka is not equipped with proper arrangements to ascertain whether a particular project is financially viable and a special arrangement to be provided to obtain a competitive and financially viable bid price for USP proposals by introducing suitable arrangements such as the "Swiss Challenge System" or "Bonus System". The research further revealed that although Sri Lanka has a framework for procurement processes for both public sector infrastructure (issued in 2006) and private sector infrastructure (issued in 1998), it does not meet the expectations of a procurement guideline. In the case of a USP, this weakness has left provisions for the private sector to forcefully influence terms and conditions in a contract. Mainly lack of transparency and the poor accountability of existing procedures have weakened the entire viability assessment process of USPs in every aspect. In the determination of the procedures that need to be followed in a future potential guideline to strengthen the viability assessment procedure of USPs, it was discovered that necessary actions have to be taken to improve the transparency of the entire approval process of USPs. Furthermore, the interview findings emphasize the importance of publishing all the information related to USPs to the public and the need for final approval for USPs to be obtained through a parliamentary process in order to improve the transparency of the USP approval procedure. Also, in order to improve the accountability of the system, it is required to establish a new independent body to handle USPs. Further, to share the both risks and rewards among the investor and the government, an arrangement like a public-private partnership for the USPs have been proposed as a result of this research. Additionally, the research further revealed that the government should not allow the infrastructure development projects for the key projects which were identified as strategically important.

○ *Recommendations*

The following recommendations are suggested for necessary reforms to improve the transparency and accountability of the viability assessment process of USPs:

- A mechanism to ensure the transparency and accountability of the entire approval process of USPs.
- Necessary arrangements have to be made to assure the viability of USPs.
- The existing provision that allows the award of USP contracts directly by the Cabinet has to be abolished.

- Establishing a new independent body (like independent commissions) to handle USPs
- Final approvals for USPs have to be obtained through a parliamentary process.
- Proposals for USPs have to be attested to through a competitive bidding process.
- Access to all the information related to USPs has to be made available to the public.
- Projects that have been identified as strategically important by the government should not be allowed to be implemented as USPs.

VI. REFERENCES

- [1] W. Widanage and S. Gunatilake, "Development of Framework to Enhance Public-Private Partnerships (PPP) Project Success Through Sustainable Stakeholder Relationships; Case of Unsolicited PPP Projects," Colombo, 2020.
- [2] P.-P. I. A. Facility, "Review of Experiences with Unsolicited Proposals in Infrastructure Projects," The World Bank, 2017.
- [3] P.-P. I. A. Facility, "Unsolicited Proposals – An Exception to Public Initiation of Infrastructure PPPs," Public-Private Infrastructure Advisory Facility, Washington, DC, 2014.
- [4] Finance Commission of Sri Lanka, "Annual Report 2018," Finance Commission of Sri Lanka, 2018.
- [5] WorldBank, "Public-Private Partnership Legal Resource Center (PPPLRC)," 24 June 2022.
- [6] ESCAP, "United Nations Economic and Social Commission for Asia and the Pacific (ESCAP)," 2018. [Online]. Available: https://www.unescap.org/ttdw/ppp/ppp_primer/62_unsolicited_projects.html.
- [7] PPIAF, "Policy Guidelines for Managing Unsolicited proposals in Infrastructure Projects," 2012.
- [8] U. Jayasinha, S. Abeyanayake, . M. Arangala and N. Mushin, "Opportunities to protect public interest in public infrastructure : review of regulatory frameworks in Sri Lanka," Verite Research, 2021.
- [9] S. Verma, "Government Obligations in Public-Private Partnership Contracts," Journal of Public Procurement, vol. 10, 2010.
- [10] F. Bergere, "The Importance of Managing Unsolicited Proposals in Infrastructure," World Bank, 12 January 2015. [Online]. Available: <https://blogs.worldbank.org/psd/importance-managing-unsolicited-proposals-infrastructure>.

[11] T. Thennakoon, H. Jayasena and U. Weerapperuma, "Investigating the motivation for implementing unsolicited proposals in the Sri Lankan construction industry," in 11th World Construction Symposium, Colombo, 2023.

[12] D. N. de Mel, "How Chinese projects lured SL away from procurement guidelines," 26 September 2022.

[Online]. Available: <https://www.themorning.lk/articles/220132>. [Accessed 26 October 2022].

[13] R. Hubbard, "International aid and credit - Financing economic growth in Sri Lanka," Sri Lanka Governance Report 2011, 2011.

The Adoptability of the Construction Industry Security of Payment Acts Enforced in Developed Countries to the Sri Lankan Construction Industry

Madhuranga Priyanath
Department of Quantity Surveying
University of Vocational Technology
Ratmalana, Sri Lanka
madhurangapriyanath@gmail.com

Roshani Palliyaguru
Department of Quantity Surveying
University of Vocational Technology
Ratmalana, Sri Lanka
rpalliyaguru@uovt.ac.lk
(<https://orcid.org/0000-0002-9786-4969>)

Abstract— This study investigates the feasibility of adopting the Construction Industry Security of Payment Acts practiced in developed countries by the Sri Lankan construction industry to tackle persistent payment delays and non-payment issues faced by the main contractors and subcontractors in the Sri Lankan construction industry. Thus, the primary aim is to evaluate the suitability of these Acts for the Sri Lankan context and determine the potential effective provisions and strategies to overcome long-term payment delays and non-payment for the main contractors and subcontractors. The research employs a comprehensive methodology, including a literature review, a desk study, and a questionnaire survey involving industry professionals. The outcomes of the research include key insights and recommendations to enhance payment practices in the Sri Lankan construction industry. To elaborate further, this research provides valuable guidance on the matter for policymakers and practitioners, ultimately leading to improved payment processes, reduced delays, and mitigation of non-payment problems in the construction industry.

Keywords— Construction Industry, Security of Payment Acts, Payment Delays, Non-payment, Subcontractor payments

VII. INTRODUCTION

A. Research Background

The construction industry is distinguished by characteristics like high production costs, lengthy processes, complexity, risk, and the creation of diverse and expansive products [1]. These products encompass everything from individual houses to substantial infrastructure projects such as roads and power plants. Key stakeholders, employers, and contractors play pivotal roles in this industry [2]. An employer contracts with a main contractor to execute the construction work, while contractors execute the work as defined in the contract agreement. The main contractor contracts with subcontractors for specialized tasks, contributing to the construction project's completion by considering their specialty and experience [3].

Payment issues in construction are particularly pronounced due to large project sizes, substantial payment sums, and credit-based payment terms [3]. Delayed payments can result in project delays, financial strain, sub-contractor disengagement, and strained client-contractor relationships [4]. To address such concerns, some countries have implemented statutory provisions, as seen in the Housing

Grants, Construction and Regeneration Act 1996 (UK Act), which have introduced mechanisms like adjudication for swift dispute resolution. Comparable measures are also adopted in Australia, New Zealand, and Singapore [3].

The sub-contractors experience long-term non-payments with regard to both interim payments and final payments, mainly in public sector projects in Sri Lanka. Due to this matter, many contractors faced various kinds of challenges and problems. But the relevant public sector authorities have not yet come up with a solution to the long-term non-payment matter. Accordingly, many researchers have focused on the causes of delayed payments, the impacts of delayed payments, and the necessity of a standard set of actions to follow up with in regard to delayed payments. But not much research has so far focused on the suitability of existing Security of Payment Acts practiced in the global context for Sri Lanka for mitigating payment-related issues.

Accordingly, this research aims to evaluate the adoptability of “Construction Industry Security of Payment Acts” in developed countries to the Sri Lankan construction industry to overcome long-term payment delays and non-payment for the main contractors and subcontractors. In achieving this aim, the following objectives were set out and achieved: (1) To identify the nature of delayed / non-payments among contractors and their impact on construction projects / parties; (2) To identify the current strategies and provisions used globally and in the Sri Lankan construction industry to mitigate payment-related issues among contractors; (3) To compare the provisions available in the Construction Industry Security of Payment Acts in developed countries to mitigate payment-related issues in the construction industry; and (4) To determine suitable provisions in a potential “Construction Industry Security of Payment Act” for the Sri Lankan construction industry.

This research is most important to the main contractors, subcontractors, and suppliers who engage in public sector construction projects, as they are the most affected parties by delayed payments.

VIII. LITERATURE REVIEW

A. Nature of the construction industry

The construction industry comprises participants from diverse backgrounds collaborating for maximum profit [5]. Participants, notably employers and contractors, play essential

roles in this sector [2]. It utilizes considerable human and financial resources for intricate, long-term projects [6]. The complexity and inherent risks are well-noted, involving numerous stakeholders such as employers and design and construction teams [7]. High risk levels arise due to the intricate, dynamic project environment, which exposes it to technical, socio-political, and business risks [8]. Consequently, dispute occurrence is a common aspect of this fragmented and complex industry [9].

B. Importance of timely payments and impacts of delayed payments on construction projects

In the construction industry, timely payment by the employer to the main contractor and by the main contractor to the subcontractors and suppliers is of paramount significance. Typically, payment terms involve credit rather than immediate delivery, making cash flow a pivotal factor affecting construction projects [3]. Deviations from the expected revenue flow, represented by the S curve, due to cash flow delays can have substantial repercussions, affecting project recovery halfway through its course. Cash flow is the lifeblood of construction projects, and delayed or non-payment by employers and main contractors emerges as a key reason for failures in this sector [10]. Moreover, the effects of delayed payments include financial hardships and may lead to project abandonment or disputes [4]. Thus, timely payments are crucial for maintaining construction progress, avoiding delays and disputes, and ensuring profitability for all stakeholders. Delays or non-payments disrupt the supply chain and subcontractor relationships, impacting project stability [11], and the impact of such issues is not confined to construction firms but extends to the broader economy, considering the industry's substantial contribution to the GDP [10].

C. Current status of construction industry payments in Sri Lanka and related causes

In Sri Lanka, delayed payments are considered one of the most common issues in construction projects, especially government-funded construction projects [12]. Also, Illangakoon mentioned that the cash flow issues due to payment delays to contractors hugely affect the implementation of construction projects and usually make a significant impact on small construction companies, and there have been many instances where several small construction companies have closed down due to payment delays in their projects [13].

Generally, most payments delays occur due to the actions of the client party rather than the main contractor's party in Sri Lanka [13]. Moreover, Illangakoon reveals that some main causes related to delayed payments within the Sri Lankan construction industry include, but are not limited to: prevailing internal system of the client (No of layers /officers passing the bill); cash problems of the client (non-availability of funds); additional works requested by client after submission of final bill; non-adherence of correct formats by contractor; improper submissions by contractor (less documentation); improper payment practices of client; lack of inter relationship between internal units and officials; lack of follow up and guidance by top level officials; no fear in contravening conditions of contract and handling too much work at a time; improper payment practices of contractor; lack of courage & confidence to complain to relevant parties/authorities about payment

delays; lack of unity among contractors who involved in public sector construction projects.

D. Strategies currently implemented to mitigate payment-related issues in developed countries

Mitigating the delayed payments on project delivery involves fostering strong stakeholder relationships, formalizing payment procedures, and ensuring stable and regular payments [14]. Stable and consistent payments stand out as a crucial solution to address payment challenges in the construction sector, providing a reliable cash flow for contractors and sustaining project progress [15]. To prevent delays and non-payments, Mohamad, Jahn Kassim, and Zakaria, suggest proactive measures during the construction phase and before resorting to alternative dispute resolution or litigation [16]. Similarly, Bissoo and Outridge, emphasize standardizing contracts to international norms, enforcing relevant laws, and utilizing government bonds to alleviate contractor debt [17].

In the context of Sri Lanka's government-funded construction projects, Samaraweera, Perera, and Dewagoda, recommend a range of strategies to deter delayed payments [18]: Swift enactment of a "Construction Industry Security of Payment Act" to safeguard and advance the construction sector; implementation of a payment bond or promissory note involving a third-party guarantee in case of default; establishment of a comprehensive quality assurance system as a checklist to prevent flawed tender documents; introduction of milestones or stage payments tied to project progress; mandatory allocation of funds to an independent escrow account; and granting contractors the right to assess the employer's financial status during bidding and understand actual project funding.

E. Security of Payments Acts

In the UK construction industry, Sir Michael Latham's 1994 report 'Constructing the Team', which is generally known as the Latham Report, laid the foundation for drafting the Housing Grants, Construction, and Regeneration Act 1996 (UK Act), and part of that Act deals with a scheme for payment and the resolution of construction disputes through a contemporaneous, speedy, and economical dispute resolution method called Adjudication [3]. Moreover, Ali mentioned that there are now similar Acts in Australia, New Zealand, and Singapore namely: the Building and Construction Industry Security of Payment Act 1999, amended in 2002 (New South Wales, Australia); the Building and Construction Industry Security of Payment Act 2002 (Victoria, Australia); the Construction Contracts Act 2002 (New Zealand); the Building and Construction Industry Payments Act 2004 (Queensland, Australia); the Construction Contracts Act 2004 (Western Australia); and the Building and Construction Industry Security of Payment Act 2004 (Singapore).

As such, the United Kingdom, nearly all states in Australia and New Zealand, and more recently Singapore, have all statutorily enacted provisions to address issues of payment in the construction industry and have introduced adjudication as a fast and economical dispute resolution method for the construction industry [3]. This was further proved by Arafat and Skaik by stating that many countries, such as the UK, Australia, and Singapore, have a "Security of

Payment" regime that includes a rapid statutory adjudication process to resolve payment disputes [10].

The purpose of a Security of Payment Act is to enable prompt payment for progress claims under a construction contract. The Acts provide for the appointment of an adjudicator to determine the payment to be made when there is a dispute relevant to the amount due. The due date for the payment and interest are also to be assessed by him. This process is established to focus on maintaining the cash flow of subcontractors with a rapid settlement procedure.

The primary focus of the Security of Payment Acts is to protect subcontractors and suppliers in the construction industry, rather than main contractors. These acts aim to ensure that subcontractors and suppliers receive timely and fair payment for their work or supplies, addressing the issue of payment delays or non-payment that often occurs in the construction sector. While creating a more equitable payment ecosystem within the construction industry where all parties involved can operate on a level playing field and receive payment for their work in a timely manner. By providing mechanisms for interim payments, facilitating dispute resolution, and establishing clear timeframes for payment, the Security of Payment Acts aim to improve cash flow for subcontractors and suppliers, reduce payment disputes, and promote fairness and transparency in the payment process.

F. Provisions in ‘Security Payment Acts’ and their effectiveness in mitigating payment related issues in the construction industry

Provisions of Security of Payment Acts related to developed countries like the United Kingdom, Australia, and Singapore are summarized in table 01.

Progress payments during the project period secure payment rights for work completed by the subcontractors and goods provided by the suppliers. In order to resolve payment disputes swiftly, a rapid and cost-effective adjudication method is established in these Acts, allowing work suspension or supply withholding for unpaid amounts [19]. The Security of Payment procedures expedite decision-making, ensuring swift payment dispute resolution and undisrupted contractor cash flow. However, their underlying purpose is to prevent payment delays for completed work and delivered goods.

Although different jurisdictions have varied Acts, the core objective of SOP remains consistent. It primarily aims to confer progress payment rights upon parties executing construction work or supplying related goods and services [20]. The Acts further enact the objectives as follows:

1. To ensure that progress payments or payments for supplying goods or services under a construction contract are recovered by the parties.
2. To ensure that a person or party is entitled to receive a progress payment by providing a legal entitlement that is enforceable in court, i.e. An adjudication determination that is enforceable in court for that payment.
3. To ensure that a person or a party is entitled to recover a progress payment by establishing an accepted procedure that consists of:

- Application of a payment claim by the person or party who claim the payment (“Claimant”)
- Providing of a payment schedule by the person or party to whom the payment is payable (“Respondent”)
- Provision for application of any undecided claim to an adjudicator for determination
- Payment of the adjudicated amount by the Respondent or the grant assurance by setting aside money due and
- Recovery of the progress payment through a court order if the Respondent fails to pay.

TABLE I. PROVISIONS IN ‘SECURITY OF PAYMENT ACTS’

Provisions available	United Kingdom	Singapore	Australia			
			New South Wales	Victoria	Queensland	Western Australia
Name of Act	Housing Grants, Construction and Regeneration Act 1996	Building and Construction Industry Security of Payment Act 2004	Building and Construction Industry Security of Payment Act 1999	Building and Construction Industry Security of Payment Act 2002	Building and Construction Industry Payments Act 2004	Construction Contracts Act 2004
Definition of time	Not defined	Not defined	Business day (Monday to Friday, excluding public holidays)	Business day (Monday to Friday, excluding public holidays)	Business day (Monday to Friday, excluding public holidays)	Business day (Monday to Friday, excluding public holidays)
Are stage payments or interim payments allowed?	Yes	Yes	Yes	Yes	Yes	Yes
Time for payment of progress payments in case of no dispute	28 days (from the due date)	30 days (from the due date)	10 business days (from the reference date)	10 business days (from the reference date)	15 business days (from the reference date)	28 days (from the due date)
Time for Payment schedule submission	Within 5 days of a written request	Within 14 days of a written request	Within 10 business days after receipt of payment claim	Within 10 business days after receipt of payment claim	Within 10 business days after receipt of payment claim	Not defined.
Initial steps before the claimant makes an adjudication application	Provide written notice	Provide written notice	Within 20 business days after providing written notice	Within 20 business days after providing written notice	Within 20 business days after providing written notice	Provide written notice
Time to submit adjudication application	Within 28 days after notice of adjudication	Within 7 days after notice of adjudication	Within 10 business days after receipt of the payment claim	Within 10 business days after receipt of the payment claim	Within 10 business days after receipt of the payment claim	Within 28 business days after receipt of the payment claim
The period for the decision of the adjudication	28 days	28 days	10 business days	10 business days	10 business days	28 days
Appointment of adjudicator	Chosen by the parties or appointed by an adjudicator nominating body	Appointed by the Singapore Mediation Centre	Appointed by the authorized nominating authority	Appointed by the authorized nominating authority	Appointed by the authorized nominating authority	Appointed by the authorized nominating authority

4. The Acts do not limit any entitlement or remedy a person or party to a construction contract may have under the contract. For example, the payment of adjudicated amount or assurance granted by setting aside money does not prejudice any claim, counter claim or review concerning the work done or material or services supplied under a construction contract to be

raised in arbitration or any other dispute resolution method.

IX. METHODOLOGY

A. Introduction

Research methodology is a way to systematically solve the research problem. It may be understood as the science of studying how research is done scientifically [21]. This section explains the research design, research approaches, research strategy, data collection techniques and data analysis techniques adopted for this research.

B. Research Design

Research design can be considered the structure of research, and it is the "Glue" that holds all of the elements in a research project together; in short, it is a plan for the proposed research work. Moreover, there are four types of research designs: exploratory design, descriptive design, explanatory design, and experimental design [22]. Accordingly, as this research finds solutions to mitigate an existing problem related to long-term payment delays and non-payment for contractors, exploratory design is used as the research design with the purpose of exploring a research problem that is relatively new and has not previously been studied in depth before.

C. Research Approaches

The research approach is a plan for moving from the research question to the conclusion, and there are three approaches to research: qualitative, quantitative, and mixed method, where mixed method is a combination of qualitative and quantitative approaches in the methodology of a study. And also, inductive, deductive, and abductive approaches are used as research approaches. Accordingly, in order to achieve the aim of this research, the numerical data collected from the questionnaire survey is used, and the aim is achieved by focusing on six different Acts. That means for this research, the quantitative method and deductive approach are used, respectively.

D. Research Strategies

A research strategy is simply a plan for how to achieve our research aim. Surveys, case studies, action research, and scientific experiments are popular research strategies involved in social science research. Accordingly, the responses of the industrial professionals are required to achieve the aim of this research, and that data was collected through a questionnaire survey. That means the survey method was used as the research strategy.

E. Research Techniques

Research techniques refer to the data collection and analysis techniques used to reach solid conclusions on the research topic. Accordingly, research techniques can be discussed under two main types: "data collection" and "data analysis".

1) Data collection techniques

A comprehensive literature review was carried out to identify the existing knowledge related to the research topic. A desk study was conducted to identify the provisions under various Payment of Security Acts used in developed countries to address payment issues and to understand the suitability of

such provisions for the Sri Lankan construction industry. The collation and review of information already available about the site is known as a desk study. Moreover, a questionnaire survey was conducted online among a sample of 40 respondents to validate the findings of the desk study and literature survey.

2) Data analysis techniques

Data analysis involves inspecting, cleaning, transforming, and interpreting the collected data to extract meaningful insights, identify patterns, draw conclusions, and make informed decisions about the research objectives. The empirical data collection of this research study focused on the identification of ground conditions for a potential Security of Payment Act in Sri Lanka through the collection of views of construction industry practitioners, and those data were statistically analyzed to build up the recommendations of this research. So, statistical analysis is one of the data analysis techniques used to analyze the data from the questionnaire survey.

a) RII Value:

The Relative Important Index (RII) method was adopted to determine the relative importance of on-time payments in construction projects, the impact of delayed payments, and the suitable provisions under various Security of Payment Acts used in developed countries. The five-point Likert scale ranging from 1 (very low importance) to 5 (very high importance) was adopted and transformed into a relative importance index using the equation: $RII = \sum W / (A \times N)$.

X. DATA ANALYSIS AND DISCUSSION

A. Introduction

This section explicates the analysis of the data collected through the questionnaire survey, which comprised a sample of construction industry professionals who are engaged in private / public sector construction projects. The profile of the respondents for the questionnaire survey was classified according to their job category, academic qualification related to the construction field, experience related to the construction industry, type of organization that they employed, and experience in abroad construction projects.

When considering the respondent's profile, the largest percentage of respondents (72.5%) were identified as subcontractors while 27.5% were identified as main contractors. The highest percentage of respondents (45%) were graduates, and similarly, 22.5% have NVQ Level qualifications, while 17.5% were undergraduates. Also, 15% hold postgraduate qualifications related to the construction industry. The highest percentage of respondents (40%) have 11 -15 years of experience. 22.5% of respondents have 6-10 years of experience, and 17.5% have 1-5 years of experience. Furthermore, 12.5% have above 20 years of experience, while 7.5% have 16-20 years' experience. The majority of respondents (74.4%) have work in the private sector, while 23.1% of respondents have work in both the public and private sectors. Only 2.5% have work experience only in the public sector. The majority (82.5%) have not worked on

construction projects in other countries, while 17.3% of respondents have worked on construction projects in other countries.

B. Current status of payments in the Sri Lankan construction industry

100% of respondents have experienced delayed or non-payment issues with their construction projects. As per figure 1, delayed or non-payment issues often arise in the public sector and sometimes arise in the private sector as well.

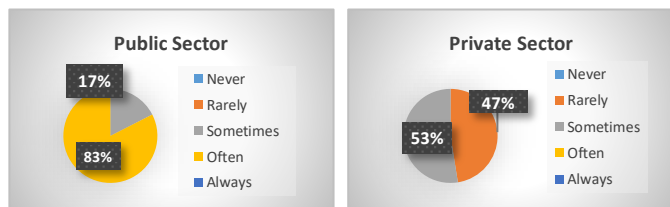


Fig. 1 Frequency levels of occurrence of delayed or non-payment

Figure 2 represents the respondents' views about the average duration of payment delays that they have experienced. Accordingly, the majority of payment delays fall in the range of 30 to 60 days, with 72.5% of respondents reporting delays in this range. Also, 12.5% experienced delays lasting between 60 to 90 days, and 15% faced delay lasting less than 30 days.

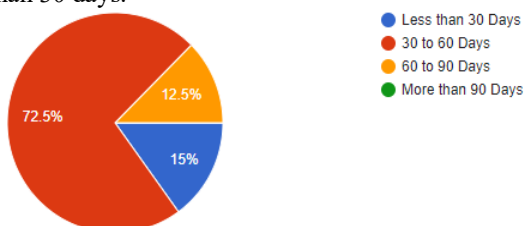


Fig. 2 Average duration related to payment delays

C. Impacts of Delayed or Non-Payment on Construction Projects/Parties

Figure 3 demonstrates the RII value related to the impacts of delayed and non-payments on construction projects and parties. The RII values related to cash flow problems, inability to pay subcontractors and suppliers, delay in project completion, reduced productivity and quality of work, and negative reputation and credibility in the industry are higher than 0.80. Similarly, the increase in legal disputes and claims and the termination of a contract have a RII value of 0.79 and 0.64 respectively.

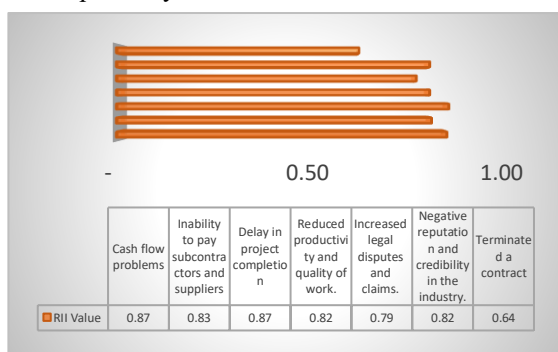


Fig. 3 Impacts of delayed or non-payment

D. The current strategies and provisions used to mitigate payment related issues in the construction industry and their effectiveness

As per Figure 4, all (100%) of respondents have used strategies to mitigate payment-related issues (non-payment/delayed payment) in their construction projects.

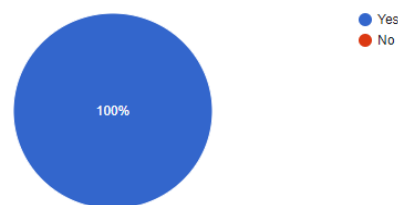


Fig. 4 Usage of strategies to mitigate payment-related issues

The rate of agreement by respondents on the usage of the mitigation strategies is presented in Figure 5.

Accordingly, "Contractual Provisions" has a RII value of 0.62 while both Payment Bonds/Guarantees and Payment Schedules have RII values of 0.57 each.

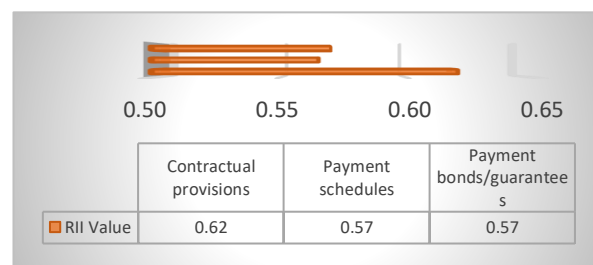


Fig. 5 Level of agreement on the usage of strategies to mitigate payment-related issues

E. Assessing the Adequacy of CIDA Conditions in Mitigating Payment-Related Issues

According to Figure 6, 62.5% of respondents indicated that the CIDA Conditions are not sufficient to mitigate payment-related issues in construction projects, while only 37.5% state that they are sufficient.

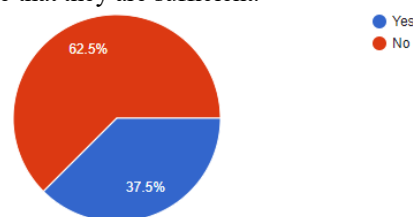


Fig. 6 Sufficiency of CIDA Conditions

F. Challenges Encountered in Implementing Payment-Related Strategies

Figure 7 demonstrates the RII value of the respondents' responses to the challenges encountered in implementing payment-related strategies in construction projects. Accordingly, the challenges namely lack of awareness, complex payment processes, insufficient communication, and insufficient transparency have a RII value greater than 0.80 while inadequate enforcement mechanisms for payment disputes, limited access to financing options for contractors,

cultural norms and practices affecting timely payments, and disputes and conflicts arising from non-standardized payment terms have a RII value greater than 0.70.

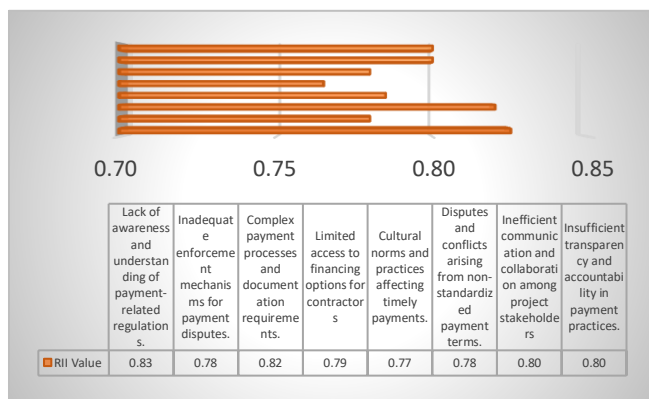


Fig. 7 Challenges encountered when implementing payment-related strategies

Sri Lankan construction industry

1) Awareness of Security of Payment Acts in other countries

47.5% of the respondents were aware the existing Security of Payment Acts in other countries, while 52.5% of respondents were not aware.

2) The familiarity of each act among the professionals

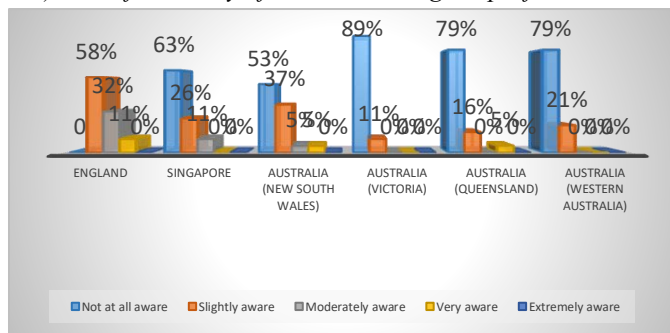


Fig. 8 Familiarity with the Security of Payment Acts

According to Figure 8, 58% of respondents were aware of the Security of Payment Acts and slightly familiar with the UK Act, while the majority of the respondents were not aware of the other five Acts.

3) Awareness of the major provisions in Security of Payment Acts

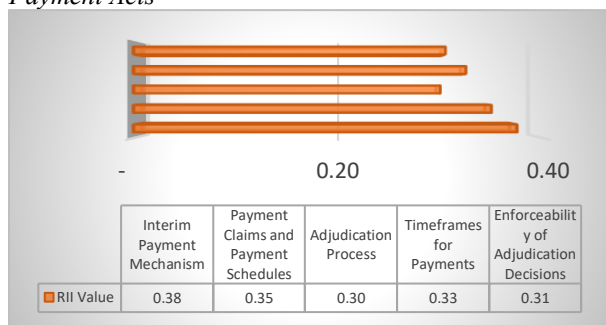


Fig. 9 Awareness of provisions in a "Security of Payment Act."

As per Figure 9, awareness regarding the major provisions in the Security of Payment Acts was very low.

H. Suitability of Security of Payments Acts in mitigating payment related issues

1) Clear and Well-Defined 'Definition of Time'

A definition for "Time" was derived through the Security Payment Act of the UK, as only it defines the term "Time". According to that, the business day is defined as Monday to Friday, excluding public holidays. The appropriateness of the definition for the Sri Lankan context is assessed through the respondents' views, the and majority of them reported that the definition is suitable as 39 respondents fell on the categories of agree and strongly agree with the definition.

2) Timeframes for Progress Payments

Figure 10 represents that "10 business days from the reference date" has a very higher RII value (0.91) when compared to the RII values of the other two time frames, called "30 days from the reference date" and "28 days from the reference date".

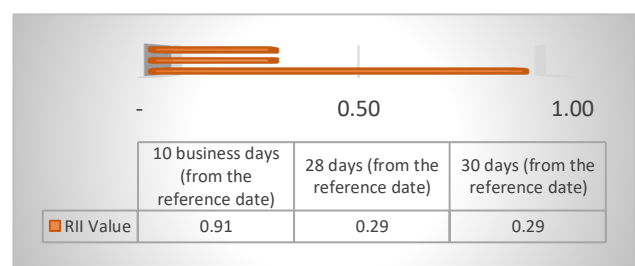


Fig. 10 Timeframe for payment of progress payments

3) Timeframe for Payment Schedule Submission

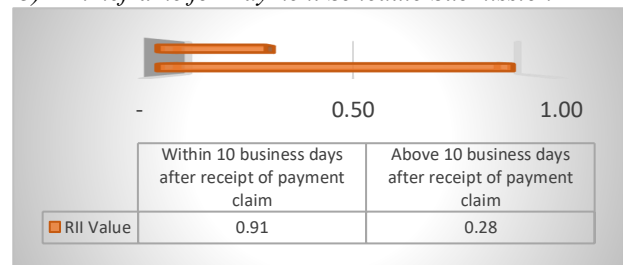


Fig. 11 Timeframe for payment schedule submission

Figure 11 shows that "within 10 business days after receipt of payment claim" has a higher RII value of 0.91, while "above 10 business days after receipt of payment claim" has a RII value of 0.28.

4) Timeframe for Initial Steps in the Adjudication Application

Figure 12 shows that "within 20 business days after providing written notice" has a higher RII value of 0.99 while "above 20 business days after providing written notice" has a RII value of 0.22.

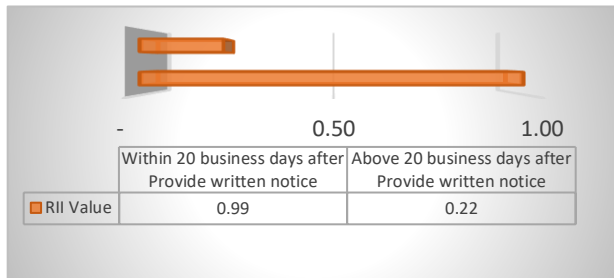
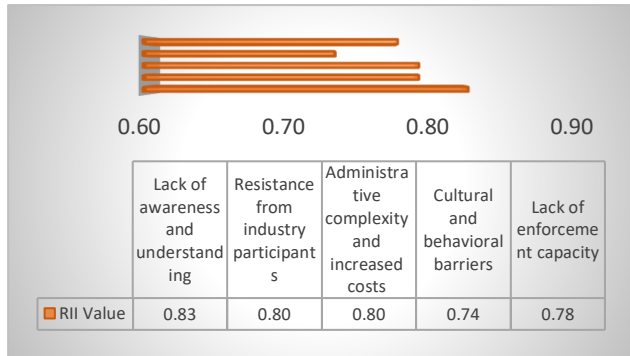


Fig. 12 Time frame for the initial step before adjudication

5) Timeframe submitting Adjudication Application

Figure 13 shows that “within 28 business days after receipt of payment claim” has a comparatively higher RII value of 0.68, while “within 10 business days after receipt of payment claim” has a RII value of 0.53.



6) Suitable Period for Adjudication Decision

Figure 14 shows that “within 10 business days” has a higher RII value of 0.89 while “within 28 business days” after receipt of the payment claim has a RII value of 0.31.

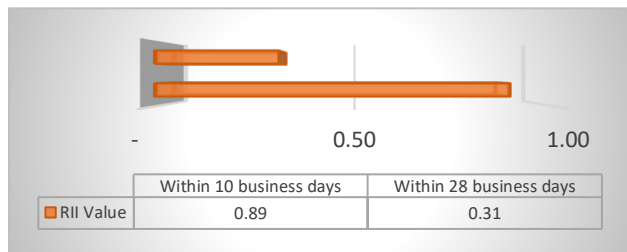


Fig. 14 Suitable period for the decision of the adjudication

I. Potential Benefits of Implementing a Security of Payment Act

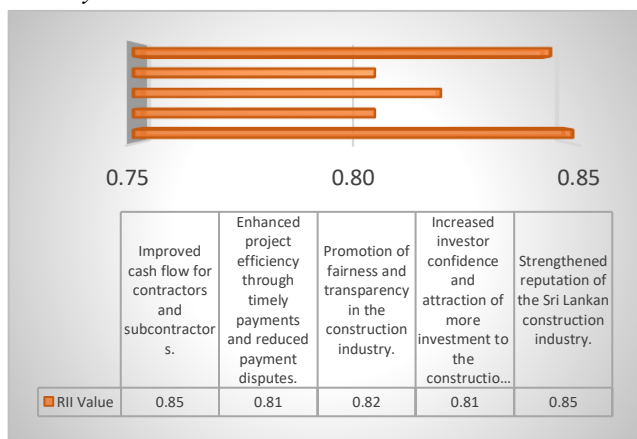


Fig. 15 Benefits of implementing a Security of Payment Act

The RII values of the all identified benefits have a RII value greater than 0.80.

J. Challenges in Implementing a Security of Payment Act for the Sri Lanka

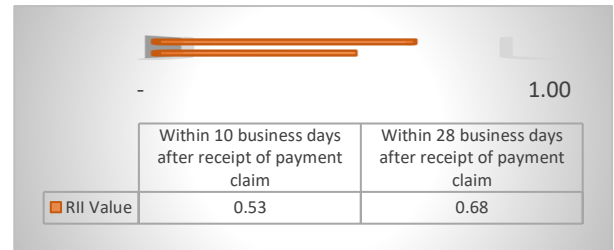


Fig. 16 Challenges in implementing a Security of Payment Act

The RII values of the challenges called lack of awareness, resistance by main stakeholders, and administrative complexity have a RII value greater than 0.80, while lack of enforcement capacity and cultural and behavioral barriers have a RII value greater than 0.70.

K. Discussion

In Sri Lanka, delayed payments are considered as one of the most common issues related to construction projects, especially in government-funded construction projects. Also [13] mentioned that the cash flow issues due to payment delays to contractors hugely affect the implementation of construction projects in Sri Lanka. The findings from the analysis proven the above statements as it revealed that 100% of the respondents have experienced delayed/non-payment issues during their working period and majority of such issues are encountered often in public sector project with more than 30 days of delay.

Delayed payments will have a devastating effect on the contractual payment chain and it expose contractors to a greater risk and most serious effects of delayed payment include delays in the project's progress, financial hardship, collapsing relationship among project stakeholders, formation of disputes, abandonment of projects, bankruptcy, etc. [4]. The findings of the research consolidated this statement as the study identified cash flow problems, inability to pay subcontractors and suppliers delay in project completion, reduced productivity and quality of work, increased legal disputes and claims, negative reputation and credibility in the industry and termination of project as major impacts due to the delay payment with higher RII value.

Mitigating delay/non-payments is very important to construction projects. Accordingly, formulation and enhancement of payment security act, introducing payment bonds, utilizing payment schedule for projects, maintaining escrow accounts, etc. are proposed by various authors as preventive measures related to delay payment [14], [17], [18]. The findings of the study revealed that standardized provisions, utilizing bonds and payment schedules as some major strategies to mitigate delay payments and they are not more effective as their RII value is low. Moreover, the study revealed that the CIDA conditions related to payments which

mostly utilized in Sri Lankan construction projects are not sufficient to mitigate delay/non-payments. However, lack of awareness, complex payment process, insufficient communication, and insufficient transparency are some major reasons for inefficiency of current strategies while inadequate enforcement mechanisms for payment disputes, limited access to financing options for contractors, cultural norms and practices and disputes and conflicts arising from non-standardized payment terms are also some factors that effect on it.

Developing countries have Security of Payments Act to mitigate payment issues related to construction projects. In the UK construction industry following UK Act and part of that Act deals with a scheme for payment and the resolution of construction disputes. Moreover, now some similar Acts were used in Australia, New Zealand and Singapore also namely Building and Construction Industry Security of Payment Act 1999 amended in 2002 (New South Wales, Australia), Building and Construction Industry Security of Payment Act 2002 (Victoria, Australia), Construction Contracts Act 2002 (New Zealand), Building and Construction Industry Payments Act 2004 (Queensland, Australia), Construction Contracts Act 2004 (Western Australia), Building and Construction Industry Security of Payment Act 2004 (Singapore) [3]. However, the primary focus of all these Security of Payment Acts is to protect subcontractors and suppliers in the construction industry, rather than main contractors. But the study shows that, in Sri Lanka delay/non-payment is a major issue that encountered by both main contractors and subcontractors and implementing Security of payment Act for mitigating those issues is appropriate. Also, the findings of the study show that majority of the construction industry professionals not aware about any Security Payment Act and the UK act is the most popular act among the once who aware of Security Payment Act. Although some are aware of act, they do not possess sound knowledge regard to its main provision called Interim Payment Mechanism, Payment Claims and Payment Schedules, Adjudication Process, Timeframes for Payments and Enforceability of Adjudication Decisions as RII value regard to them are very low and range between 0.30-0.40.

The Security of Payment Acts provides various benefits such as ensure that progress payment or payments for supplying goods or services under a construction contract are recovered by the parties, ensuring that a person or party is entitled to receive a progress payment by providing a legal entitlement, which is enforceable in court, i.e. adjudication determination which is enforceable in court, to that payment, ensuring that a person or a party is entitled to recover a progress payment by establishing an accepted procedure that consist of, and does not limit any entitlement or remedy a person or party to a construction contract may have under the contract. The findings of the study consolidated from the literature survey as improving cash flow for contractors and subcontractors, enhancing project efficiency through timely payments and reduced payment disputes, promoting fairness and transparency in the construction industry, increasing investor confidence and attraction of more investment to the construction sector and strengthened reputation of the Sri Lankan construction industry were identified as major benefits of using Security Payment Act with higher RII values through the study.

XI. CONCLUSIONS AND RECOMMENDATIONS

This chapter presents the derived conclusions from research findings and discussion in previous chapter relating to analyzed data and literature. Further, the accomplishment of each objective of this research is discussed. Subsequently, recommendations are provided based on research findings and determine suitable provisions in a potential “Construction Industry Security of Payment Act” for the Sri Lankan construction industry.

A. Conclusions

The empirical data analysis shows that delayed or non-payment issues are prevalent in the Sri Lankan construction industry, affecting both the public and private sectors. These payment challenges lead to various negative consequences, such as cash flow problems, project delays, and reduced productivity. Addressing these issues is crucial to improving the overall health of the construction industry and ensuring timely and fair payments to contractors and stakeholders.

The data reveals that there is a high level of awareness and experience of payment-related issues in the Sri Lankan construction industry. While many respondents have used strategies to mitigate these issues, challenges related to awareness, enforcement mechanisms, payment processes, financing options, and cultural norms still exist. The opinions on the sufficiency of the CIDA Conditions for mitigating payment-related issues are varied. To address these challenges effectively, respondents suggested various additional contractual provisions like escrow account, project trust fund and mechanisms to ensure timely and fair payments in the construction industry.

In regard to this various suggestions were collected from the respondents who participated for questionnaire survey about the suitable strategy to mitigate payment-related issues and the majority proposed to introduce new contractual provisions related to payments, use payment schedules and payment bonds/guarantees, implement proper guidelines by the government, introduce sufficient penalties or compulsory interest claim methods, improve the attitude towards payment obligations, and develop claims and disputes conditions in contracts as suggestions. Similarly, minority of respondents proposed to include the use of escrow accounts, project bank accounts, and project funds secure systems to ensure timely and secure payments.

The comparison of provisions of Security of Payments Acts that used in various developed countries in relation to avoiding payment related issues is included in the Table 1 and Table 2. As per the findings the major comparable provisions are Interim Payment Mechanism, Payment Claims and Payment Schedules, Adjudication Process, Timeframes for Payments, Enforceability of Adjudication Decisions.

The data indicates that there is varying awareness of Security of Payment Acts in other countries among respondents. Also, the familiarity with specific provisions of such Acts also varies. However, when considering the same provisions in various Acts, they demonstrate slight differences and through the respondents’ view most suitable version of each provision in Sri Lankan context were identified.

B. Recommendations

In order to mitigate payment related issues in construction projects, developed countries like England, Singapore, and Australia have used Security of Payment Acts. By referring to those Acts, in this study identified some different provisions suitable for an act to mitigate payment related issues.

Based on the responses obtained from the research questionnaire, the following recommendations are made regarding the provisions.

TABLE II. RESPONDENTS RECOMMENDATIONS

Provisions	Recommendations
Definition of Time (Business Day)	Monday to Friday, excluding public holidays.
Timeframe for payment of progress payments	At least 10 business days to ensure an adequate period for processing payments in the absence of any disputes.
Timeframe for payment schedule submission	Within 10 business days for payment schedule submission to align with the preference of the majority of respondents.
Timeframe for making an adjudication application	Within 20 business days after providing written notice for the initial steps required before making an adjudication application.
Timeframe for submitting an adjudication application	Within 28 business days for submitting an adjudication application to allow claimants sufficient time to prepare and submit their applications.
Period for the decision of the adjudication	Decision on adjudication should be made within 10 business days .

References

- [42] R. Rameezdeen, "Construction Industry in Sri Lanka: Opportunities and Challenges," *Built-Environment Sri Lanka*, vol. 6, no. 1, pp. 27-36, 2006.
- [43] G. Croeser, "Construction Industry Security of Payment Act: A Contractor's Right to Payment for Works Performed," *South African Mercantile Law Journal*, vol. 22, no. 3, pp. 456-475, 2010.
- [44] M. Ali, "Payment practices in the Australian construction industry," *International Journal of Project Management*, vol. 24, no. 5, pp. 457-464, 2006.
- [45] S. K. Ansah, "Investigating the Causes and Effects of Delayed Payment on Construction Projects," *Journal of Engineering, Design, and Technology*, vol. 9, no. 2, pp. 147-161, 2011.
- [46] A. Aryal and K. Dahal, "Factors affecting the performance of construction projects in Nepal," *Engineering, Construction and Architectural Management*, vol. 25, no. 6, pp. 798-814, 2018.
- [47] T. Negrut, A. Draghici, and R. V. Petrescu, "Construction project risk management," *Procedia Economics and Finance*, vol. 15, pp. 1524-1531, 2014.
- [48] E. D. Boadu, I. I. Kakulu, and H. A. Danso, "An exploration of stakeholder management in construction projects," *Built Environment Project and Asset Management*, vol. 10, no. 4, pp. 661-672, 2020.
- [49] N. Ehsan, N. A. Hamed, and J. Hu, "An overview of risk management in construction projects," *Journal of Engineering, Design and Technology*, vol. 8, no. 2, pp. 145-157, 2010.
- [50] R. U. Farooqui, Z. Riaz, and S. M. Ali, "Identification of causes and effects of construction disputes in Pakistan," *KSCE Journal of Civil Engineering*, vol. 18, no. 1, pp. 128-135, 2014.
- [51] H. A. Arafat and N. Skaik, "Critical success factors for construction projects: Case study of Gaza Strip," *Journal of Engineering, Design and Technology*, vol. 14, no. 2, pp. 364-384, 2016.
- [52] H. M. Judi and M. Z. A. Rashid, "Causes and effects of delays in Malaysian construction industry," *International Journal of Facility Management*, vol. 1, no. 1, pp. 1-12, 2010.
- [53] M. R. K. Perera and R. G. Dewagoda, "Factors affecting delayed payment in construction projects: A case of Sri Lanka," *Built-Environment Sri Lanka*, vol. 15, no. 2, pp. 101-115, 2021.
- [54] D.H.S.Illangakoon, "Study on Payment Delays in Small Scale Construction Projects in Sri Lanka (Based On Case Studies)," *Dep. Civ. Eng. Univ. Moratuwa Sri Lanka May*, no. May, p. 60, 2017.
- [55] B. Wilkinson, "Payment in the construction industry: Its importance and rationale," *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*, vol. 8, no. 4, p. 04516001, 2016.
- [56] T. Ramachandra, R. Kumar, and K. N. Prasad, "Payment issues in construction industry," *Procedia Engineering*, vol. 118, pp. 825-833, 2015.
- [57] N. F. Mohamad, P. S. Jahn Kassim, and Z. Zakaria, "Mitigating delay and non-payment issues in the construction industry: Insights from Malaysia," *Procedia Engineering*, vol. 212, pp. 131-138, 2018.
- [58] T. F. Bissoo and P. Outridge, "Construction payments: The case for standardization and enforceability of contracts," *Procedia Engineering*, vol. 233, pp. 326-333, 2020.
- [59] D. Samaraweera, B. A. S. Perera, and R. G. Dewagoda, "Identifying preventive measures for delayed payments in government-funded construction projects in Sri Lanka," *Built-Environment Sri Lanka*, vol. 15, no. 2, pp. 159-172, 2019.
- [60] D. Carmichael, M. Samuel, and D. Hammer, "Fast-track construction dispute resolution in the UK," *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*, vol. 2, no. 4, pp. 173-178, 2010.
- [61] "Building and Construction Industry Security of Payment Act: Act 15 of 2002," 2002.
- [62] M. Patel and N. Patel, "A Comprehensive Approach to Research Methodology," *International Journal of Research in Engineering, Science and Management*, vol. 2, no. 5, pp. 1-6, 2019.
- [63] D.M.I. Akhtar, "Research Methodology: A Step-by-Step Guide for Beginners," *The IUP Journal of Management Research*, vol. 15, no. 2, pp. 40-52, 2016.



University of Vocational Technology
No. 100, Kandawala, Rathmalana.
0112-630700
www.uovt.ac.lk



ISSN 2602-8778