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to Global Challenges”

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Message from the Conference Chair

Dr. Sampath Kannangara

Executive Director & Chief Executive Officer – International College of Business and Technology

It is with great pleasure that I welcome you to the Annual International Research Symposium of ICBT, ‘AIRS 2024.’ This year marks the seventh edition of this prestigious event, which has consistently served as a platform for researchers, academics, and industry professionals to share knowledge, foster collaborations, and contribute to global discourse.



The theme for this year, “Innovating for a Resilient Future: Cross-Disciplinary Approaches to Global Challenges,” reflects our commitment to addressing critical global issues through interdisciplinary research and innovation. As we navigate an ever-evolving landscape, it is imperative that we embrace collaborative approaches to develop sustainable and impactful solutions.

This year’s symposium encompasses diverse research fields, including Business Management, Information Technology, Health Science, Social Science, Engineering, and Construction. The breadth of topics underscores the importance of cross-disciplinary collaboration in tackling the challenges of today and shaping the future.

I would like to extend my sincere appreciation to all the researchers, authors, and presenters for their invaluable contributions. Your dedication to advancing knowledge and sharing insights enriches this symposium and drives meaningful discussions. I also express my gratitude to the organizing committee and the reviewers for their unwavering support and commitment to making this event a success.

AIRS 2024 continues to grow under the digital ISSN: 2961-502X, ensuring that our collective knowledge and discoveries remain accessible to the wider academic and professional communities.

I encourage all participants to engage actively, exchange ideas, and explore new possibilities. I wish you all a productive and inspiring conference.

Message from the Editor-in-Chief

Dr. (Eng.) Sanath Divakara

Welcome all to the Proceedings of the 7th ICBT Annual International Research Symposium- **AIRS'24** under the theme of “**Innovating for a Resilient Future: Cross Disciplinary Approaches to Global Challenge**”.



It is pleasure to be the Editor-in-Chief in Annual International Research Symposium in contributing to disseminate the knowledge of research. My sincere appreciation to all the authors and co-authors for your valuable contribution and commitment made upon the success of the proceedings of 7th AIRS'. Your enthusiasm to share the knowledge in AIRS'24 make a significant change and motivation on organizing such a valuable conference in a great manner. I am sure that your contribution in all the ways of submitting the research papers, participation and presenting will further enlighten both the conference and your life.

AIRS is a great platform for all researchers to initiate their publications and disseminate the research knowledge. Research publication become a vital requirement in both sectors of academia and industry at present. Completing research is merely adding the qualification but publication will embed the research mindset to the researchers in solving problems in a scientific and systematic manner. Research publication would add more value to career and consolidate the philosophical and system thinking toward the bridging gap of innovation under highly competitive environment.

On behalf of the editorial board, my sincere thanks to our track chairs/ co-chairs for their great efforts in reviewing the papers, comments for improvements in their tracks, the volunteer contribution as reviewers, the conference technical program committee members, and the designated reviewers.

I sincerely extend my gratitude to all contributors such of conference chair, editorial board members, organizing committee and looking forward for continuous support in future. I look forward to an exciting day of insightful presentations, discussions, and sharing of new knowledge with colleagues around the world.

My great appreciation for all participants to the conference and I hope that everyone will enjoy the conference AIRS' 24.

KEYNOTE SPEAKERS

Profile	Title of Speech	
	<i>Chief guest and Keynote Speaker</i>	
	Dr Jagath Alwis Chairman, ICBT Campus Executive Chairman Ceylinco General Insurance Limited	
<i>Keynote Speaker</i>		
	Prof. David Brooksbank Pro Vice Chancellor, Department: Senior Management Team Office/Location: O2.35, Ogmore Building, Cardiff School of Management, Llandaff Campus	<i>“Cross-disciplinary Approaches to Innovation. Thoughts on addressing today’s global challenges?”</i>
	<i>Keynote Speaker</i>	
	Prof. Eresha Mendis Professor of Food Science & Technology, Department of Food Science & Technology, Faculty of Agriculture, University of Peradeniya, Sri Lanka	<i>The vital role of multidisciplinary research in food and agriculture for a sustainable future</i>

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*"Strategic Business
Ecosystem for Innovations &
Resilience"*

Keynote Speaker



Prof. Anjana Silva

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*"Four advices for young
scientists"*

Keynote Speaker



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Innovator Expert Lecturer

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University and University of Moratuwa

*"Wearable Technologies and
Biomedical Innovations:
Addressing Global
Challenges in Health and
Aging"*

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Chapter 01:
BUSINESS MANAGEMENT

**THE IMPACT OF DIGITAL BUSINESS TRANSITION ON BUSINESS
PERFORMANCE OF ABC FINANCE PLC, SRI LANKA WITH MODERATING
EFFECT OF EMPLOYEE ENGAGEMENT**

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Abstract

The digital business transition has significantly impacted industries' long-term success, despite Sri Lanka's financial sector not receiving sufficient research to establish its significance. The gap is aimed to be filled, and the situation is clarified. The current research is carried out to examine the impact of digital business transition on the business performance of ABC Finance PLC, Sri Lanka with the moderating effect of employee engagement. The Morgans table determined the study sample. Out of a population of 1,458, 305 people made up the sample size. SPSS software was used to conduct the necessary statistical analyses. The method was quantitative. The research study's conclusions demonstrated that the digital business transition significantly impacts business performance, and employee engagement does not significantly moderate this effect. Considering the findings of the research, it is recommended that ABC Finance PLC to focus more on sustainable marketing strategies, enhancing digital infrastructure, and investing in cybersecurity.

Keywords: Business performance, Cybersecurity, Digital business transition, Digital infrastructure, E-commerce adoption, Employee engagement.

Introduction

The digital business transition has become a significant topic in the past two decades (Maragaoda,2019). Digital transitions are transforming the economy and society, improving welfare, and addressing issues. They prompt organizations to rethink models and leverage digital technologies for competitive advantage but also present new challenges (Mubarak et al.,2019). The aligned context industry is the finance sector. Despite that, Failure to conduct this research can result in inefficient resource allocation, missed growth opportunities, and loss of competitive advantage. Moreover, Failure to assess the digital transition of an organization can lead to strategic mistakes, operational inefficiencies, and loss of market share. Furthermore, Business performance is the benchmark for the success of a business (Octavia et al.,2020). This research aims to explore the impact of digital business transitions on business performance, clarifying the theory and proposing feasible solutions. Furthermore, this study investigates the moderate impact of employee engagement on the business performance of digital business transition, as previously found, in line with previous studies (Verhoef et al, 2021). Gupta (2021) highlights the importance of employee engagement in digital business transition initiatives, as it boosts productivity and innovation. Furthermore, Transition means moving from one state to

another state, this will smoothly happen in the business context when there is an employee involved (Benson et al., 2013).

Research Problem & Objectives

ABC Finance PLC in Sri Lanka faces challenges in business performance despite digital transitions, including low customer satisfaction and unclear financial benefits. The information gap and literature gap necessitate an investigation into the impact of digital business transition on performance (Biyagama,2024).

The main objective of the study is to investigate the impact of digital business transitions on the business performance of ABC Finance PLC, Sri Lanka.

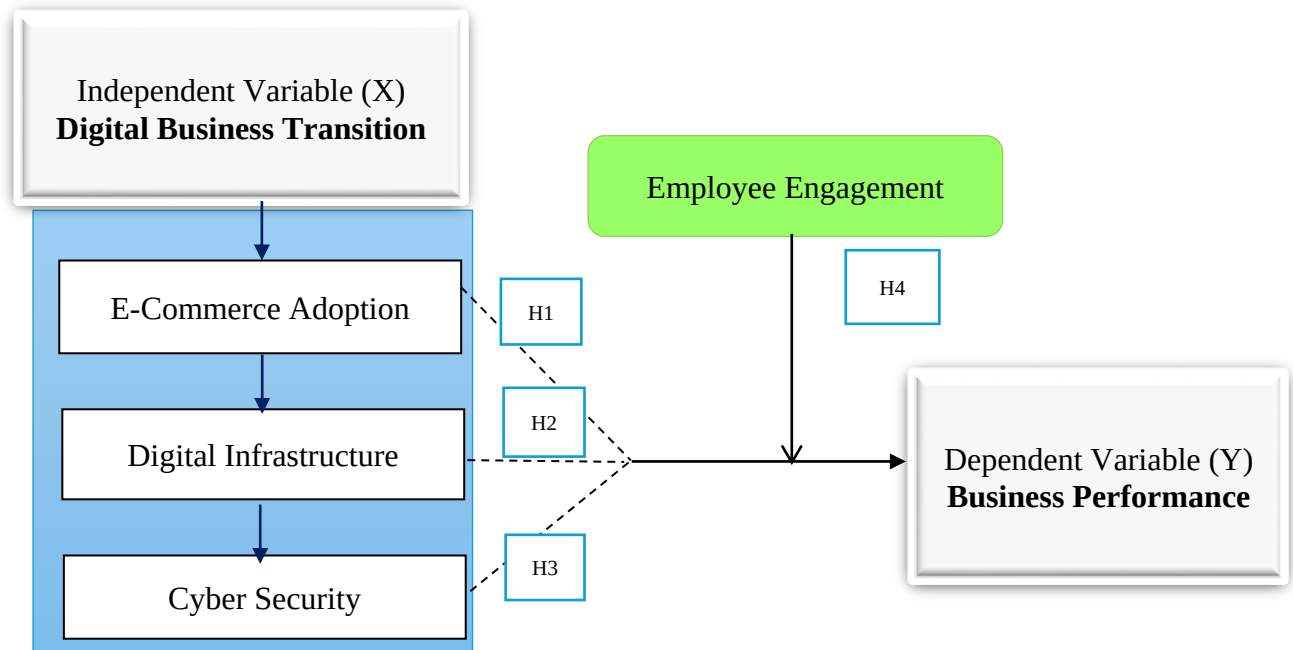
1. To investigate the impact of e-commerce adoption on the business performance of ABC Finance PLC, Sri Lanka.
2. To examine the impact of digital infrastructure on the business performance of ABC Finance PLC, Sri Lanka.
3. To examine the impact of cyber security on the business performance of ABC Finance PLC, Sri Lanka.
4. To examine the moderating impact of employee engagement on the relationship between digital business transition and the business performance of ABC Finance PLC, Sri Lanka.

Significance of the study

The findings can be used by decision-makers to strategize enhancements, allocate resources effectively, and benchmark performance metrics. Policymakers can also use this information to regulate standards and promote best practices in digital transformation.

Methodology

Figure 1: Conceptual framework



Source: Researcher's work (2024).

Development of hypothesis

Hypothesis 1

H1₀: There is no impact of e-commerce adoption on business performance of ABC Finance PLC, Sri Lanka.

H1₁: There is an impact of e-commerce adoption on business performance of ABC Finance PLC, Sri Lanka.

Hypothesis 2

H2₀: There is no impact of digital infrastructure on business performance of ABC Finance PLC, Sri Lanka.

H2₁: There is an impact of digital infrastructure on business performance of ABC Finance PLC, Sri Lanka.

Hypothesis 3

H3₀: There is no impact of cyber-security on business performance of ABC Finance PLC, Sri Lanka.

H3₁: There is an impact of cyber-security on business performance of ABC Finance PLC, Sri Lanka.

Hypothesis 4

H4₀: Employee engagement doesn't moderate the impact of digital business transition on business performance of ABC Finance PLC, Sri Lanka.

H4₁: Employee engagement moderates the impact of digital business transition on business performance of ABC Finance PLC, Sri Lanka.

Hypothesis 5

H5₀: There is no impact of digital business transition on business performance of ABC Finance PLC, Sri Lanka.

H5₁: There is an impact of digital business transition on business performance of ABC Finance PLC, Sri Lanka.

Table: 1 Operationalization table

Variable	Dimension	Indicators	Measurement	Question no in the questionnaire	Source
Digital Business Transition	E-Commerce Adoption	Customer Awareness	5 Point Likert scale	6,7	(Wirdiyanti et al.,2023; Basarir and Mardikyan,2017).
		Trust		8,9	
		Satisfaction		10,11	
	Digital Infrastructure	Speed of Internet network		12,13	(Taheri,2012; Author construct,2024) by adopting (Griffin,2023, and Gulliver, 2021)
		Server Response time		14,15	
		User-friendly application		16,17	
	Cyber Security	Loss of Money / Data		18,19	(Author construct,2024) by adopting (Zwilling et al,2022)
		Protection		20,21	
		Customer Complaints / Awareness Related Security		22,23	
Business Performance	Financial Performance	Sales turnover	5 Point Likert scale	24,25	(Zulkiffli,2011; Popović,2019; Author construct,2024)
		Profitability		26,27	
	Non-Financial performance	Customer loyalty/retention		28,29	
		Employee Performance and Satisfaction		30,31	
Employee Engagement		Enthusiasm		32,33	(Kifor et al, 2022; Author construct,2024)
		Dedication		34,35	
		Effectiveness		36	

Source: Researcher's work (2024).

Research design

The data was collected among the executive and Above employees with specific exposure to performance. The sample size, determined from the 1,458 population, was 305, as per the Morgan Table (1970). Further simple random sampling techniques were used to select the sample due to the known size of the research population. Questionnaires were circulated to the employees using Google Forms with different branches and departments. The required statistical analysis was performed using SPSS software.

Results

A literature review, alignment with existing theories, and context professional input confirmed the study's content validity. The survey's instruments, including questionnaire techniques, were evaluated for reliability using Cronbach's alpha, achieving elevated alpha values for essential constructs, and indicating robust internal consistency and reliability. The study's ultimate conclusions are built on a strong foundation of validity and reliability. Furthermore, the strength of the research design, the comprehensiveness of data collection and analysis, and the transparency in reporting enhance the clarity and credibility of the study.

Table 2: Summary of background information

Variable Components	Frequency	Percentage (%)	Mode	Std. Deviation	Total Respondents
Gender of respondent					305
Male	174	57.00%	1	0.496	
Female	131	43.00%			
Age					
Below 30	153	50.2%	1	0.646	
31-40 years	134	43.9%			
41-50 years	14	4.6%			
Above 50	4	1.3%			
Years of experience in the company					
Below 5	105	34.4%	1	1.037	
6 - 10 years	103	33.8%			
11 -15 years	73	23.9%			
16 - 20 years	13	4.3%			
Above 20	11	3.6%			
The education qualification of the respondent					
A/L or equivalent	62	20.3%	2	1.152	
Diploma level	116	38.0%			
Bachelor’s Degree	100	32.8%			
Master’s Degree	10	3.3%			
Doctoral Degree	3	1.0%			

Professional	14	4.6%			
Job Position					
Executive	219	71.8%	1	0.648	
Manager	71	23.3%			
Senior Manager	8	8%			
Top Senior Manager	7	2.3%			

Source: Researcher's work (2024).

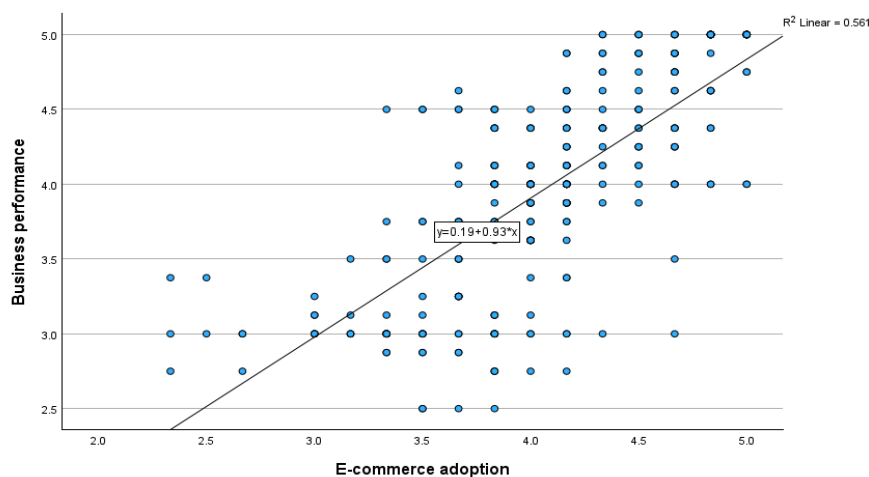
Table 2 presents the background profile of the respondents. The survey revealed that 57% of the respondents were male, with the majority, 50.2%, being young employees under the age of 30. Moreover, 34.4% of the respondents had less than five years of experience. Diploma holders made up 38% of the respondents, followed by bachelor's degree holders as the second largest group. Furthermore, most respondents, 71.8%, were executive-level employees.

Table 3: Summary of correlation analysis

No	Independent variables (Dimensions)	Dependent variable (BP)	p-value
1	E-commerce Adoption	0.749	<.001
2	Digital Infrastructure	0.784	<.001
3	Cyber Security	0.779	<.001

Source: Researcher's work (2024).

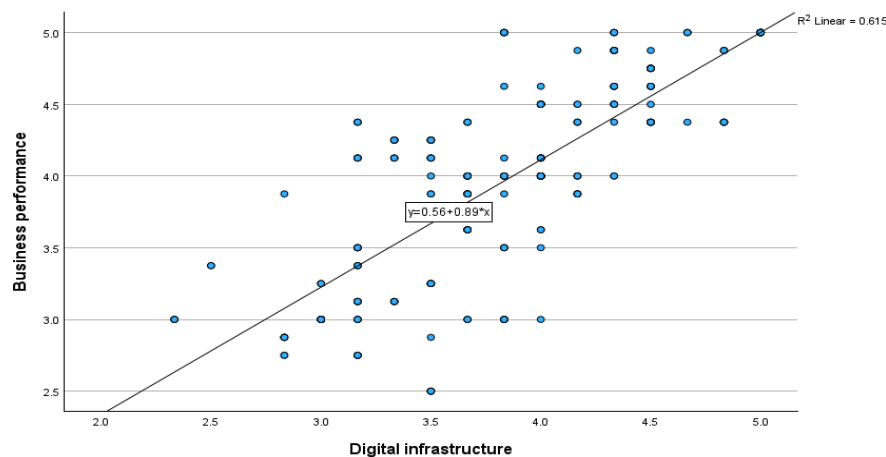
Figure 2: Relationship between ECA and BP



Source: Researcher's work (2024).

Table 3 and Figure 2 demonstrate the ECA and BP correlate value is 0.749 at a significant 5% level. Approximately, there is a highly positive relationship between all the dimensions of ECA and BP.

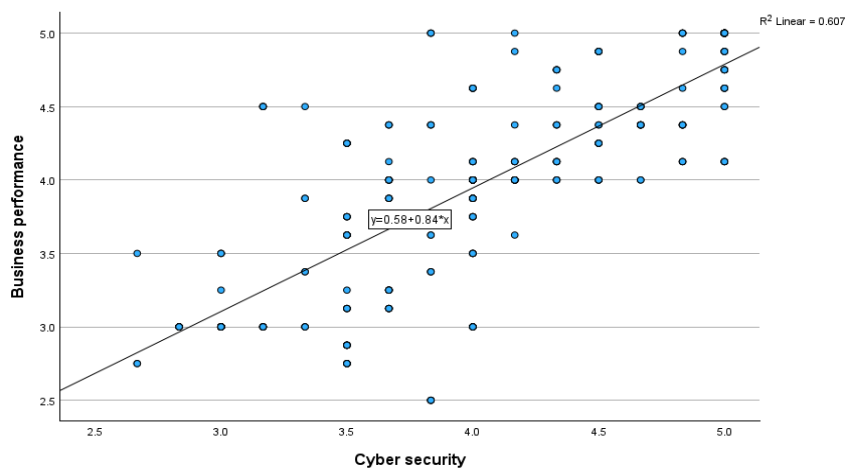
Figure 3: Relationship between DI and BP



Source: Researcher's work (2024).

Table 3 and Figure 3 demonstrate the DI and BP correlate value is 0.784 at a 5% significant level. Therefore, there is a strong positive relationship between all the dimensions of DI and BP.

Figure 4: Relationship between CS and BP



Source: Researcher's work (2024).

Table 3 and Figure 4 demonstrate the CS and BP correlate value is 0.779 at a 5% significant level. Therefore, there is a strong positive relationship between all the dimensions of CS and BP.

What is the impact of ECA, DI, and CS on Business performance (BP)?

Table 4: Summary of multiple regression analysis

Method	Linear
R Square	0.715
Adjusted R-value	0.712
F	252.048 at p <.001

B -Constant		-0.202		
Independent Variables	B value	Beta value	t value	p-value
E-commerce adoption (ECA)	0.269	0.217	4.196	<.001
Digital Infrastructure (DI)	0.409	0.361	6.984	<.001
Cyber Security (CS)	0.373	0.346	6.749	<.001

Source: Researcher's work (2024).

According to Table 4, the beta coefficient of ECA is provided as 0.217 at $p = 0.001 < \alpha = 0.05$ and $t = 4.196$. Therefore, the statistical evidence clearly proves that ECA is a significant predictor in predicting BP. Moreover, the beta coefficient of DI is given as 0.361 at $p = 0.001 < \alpha = 0.05$ and $t = 6.984$. This figure significantly denotes that DI is significant in predicting BP. Finally, the beta coefficient of CS gets 0.346 at $p = 0.001 < \alpha = 0.05$ and $t = 6.749$. Statistical evidence shows that CS significantly affects BP.

What is the impact of DBT on Business performance (BP)?

Table 5: Summary of overall impact

Method		Linear			
R Square		0.713			
Adjusted R-value		0.713			
F		754.453 at $p < .001$			
B -Constant		-0.252			
Independent Variables	B value	Beta value	t value	p-value	Part
Digital Business Transition (DBT)	1.061	0.845	27.467	<.001	0.845

Source: Researcher's work (2024).

As denoted by Table 5 the beta coefficient of DBT is provided as 0.845 at $p = 0.001 < \alpha = 0.05$ and $t = 27.467$. Therefore, statistical evidence proves that DBT has a significant impact on BP.

What is the effect of moderating variable?

Table 6: Summary of multiple regression analysis of EE on BP.

Method		Linear			
R Square		0.716			
Adjusted R-value		0.714			
F		380.592 at $p < .001$			
B -Constant		-0.064			
R Square change		0.716			
Independent Variables	B value	Beta value	t value	p-value	Part
Digital Business Transition (DBT)	1.051	0.837	26.999	<.001	0.828
Employee Engagement (EE)	-0.096	-0.050	-1.626	0.105	-0.50

Source: Researcher's work (2024).

The Table 6 regression model has given the beta coefficient of DBT as 1.051 at $p = 0.001 < \alpha = 0.05$ and $t = 26.999$ whilst the beta coefficient of EE gets -0.096 at $p = 0.105 > \alpha = 0.05$ and

$t = -1.626$. This statistical evidence confirms that DBT is a significant predictor of BP, but EE is an insignificant predictor of BP.

Table 7: Hierarchical multiple regression analysis

Method		Linear 1		Linear 2	
R Square		0.716		0.717	
Adjusted R-value		0.714		0.714	
F		380.592 at $p < .001$		254.307 at $p < .001$	
B -Constant		-0.064		-0.804	
R Square change		0.716		0.001	
1. Variables	B value	Beta value	t value	p-value	Part
Digital Business Transition (DBT)	1.051	0.837	26.999	$< .001$	0.828
Employee Engagement (EE)	-0.096	-0.050	-1.626	0.105	-0.50
2. Variables	B value	Beta value	t value	p-value	Part
Digital Business Transition (DBT)	1.232	0.981	7.305	$< .001$	0.224
Employee Engagement (EE)	0.393	0.206	0.876	0.382	0.027
Interaction IV and MV	-0.120	-0.277	-1.100	0.272	-0.034

Source: Researcher's work (2024).

As Table 7 demonstrated, Model two of the regression model has given the beta coefficient of the interacting variable as -0.120 at $p = 0.272 > \alpha = 0.05$ and $t = -1.100$. This statistically confirms that the moderator variable is insignificant in moderating the impact of an independent variable on the dependent variable.

Table 8: Overview of hypothesis

Independent variables	Dependent variable	Relationship	Hypothesis	
			H ₀	H ₁
E-commerce adoption	Business performance	Strong Positive	Rejected	Accepted
Digital Infrastructure		Strong positive	Rejected	Accepted
Cyber Security		Strong positive	Rejected	Accepted
Digital business transition		Strong positive	Rejected	Accepted

Source: Researcher's work (2024).

Table 9: Overview of moderating variable hypothesis

Independent variable	Dependent variable	Moderating variable	Hypothesis	
			H ₀	H ₁
Digital business transition	Business performance	Employee engagement	Accepted	Rejected

Source: Researcher's work (2024).

Discussion

The study reveals that implementing digital business transition significantly enhances ABC Finance PLC, Sri Lanka's business performance this finding is compatible with previous literature As theoretically explained by Mubarak et al. (2019) found Pakistan SME Context that digital transition positively impacts business performance, And Prabodhi et al (2020) argued that digital transition positively impacts business performance of commercial banks in Sri Lanka, Moreover, Azmi et al. (2020) Conducted a qualitative study on the impact of digitalization on bank performance. According to the findings, the impact of digital business transition on business performance supported many of the literature reviews in the literature survey. Conversely, the study reveals that Employee engagement doesn't moderate the impact of digital business transition on business performance of ABC Finance PLC, Sri Lanka. This finding is not compatible with previous literature, Kozanoglu and Abedin (2021) found that employees benefit significantly from digital transition, Harter et al. (2002) and Schaufeli et al. (2002) empirically suggest that high employee engagement leads to increased productivity and raises awareness of digital transition, The data analysis indicates that the benefits of digital transition are likely to be realized regardless of employee engagement level, contradicting previous literature with context.

Conclusions and Recommendations

As per the findings of this study, it can be concluded that e-commerce adoption significantly impacts business performance. Furthermore, the findings of this study concluded that digital infrastructure has a significant impact on business performance. Then, the findings of the study conclude that cyber security has a significant impact on business performance. Overall, the study concluded that digital business transition has a significant impact on business performance. Finally, the findings of the study conclude that the impact of digital business transition on business performance is not moderated by employee engagement.

Considering the findings of the research study, it is recommended to improve comprehensive digital strategy for enhanced corporate outcomes, outlining roadmap, initiatives, schedule, and intended results to align with business goals for efficient and high-quality outcomes. Recommends developing innovative marketing strategies that clearly outline the target market, goals, and roadmap for enhancing business through e-commerce, ensuring clear and effective results Moreover, recommends developing a new application to regularly resolve digital infrastructure issues, maintain a feedback system for employees and customers, and generate weekly or daily reports to ensure the correct state of digital infrastructure is maintained. Further Recommend Investing in cyber-security measures and monitor emerging risks to enhance security, while increasing and maintaining the quality assurance team.

The recommendations will enable ABC Finance PLC and other decision-makers to realize the advantages of digital transition, further creating an efficient work background for sustainable business performance.

References

- Basarir-Ozel, B. and Mardikyan, S., (2017). Factors affecting E-commerce adoption: A case of Turkey. *The International Journal of Management Science and Information Technology (IJMSIT)*, (23), pp.1-11. Available at: <https://www.econstor.eu/handle/10419/178834> [Accessed 21 June 2024].
- Buckley, R.P., Arner, D.W., Zetsche, D.A. and Selga, E., (2019) The dark side of digital financial transformation: The new risks of fintech and the rise of techrisk. *UNSW Law Research Paper*, (19-89). Available at: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3478640 [Accessed 7 June 2024].
- Benson, G.S., Kimmel, M. and Lawler III, E.E., 2013. Adoption of employee involvement practices: Organizational change issues and insights. In *Research in organizational change and development* (pp. 233-257). Emerald Group Publishing Limited. Available at: https://www.researchgate.net/publication/285716480_Adoption_of_Employee_Involvement_Practices_Organizational_Change_Issues_and_Insights/stats [Accessed 19 January 2025]
- Griffin T., (2023). Five Features That Can Make Your Software More User-Friendly Available at: <https://www.forbes.com/sites/forbestechcouncil/2023/08/24/five-features-that-can-make-your-software-more-user-friendly/> [Accessed 22 June 2024].
- Gulliver, R., Fahmi, M. and Abramson, D., (2021). Technical considerations when implementing digital infrastructure for social policy. *Australian Journal of Social Issues*, 56(2), pp.269-287. Available at: <https://onlinelibrary.wiley.com/doi/abs/10.1002/ajs4.135> [Accessed 26 July 2024].
- Gupta, M., (2021). Employee engagement through digital innovation: A research study. *DR. DY PATIL B-SCHOOL, PUNE, INDIA*, p.381. https://www.researchgate.net/publication/353357231_Employee_engagement_through_digital_innovation_A_research_study [Accessed 19 January 2025]
- Hustad, E. and Olsen, D.H., (2021). Creating a sustainable digital infrastructure: The role of service-oriented architecture. *Procedia Computer Science*, 181, pp.597-604. Available at: <https://doi.org/10.1016/j.procs.2021.01.210> [Accessed 19 June 2024].
- Kifor, C.V., Săvescu, R.F. and Dănuț, R., (2022). Work from home during the COVID-19 pandemic—the impact on employees’ self-assessed job performance. *International Journal of Environmental Research and Public Health*, 19(17), p.10935. Available at: <https://www.mdpi.com/1660-4601/19/17/10935> [Accessed 21 June 2024].
- Kozanoglu, C D. and Abedin, B., (2021). Understanding the role of employees in digital transformation: conceptualization of digital literacy of employees as a multi-dimensional organizational affordance’ *Journal of enterprise information management.*, 34(6). Available at: <https://doi-org.sunderland.idm.oclc.org/10.1108/JEIM-01-2020-0010> [Accessed 11 June 2024].
- Maragaoda, W.S., (2019). *Customers’ motivation to embrace digital banking in Sri Lanka: a case study of Sampath Bank PLC* (master’s thesis). Available at: <https://www.researchbank.ac.nz/server/api/core/bitstreams/75343e14-db42-420e-a3d5-acc7da9cab8/content> [Accessed 16 May 2024].
- Mubarak, M.F., Shaikh, F.A., Mubarik, M., Samo, K.A. and Mastoi, S., (2019). The impact of digital transformation on business performance: A study of Pakistani SMEs. *Engineering*

technology & applied science research, 9(6), pp.5056-5061. Available at:

<https://epubl.ktu.edu/object/elaba:46768105/> [Accessed 11 June 2024].

Octavia, A., Indrawijaya, S., Sriyudha, Y. and Hasbullah, H., (2020). Impact on E-commerce adoption on entrepreneurial orientation and market orientation in business performance of SMEs. *Asian Economic and Financial Review*, 10(5), p.516. Available at:

<https://www.proquest.com/openview/38ee38f581b1ea06ba23077d2cd1a7cb/1?pq-origsite=gscholar&cbl=1786341> [Accessed 15 May 2024].

Popović, P.S., Semenčenko, D. and Vasilčić, N., (2019). The influence of digital transformation on business performance: Evidence of the women-owned companies. *Ekonomika preduzeća*, 67(7-8), pp.397-414. Available at:

https://www.ses.org.rs/uploads/sanja_et_al_200129_100909_976.pdf [Accessed 22 June 2024].

Ramanathan, R., Ramanathan, U. and Hsiao, H.L., (2012). The impact of e-commerce on Taiwanese SMEs: Marketing and operations effects. *International Journal of Production Economics*, 140(2), pp.934-943. Available at: <https://doi.org/10.1016/j.ijpe.2012.07.017> [Assessed 9 July 2024].

Taheri, A., (2012). The adoption of E-Commerce, a study of the Iranian oil industry. Available at: <https://www.diva-portal.org/smash/record.jsf?pid=diva2%3A829971&dswid=6660> [Accessed 22 June 2024].

Verhoef, P.C., Broekhuizen, T., Bart, Y., Bhattacharya, A., Dong, J.Q., Fabian, N. and Haenlein, M., (2021). Digital transformation: A multidisciplinary reflection and research agenda. *Journal of business research*, 122, pp.889-901. Available at: <https://www.sciencedirect.com/science/article/pii/S0148296319305478> [Accessed 9 June 2024].

Wirdiyanti, R., Yusgiantoro, I., Sugiarto, A., Harjanti, A.D., Mambea, I.Y., Soekarno, S. and Damayanti, S.M., (2023). How does e-commerce adoption impact micro, small, and medium enterprises' performance and financial inclusion? Evidence from Indonesia. *Electronic Commerce Research*, 23(4), pp.2485-2515. Available at: www.researchgate.net/profile/Indra-Mambea/publication/359778620_How_does_e-commerce_adoption_impact_micro_small_and_medium_enterprises%27_performance_and_financial_inclusion_Evidence_from_Indonesia/links/64808c822cad460a1bfc2f8e/How-does-e-commerce-adoption-impact-micro-small-and-medium-enterprises-performance-and-financial-inclusion-Evidence-from-Indonesia.pdf [Accessed 21 June 2024].

Zulkiffli S N A., (2011). A literature analysis on business performance for SMES - subjective or objective measures? Available at: <https://ro.uow.edu.au/cgi/viewcontent.cgi?referer=&httpsredir=1&article=1315&context=gsbpapers> [Accessed 22 June 2024].

Zwilling, M., Klien, G., Lesjak, D., Wiechetek, Ł., Cetin, F. and Basim, H.N., (2022). Cyber security awareness, knowledge and behavior: A comparative study. *Journal of Computer Information Systems*, 62(1), pp.82-97. Available at: www.researchgate.net/profile/Lukasz-Wiechetek/publication/339273589_Cyber_Security_Awareness_Knowledge_and_Behavior_A_Comparative_Study/links/5e46d7d9458515072d9db266/Cyber-Security-Awareness-Knowledge-and-Behavior-A-Comparative-Study.pdf [Accessed 22 June 2024].

**IMPACT OF ECONOMIC RISKS ON THE SUSTAINABILITY OF SMALL AND
MEDIUM ENTERPRISE SERVICE SECTOR IN THE COLOMBO DIVISIONAL
SECRETARIAT, SRI LANKA**

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Abstract

The present study examines the impact of economic risks on the sustainability of the SME service sector in the Colombo Divisional Secretariat, Sri Lanka. Economic risks were considered as the independent variable, including four dimensions, e.g., inflation, labor shortage, economic downturn, and disruption to critical infrastructure. Sustainability has been considered as the dependent variable. The research population consisted of all registered and current service SMEs in the Colombo Divisional Secretariat of Sri Lanka. This study was conducted using a simple random sampling procedure, with a sample size of 129 service SME owners from the Colombo Divisional Secretariat. The study used a quantitative research method and distributed a survey closed-ended questionnaire with numerically rated items. This study was based mainly on the positivism paradigm followed by the deductive approach. Moreover, in this research, the researcher used a cross-sectional study, which took place at a single time. According to the data analyzed, the findings showed that inflation and labor shortage had significantly impacted on the sustainability of SMEs, and it denoted that the higher the inflation and labor shortage, the more significant the impact on the sustainability, which led to a slowdown of many SMEs business processes or closed down within a year after the commencement. However, economic downturn and disruption to critical infrastructure did not significantly impact on the sustainability of SMEs. Overall, as per the simple linear regression analysis, it was concluded that economic risks significantly impacted the sustainability of the SME service sector in Colombo Divisional Secretariat, Sri Lanka.

Keywords: Disruption to Critical Infrastructure, Economic downturn, Inflation, Labor shortage, Sustainability

Introduction

"Recent SME research consistently demonstrates the importance of SME contributions to employment and economic growth, and they also perform a crucial role in local, national, and global economics (Asgary, Ozdemir, and Ozyurek, 2020). According to the Global Compact Network Sri Lanka (2021), the Sri Lankan government identifies SMEs as the backbone of the economy, accounting for more than 75% of the total number of businesses, employing approximately 45% of the population, and contributing 52% of Sri Lanka's GDP. It is also regarded as a driving force of change for inclusive economic growth, regional development, employment generation, and poverty reduction.

However, The World Bank vice president for the South Asia region, Raiser (2023), emphasized that from 2022, most SMEs in Sri Lanka lost their right balance due to a severe economic downturn; as a result, half a million individuals lost their employment. Most of them worked in the industrial and service sectors and were women. Central Bank of Sri Lanka (2023) also highlights, due to challenges faced by SMEs, they failed to maintain sustainability, ultimately leading to low productivity of SMEs compared to large firms. Gamage et al. (2020) highlighted that the downfall rate of SMEs is relatively higher in Sri Lanka than in other developing countries because, in Sri Lanka, most SMEs close their businesses within a year after the commencement. Amaradiwakara and Gunathilaka (2016) also considered this was a significant issue because it indicates that these existing SMEs could not maintain their position in their environment or never achieved it. As a result, it is evident that even when business owners begin their ventures with the best intentions and work long, hard hours, only a few businesses survive, while most fail.

Objectives of the research

1. To determine SMEs' current economic risks in the service sector of Colombo divisional secretariat, Sri Lanka.
2. To investigate the factors affecting the sustainability of the SME service sector in the Colombo divisional secretariat, Sri Lanka.
3. To critically analyze how economic risks impact the sustainability of the SME service sector in the Colombo divisional secretariat, Sri Lanka.
4. To recommend practical recommendations to mitigate the economic risks faced by the SME service sector in the Colombo divisional secretariat, Sri Lanka.

As a result, it can highlight the importance of my research findings to the government, policymakers, and SME businesses. Furthermore, by mitigating economic risks, SMEs can contribute more to the GDP of Sri Lanka, including regional development, employment generation, and poverty reduction.

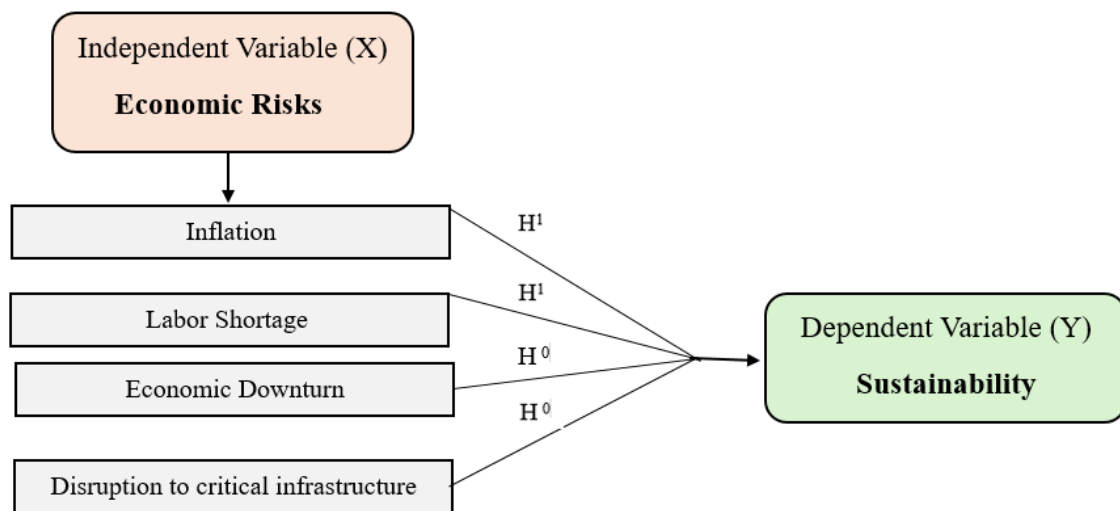
Methodology

Research Strategy

In this research, the researcher collected quantitative data through using survey closed-ended questionnaire with numerically rated items.

Conceptual Framework

Figure 1: Conceptual Framework



Source: Author Construct by adopting WEF (2024)

Research Hypothesis

H₁: Inflation has an impact on the sustainability of the SMEs service sector of the Colombo divisional secretariat, Sri Lanka.

H₁: labor shortage has an impact on the sustainability of the SMEs service sector of the Colombo divisional secretariat, Sri Lanka.

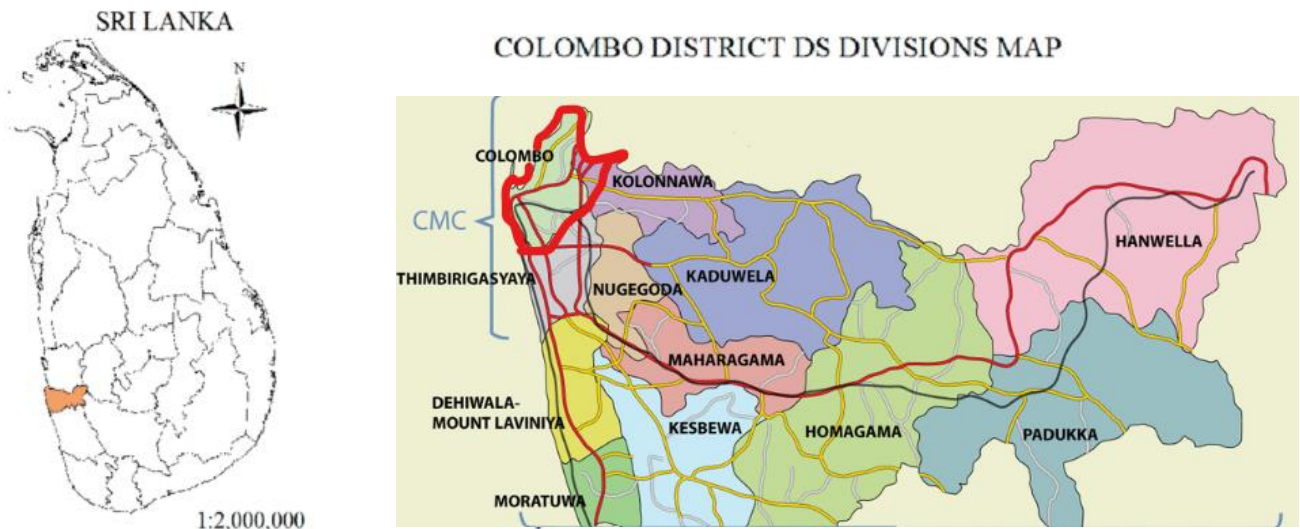
H₀: Economic downturn has no impact on the sustainability of the SMEs service sector of the Colombo divisional secretariat, Sri Lanka.

H₀: Disruption to Critical Infrastructure has no impact on the sustainability of the SMEs service sector of the Colombo divisional secretariat, Sri Lanka

Sample Selection

According to the map below, the Colombo district includes 12 divisional secretariats. Hence, due to time constraints, the researcher focused on all registered and existing service SMEs only under the Colombo Divisional Secretariat as a population of the study. According to the Colombo Divisional Secretariat, Anuruddha (2024), the service sector SMEs population was 192.

Figure 2: Colombo District Divisional Secretariat Map



Source: Research Gate (2016)

According to the Morgan table, the study sample size was 129 owners of the service sector SMEs of the Colombo Divisional Secretariate. Moreover, the researcher used a simple random sampling technique under probability sampling.

Data Collection

The researcher administered a survey questionnaire. It consisted of 39 questions and is separated into three sections: A, B, and C. Section A consists of closed-ended questions designed to obtain demographic information about the SME's owner. Sections B and C consisted of five-point Likert Scale question statements to collect data on the perceived status of the respondents on the impact of economic risks on the sustainability of service sector SMEs.

Results

Reliability of the variables

The summary of Cronbach's Alpha analysis is given in Table 1

Variable	Number of Question Statements	Cronbach's Alpha Value	Decision
Inflation (IN)	05	0.854	Reliable
Labor Shortage (LS)	06	0.853	Reliable

Economic Downturn (ED)	06	0.912	Reliable
Disruption to Critical Infrastructures (DC)	05	0.868	Reliable
Sustainability (SUS)	12	0.956	Reliable

Source: Author Construct (2024)

Validity of the Variables

Table 2: Validity of the Variables

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.930
Bartlett's Test of Sphericity	Approx. Chi-Square	3612.691
	df	561
	Sig.	<.001

Source: Author Construct (2024)

Correlation Analysis

Table 3: Summary of Correlation Analysis

Independent Variable	Dependent Variable (SUS)	Sig. Value
IN	0.633	0.001
LS	0.637	0.001
ED	0.614	0.001
DC	0.608	0.001

Source: Author Construct (2024)

Regression Analysis

Table 4: Summary of Multiple Regression Analysis

Method		Linear		
R Square		0.478		
Adjusted R Square		0.461		
F		28.413 at Sig 0.001		
B-Constant		0.897		
Independent Variable	B	Beta	t	Sig
IN	.304	.286	2.669	.009
LS	.265	.258	2.102	.038
ED	.115	.120	.958	.340
DC	.099	.098	.811	.419

Source: Author Construct (2024)

Based on the regression outcomes, the regression model can be developed as follows.

$$\text{SUS} = 0.897 + 0.304 \text{ IN} + 0.265 \text{ LS} + 0.115 \text{ ED} + 0.099 \text{ DC}$$

As per Table 4, the beta coefficient of IN is given as 0.286 at $P = 0.009 < \alpha = 0.05$ and $t = 2.669$. This statistical evidence proves that IN is a significant predictor of SUS. The beta coefficient of LS gets 0.258 at $P = 0.038 < \alpha = 0.05$ and $t = 2.102$. This evidence proved that LS also made a significant impact on SUS. However, the beta coefficient of ED draws 0.120 at $P = 0.340 > \alpha = 0.05$ and $t = 0.958$. This denotes that ED does not make a significant impact on SUS. Furthermore, the beta coefficient of DC gets 0.098 at $P = 0.419 > \alpha = 0.05$ and $t = 0.811$. It clearly emphasizes that DC also does not significantly impact SUS.

Overall Impact

Table 5: Summary of simple linear regression analysis for overall impact

Method		Linear		
R Square		0.470		
Adjusted R Square		0.466		
F		112.780 at Sig 0.001		
B-Constant		0.985		
Independent Variable	B	Beta	t	Sig
Economic risks	.763	.686	10.620	.001

Source: Author Construct (2024)

According to table 5, the beta coefficient of economic risks is 0.686 at $P = 0.001 < \alpha = 0.05$ and $t = 10.620$. Overall, these statistical evidences indicate that economic risks significantly impact the sustainability of SMEs service sector in the Colombo Divisional secretariat, Sri Lanka.

Discussion

Research Question 1

What are the Current Economic Risks Faced by the SME Service Sector in the Colombo Divisional Secretariat, Sri Lanka ?

The World Economic Forum (2024) indicates that the economic risk category consists of inflation, labor shortage, economic downturn, and disruption to critical infrastructure. The researcher clearly recognized those four variables as they supported making reliable and valid questions for the respondents. According to the analysis, Cronbach's Alpha value is well above 0.8 for all independent variables. Moreover, these current economic risks are highly compatible with the World Economic Forum report (2024), which argued that these risks would be more vulnerable to countries like Sri Lanka. This answer is also compatible with the World Bank vice president for the South Asia region, Raiser (2023), who emphasized that from 2022, most SMEs in Sri Lanka lost their right balance due to a severe economic downturn, including inflation and labor shortage.

Research Question 2

What factors affect the sustainability of the SME service sector in the Colombo Divisional Secretariate, Sri Lanka ?

The researcher has identified several important factors that affect the sustainability of the SME service sector, such as increasing utility costs, tightening credit policies, higher transportation costs, skill migration, a decline in the job market, disruption to the commodity market, lack of technological skills, level of education of the owner, market share, and customer satisfaction, etc. These facts are compatible with Wickramasinghe (2011), who identified significant factors like unfavorable economic policies and difficulties accessing credit. According to correlation analysis, these factors have a moderate positive relationship with the dependent variable, which was recorded above 0.6 to 0.64. These findings are also moderately compatible with those of Amaradiwakara and Gunathilake (2016) and Azim, Ahmed, and Khan (2015), who indicated that the above facts affect the sustainability of SMEs.

Research Question 3

How do Economic Risks Impact the Sustainability of the SME Service sector in the Colombo Divisional Secretariate, Sri Lanka

According to the results, the Inflation significantly impacts SMEs' sustainability in the service sector and these findings are highly compatible with Webster (2023), who argued that current inflationary trends are making it harder for SMEs because inflation impacts every area of business when it is out of control. The labor shortage in the Colombo Divisional Secretariate, Sri Lanka, also affects SMEs' sustainability. The pandemic and economic crises have severely impacted Sri Lanka's businesses, causing catastrophic losses in travel, tourism, and service industries. This has led to more redundancies and a significant drop in economic activities. Moreover, these findings highly matched with the International Labor Organization (2023), which indicated that the Sri Lankan economy lost 73,441 jobs in the last quarter.

The results highlights that economic downturn has no significant impact on the sustainability of SMEs in the service sector of Colombo Divisional Secretariate, Sri Lanka. These research findings are incompatible with Rohanachandra (2022), who argued that an economic downturn results in a decline in the job market, a rise in unemployment, and poor living conditions, all of which could lead to the closedown of SMEs within a very short time. These findings also did not agree with Sriyani (2022), who stated that SMEs face severe financial issues during economic downturns. However, the researcher's findings are compatible with Weaven, et al. (2021), who argue that SME owners who use dynamic capabilities enable their businesses to survive and grow during an economic downturn. The results specifies that disruption to critical infrastructure also has no significant impact on the sustainability of SMEs in the service sector of Colombo Divisional Secretariate, Sri Lanka. These research findings are incompatible with Mukherjee et al. (2023), who highlighted that countries like Sri Lanka experience floods, cyclones, and landslides, disturbing critical infrastructures like roads, electricity, and railway networks. Moreover, these findings did not agree with Mausudeen and Rauf (2022), who

argued that economic prosperity relies on highly developed infrastructures like power, water, and roads, and Sri Lanka's SMEs suffer greatly from inadequate infrastructure. However, the researcher's findings are compatible with Ojiba and Olotu (2024), who indicated that despite infrastructures difficulties, challenges, or dangers, some SMEs adopt innovation, which is more likely to survive because it depends on how the organization operates dynamic capabilities on its resources effectively.

Conclusions and Recommendations

Conclusions

This study's detailed analysis and discussions support the conclusion that inflation and labor shortage significantly impact the sustainability of the SMEs service sector. However, economic downturn and disruption to critical infrastructure do not significantly impact the sustainability of the SMEs service sector. Overall, the summary of simple linear regression analysis for overall impact denotes that economic risks significantly impact the sustainability of SMEs service sector in the Colombo Divisional Secretariate, Sri Lanka.

Recommendations

According to the findings, the current economic crisis in Sri Lanka highlights the vital need for an independent central bank free of political interference. Tax reforms are crucial for revenue-based fiscal consolidation because they might prevent the Treasury from generating income and forcing it to prioritize fiscal consolidation. Instead of just hiking taxes, the Sri Lankan government should increase its tax base and build an effective revenue collection structure (Rafi, 2024).

Eikelenboom and Jong (2019) emphasize the importance of SMEs engaging in constant learning, change, improvement, and development to adapt to the continuously changing environment. Dynamic capabilities enable businesses to gain adaptive flexibility and make ongoing adjustments.

Hesary and Yoshino (2016) indicated several recommendations for tackling SME development challenges during the economic downturn, describing three primary methods for easing SME financing by developing (1) a credit guarantee scheme by the government, (2) private banks for SME financing (3) hometown investment trust funds for financing to risky SMEs and startup businesses.

Figure 3: explains Japan's credit guarantee scheme

Source: Japan Federation of Credit Guarantee Corporations (2014)

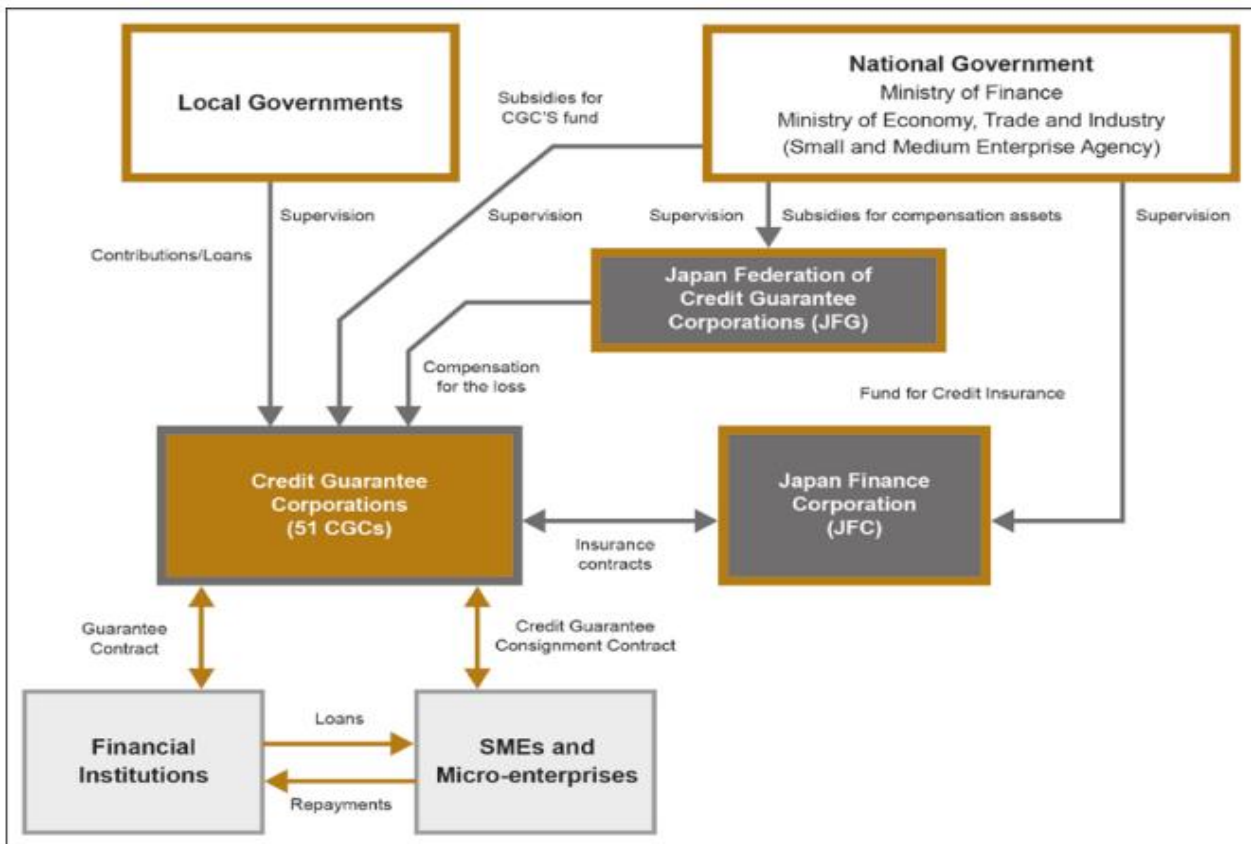
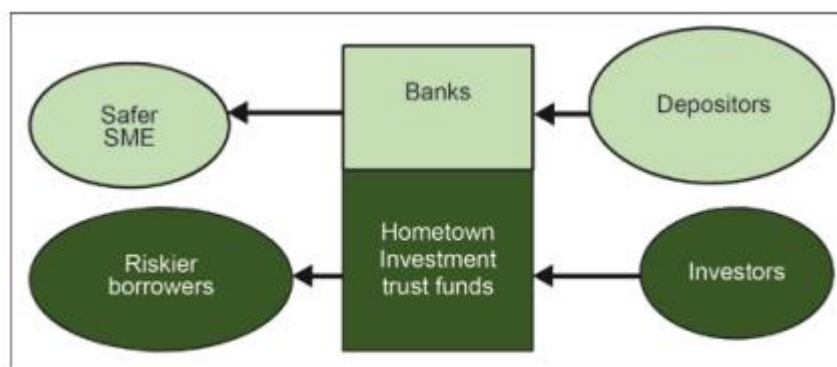


Figure 4: Bank-based SMEs Financing and Hometown Investment Financing to Riskier Borrowers



SME = small and medium-sized enterprise.

Source: Yoshino and Taghizadeh-Hesary (2015a).

Source: Yoshino and Taghizadeh-Hesary (2015)

References

- Amaradiwakara, A.U and Gunathilaka, M.M, 2016. *Factors affecting the growth of small and medium enterprises in Sri Lanka*. Journal of Business of Economic.
- Anuruddha, S., 2024. *List of Registered SME service sector*. Divisional Secretariate office, Colombo.
- Asgary, A., Ozdemir, A.I. and Özyürek, H., 2020. *Small and medium enterprises and global risks: evidence from manufacturing SMEs in Turkey*. International Journal of Disaster Risk Science, 11, pp.59-73.
- Azim, M.D., Ahmed. H. and Khan., 2015. *ATMS Operational performance and profitability*. Research Gate.
- Central Bank of Sri Lanka, 2023. *Economic and Social Infrastructure*. Central Bank of Sri Lanka
- Eikelenboom, M. and de Jong, G., 2019. *The impact of dynamic capabilities on the sustainability performance of SMEs*. Journal of Cleaner Production, 235, pp.1360-1370
- Gamage, N.S.K., Ekanayake, E.M.S., Abeyrathne, G.A.K.N.J., Prasanna, R.P.I.R., Jayasundara, J.M.S.B. and Rajapakshe, P.S.K., 2020. *A review of global challenges and survival strategies of small and medium enterprises (SMEs)*. Economies, 8(4), p.79.
- Global Compact Network Sri Lanka, 2021. *SMEs- A Boon to the Sri Lankan Economy*.
- Hesary, T.F and Yoshino, N., 2016. *Major Challenges Facing SMEs in Asia*. Asian Development Bank.
- International Labor Organization, 2023. *Impact of Multiple Crisis on Sri Lanka's Micro, Small, and Medium-sized Enterprises*. International Labor Organization
- Jayawardena, P., 2020. *COVID-19 and Sri Lanka's Labor Market Gaps: Permanent Protection for Temporary Employees*. Institute of Policy Studies Sri Lanka.
- Lani Mausudeen, G.S. and Abdul Rauf, A.L., 2022. *Factors influence on growth of small and medium enterprises (SMEs) in Sri Lanka*. Faculty of Arts and Culture Southeastern University of Sri Lanka, University Park, Oluvil.
- Mukherjee, M., Abhinay, K., Rahman, M.M., Yangdhen, S., Sen, S., Adhikari, B.R., Nianthi, R., Sachdev, S. and Shaw, R., 2023. *Extent and evaluation of critical infrastructure, the status of resilience and its future dimensions in South Asia*. Progress in Disaster Science, 17, p.100275.
- OJIBA, C.V. and OLOTU, O., 2024. *Assessment of Basic Infrastructural Development and Survival of Small and Medium Enterprises in North-Central, Nigeria*.
- Rafi, T., 2024. *How Sri Lanka can Overcome Its Economic Crisis*. The Diplomat.
- Raiser, M., 2023. *Sri Lanka's Crisis offers an opportunity to reset its Development Model*. World Bank.

Rohanachandra, Y.M., 2022. *Economic recession: The effects on children and adolescents*. Sri Lanka Journal of Child Health, 51(3).

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), pp.79-99.

Weaven, S., Quach, S., Thaichon, P., Frazer, L., Billot, K. and Grace, D., 2021. *Surviving an economic downturn: Dynamic capabilities of SMEs*. Journal of Business Research, 128, pp.109-123.

Webster, J., 2023. *Inflation Affects More Than Small Businesses*. Forbes.

Wickramasinghe, SI, 2011. *The status of SMEs in Sri Lanka and promotion of their innovation output*. Tech Monitor, 3(1), pp.11-19.

World Economic Forum, 2024. *The Global Risks Report 2024 19th Edition*. World Economic Forum.

RETENTION OF TACIT KNOWLEDGE AMID RAPID EMPLOYEE EXODUS: IMPLICATIONS OF HUMAN CAPITAL ATTRITION IN SRI LANKA'S BANKING SECTOR

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Abstract

Organizational knowledge is in two forms as Explicit and Implicit. The explicit knowledge contains the codified knowledge which is articulated, documented and transferred. The implicit knowledge, popularly known as the Tacit Knowledge among the scholars, is the personal experiences, intuition and expertise accumulated within the employees.

This qualitative study identifies the importance of tacit knowledge in the Sri Lankan Banking Sector, its being lost and implications. The study also aims to explore the factors affecting tacit knowledge loss, the impact to the customer relationship and operational efficiency of the industry. Firstly, it traces the vast literature on organizational knowledge and tacit knowledge and identifies the salient themes of the subject area. Secondly, the study focuses on primary research of the industry. Human Resource Professionals and senior operational officers of the banking fraternity become the population. Accordingly, seven participants representing above fraternity were selected as the sample. The primary data gathering involved seven interviews being conducted among the sample participants. A thematic analytical model including themes and codes such as dynamics of employee turnover, knowledge documentation, formal knowledge transfer process etc, was used in analyzing the data gathered through semi structured interviews.

Finally, a comprehensive home-grown model in the light of established theories has been developed for the effective tacit knowledge management in the industry.

Keywords: Employee Exodus, Employee Turnover, Organizational Knowledge, Tacit Knowledge, Explicit Knowledge, Economic Recession.

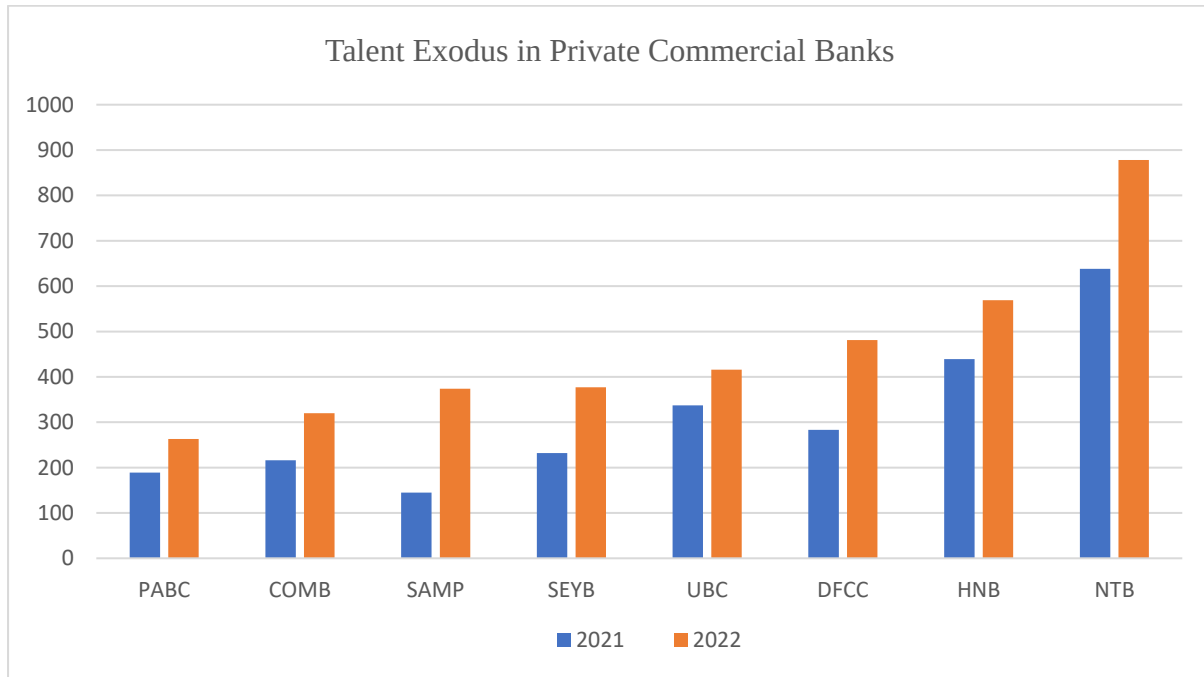
Introduction

The negative macroeconomic sentiments and social realities of the country have led skilled personnel including academics, professionals to seek migration and foreign employment. This has been aggravated to a severe human capital crisis during last two- year period. Many scholars in human resource and personnel management fields perceive this as a major phenomenon of knowledge loss (Samath, F 2023).

The banking industry in Sri Lanka has been experiencing a catastrophic loss of human capital. There are 24 commercial banks with licenses in the nation. According to research by Capital Alliance Ltd. (CAL), there were approximately 3,000 resignations from eight listed banks in 2022—a 67.8% rise from 2021 (CAL research, 2023). Furthermore, statistics from the Central

Bank of Sri Lanka (CBSL) indicates that 10,000 banking staff members looked for foreign employment in 2023. The industry's attrition rate increased from 4% to 10%, forcing banks to hire new employees quickly (CBSL, 2023).

Figure 01 : Talent exodus in Private Commercial Banks – Sri Lanka



Source : Publication by Capital Alliance Holding (CAL Report, 2023)

The alarming factor caused by the massive turnover among the experienced employee category is that the banking industry is losing tacit knowledge in a rapid pace. The most noteworthy fact is that the banking industry loses tacit knowledge during an era where the industry needs high level of acumen and skills within the employees (CBSL,2022).

The main objective of the study is to identify the factors influencing tacit knowledge loss and its implications in the banking sector of Sri Lanka. Identification of tacit knowledge retention strategy is also ancillary to the main objective. Finally, the study aims to develop a model for the Sri Lankan Banks for the management of tacit knowledge during this crisis situation.

Methodology

In order to better understand the causes impacting tacit knowledge loss in the Sri Lankan banking industry, particularly during times of high employee turnover, this research uses an inductive qualitative approach. This study, which takes a constructivist epistemology, recognizes that knowledge is contextually and socially created (Creswell & Poth, 2017).

The study firstly focused on the vast literature on organizational knowledge. It further dissects down the knowledge from human capital theory to the broader classification of institutional knowledge as implicit and explicit knowledge. The study traces the work of Polanyi in recognizing the tacit knowledge in the domain of organizational knowledge. The work of Nonaka and Takeuchi in the area of tacit knowledge conversion and SECI Model (Socialization, Externalization, Combination and Internalization) is vastly investigated to realize the importance of tacit knowledge in the modern institution

The human resource professionals and senior operational level officers in the banking fraternity were identified as the population. The sample selection methodology involves convenient, purposive and snow ball sampling techniques. Seven participants representing above-described participants from the licensed government and private commercial banks and specialized banks were selected.

Qualitative Analysis techniques such as Thematic Analysis methods are the most suitable analytical techniques used for the qualitative and inductive studies (Creswell, J.W. & Poth, C.N. (2018). The data gathered from the interviews were analyzed using thematic analysis method to find reoccurring themes, patterns, and insights on knowledge loss, attrition of human capital, and their effects on organizational dynamics.

Discussion

Key Factors contributing to the Tacit Knowledge Loss in Sri Lankan Banks during Rapid Employee Turnover.

The main cause of tacit knowledge is employee turnover. When the key factors affecting employee turnover are investigated in the light of literature, the study finds, inadequate salary benefits, poor job security, lack of career advancement, lack of motivation and many organizational factors. However, the study also sees. an unprecedented turnover in Sri Lankan Banking Industry mainly due to macroeconomic vulnerabilities such as tax, cost of living, instability, quality of life, migration trend among the employee category who leave.

Organizational Factors which cause Tacit Knowledge Loss

In the area of tacit knowledge, while identifying employee turnover caused by uncontrollable external factors, the participants identify several organizational factors such as deficiencies in knowledge documentation, resistance for knowledge sharing, lack of mentorship, problems in on-boarding for training and weak continuous learning culture.

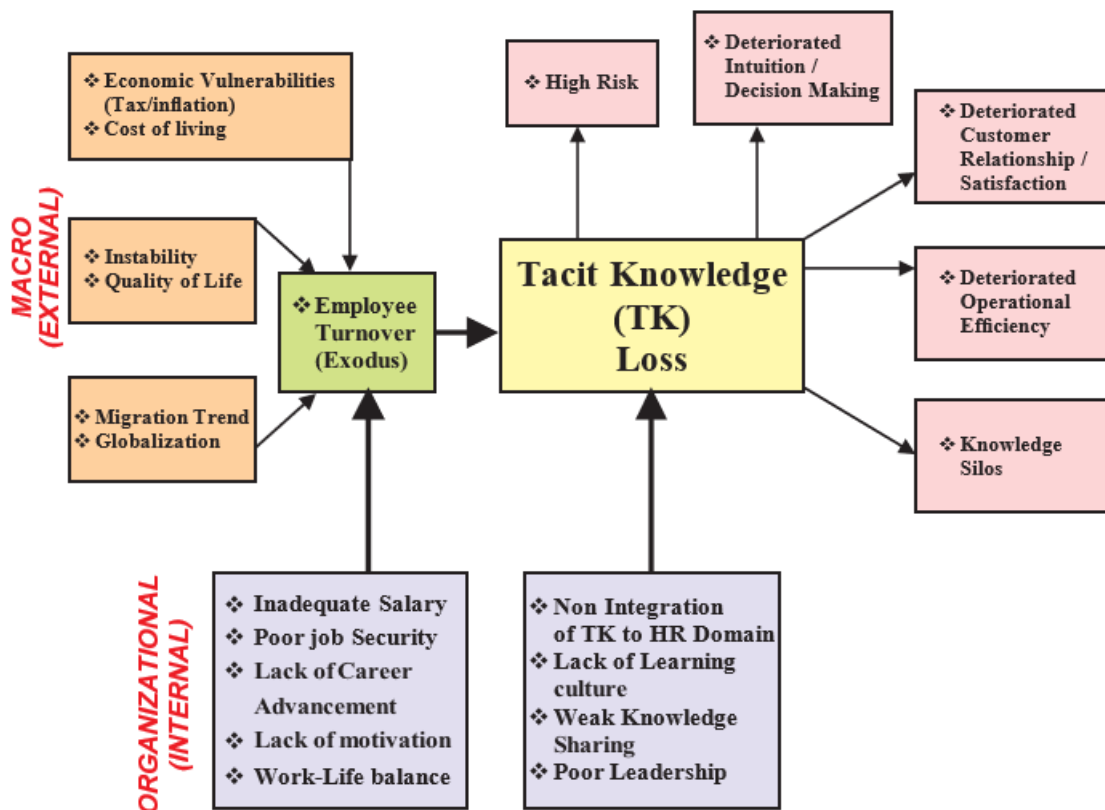
The Influence of Tacit Knowledge in the Banking Sector Efficiency and Performance

All participants agreed on the importance of tacit knowledge in the area of building up strong customer relationships thereby increasing customer satisfaction. Especially, 90% relates the importance of tacit knowledge in handling vast number of restructures and rescheduled loans aftermath of unprecedented economic calamities followed by moratoriums. 20% does not mention its tacit knowledge but emphasizes on accumulated experience which is being lost due to turnover. Under current situation of the economy the banker is supposed not only to offer concessionary finance, but to play a consultant role for the enterprises, especially for the SME's. Even, one participant suggests *“comprehensive research on customer satisfaction level in the banking sector during this crisis situation”*.

Primary data also strongly suggests the effect of tacit knowledge towards operational efficiency. All agree that tacit knowledge is very vital for operational efficiency. 15% highlights the importance of implicit knowledge in managing operational risks in the industry. They also doubt the resilience of the sector during this massive exodus. However, 47% believes that the sector still has capabilities due to improved technology especially in the light of digitalization. But two participants (28%) strongly argue that *“human factor overshadows the technology and tacit knowledge of employees is the key to have operational excellence”*.

Having discussed the primary information gathered in the light of literature and secondary data in answering the research questions, the study presents a conceptual model which describes the factors influencing tacit knowledge loss and its implications to the Sri Lankan Banking Industry. It clearly shows the level of influence of macro (external) factors against organizational (internal) factors which is somewhat contrast to the established literature. But it is a country specific phenomenon.

Figure 02 : Conceptual Model on Factors influencing tacit knowledge loss and implications in the Sri Lankan Banking Industry



Source : Author Developed, 2024.

Contrasting Tacit Knowledge from the general knowledge domain and identification of its importance

Polyani (1996) introduces the differentiation of tacit knowledge from organizational knowledge domain and Spender (1996) and Nonaka & Takeuchi all have further developed the concept. Our further perusal on the literature of organizational knowledge reveals modern corporate sector is actively engaged in tacit knowledge management. However, in contrast to the theory it seems that Sri Lankan Banking sector still does not thoroughly distinguish tacit (implicit) knowledge from explicit knowledge. The study investigates the current position the tacit knowledge has in the knowledge management spectrum of the banking sector. Only 28% of the respondents identify tacit knowledge as a specific area while the rest only perceive all as the organizational knowledge. In fact, only two Heads of Human Resources had clear differentiated perception on tacit knowledge

Investigation on current tacit knowledge retention strategies adopted by Sri Lankan Banks

90% relies on conventional training modules, mentoring and knowledge sharing sessions. 28% (represents operational level officers) mentions that even they continuously losing mentors due to resignations. Importantly, 60% uses knowledge repositories. This seems a good

development as scholars still identifies documentation and codification of tacit knowledge of employees and making repositories is crucial in retention of tacit knowledge. But it is evident that specialized banking sector does not possess well-tailored mechanisms for tacit knowledge retention. All endorsed that *“social media platforms such as WhatsApp, Facebook together with enterprise social networking tools such as Yammer (Viva Engage) are being used for tacit knowledge transfer and retention”*.

Position of Tacit Knowledge Strategies in the conventional training

All respondents agree that tacit knowledge aspect should be one of the priority areas of the training modules. However, when deeply inquired of the modules and tools in the current training programs it was revealed that basic tacit knowledge transfer techniques such as mentoring, knowledge sharing and cross departmental training are considered by them as tacit knowledge aspect. The conventional methods have also been discussed in the literature (Brown and Duguid, 1998; Grant, 1996). Only 40% uses comparatively new methods such as storytelling and case study analysis.

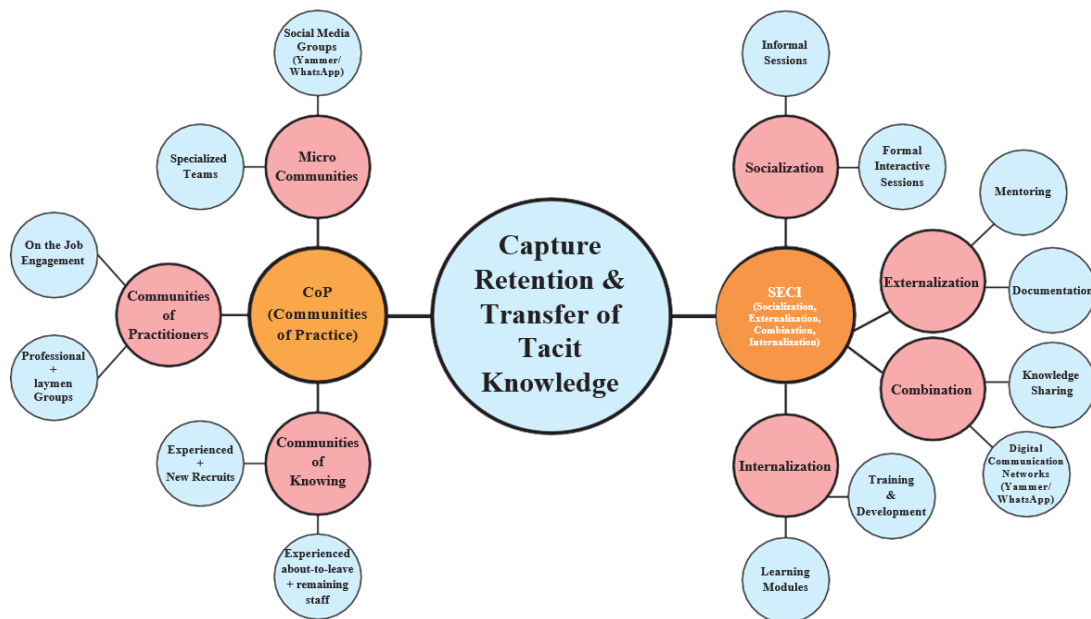
Building up a Context Specific Strategic Conceptual Model for the capture, retention and transfer of Tacit Knowledge in the Sri Lankan Banking Sector

Sri Lankan Banking industry experiences a massive drain of human capital while experiencing an economic recession. In this backdrop it is essential that training modules should be having deep tacit knowledge management theories such as SECI model (Nonaka & Takeuchi 1995), CoP (Lave & Wenger 2004), Tacit Knowledge Diffusion (Droege, S.B & Hoobler, J.M (2003) and Enterprise Ontology Model (Rao, S.S.& Nayak, A, 2017).

Participant feedback reveals that above discussed models and theories are yet to be integrated into the training modules of the banking industry. Only 28% slightly uses tacit knowledge externalization (one aspect of SECI model of Nonaka & Takeuchi), CoP (such as Yammer & WhatsApp groups) and Tacit Knowledge diffusion in terms of knowledge sharing and case study discussion.

Having identified the typical characteristics of the exodus and lacuna in the tacit knowledge management landscape the study proposes a context specific strategic conceptual model to capture, retain and transfer tacit knowledge in the Sri Lankan Banking Sector. It is a combination of SECI and CoP models.

Figure 03 : Conceptual Model for Capture Retain and Transfer Tacit Knowledge in the Sri Lankan Banking Sector.



Source : An hybrid model of SECI & COP Models .

Proposed conceptual model is a hybrid of SECI Model (Nonaka and Takeuchi 1995) and CoP Model (Lave and Wenger, 1991) which would incorporate a strategic approach for the tacit knowledge management of the industry.

Conclusion

In the light of the analysis of literature, secondary and primary data of the study on tacit knowledge loss of the Sri Lankan Banking Industry during a massive exodus of employees, the study makes following conclusions to the Human Resource Domain of the banking industry.

Banking Sector Human Resource domain should distinguish Tacit Knowledge from the Explicit Knowledge of the banking industry. List of tacit knowledge operate in the different aspects of banking should be documented. The implicit and tacit knowledge and skills required for customer relationship management should be mapped.

In identifying the influencing factors of employee turnover and tacit knowledge loss, the study suggests the application of conceptual model developed by the study. Separate training module should be developed to identify, externalize, elicit, transfer and retain tacit knowledge in the banking.

Currently practiced tacit knowledge retention and transfer techniques such as Knowledge sharing, story-telling, case study and social media grouping should be integrated with theoretical models developed in the tacit knowledge management arena such as, SECI (Socialization , Externalization , Combination & Internalization), CoP (Communities of

Practitioners), Enterprise Ontology Model and Tacit Knowledge Diffusion. In this regard the study recommends hybrid conceptual model developed by this study to be integrated in the knowledge management domain of the human resource arena of the banking industry.

References

- Abdul Basit, Tehmina Fiaz Qazi and Abdul Aziz Khan Niazi (2020) ‘Expounding dynamics of tacit knowledge critical to credit decision making: Juxtaposed findings of GRA and Redit’, *Journal of Accounting and Finance in Emerging Economies*, 6(1), pp. 87–106. doi:10.26710/jafee.v6i1.1044.
- Brown, J. S., & Duguid, P. (1991). Organizational Learning and Communities-of-Practice: Toward a Unified View of Working, Learning, and Innovation. *Organization Science*, [online] 2(1), 40–57. <http://www.jstor.org/stable/2634938> [Accessed 17 Mar. 2024].
- Central Bank of Sri Lanka (2022). *Annual Report 2022 | Central Bank of Sri Lanka*. [online] www.cbsl.gov.lk. Available at: <https://www.cbsl.gov.lk/en/publications/economic-and-financial-reports/annual-reports/annual-report-2022> [Accessed 17 Mar. 2024].
- Creswell, J.W. & Poth, C.N. (2018) *Qualitative Inquiry and Research Design: Choosing Among Five Approaches*. 4th edn. Thousand Oaks, CA: SAGE Publications.
- Davenport, T.H. & Prusak, L., 1998. *Working Knowledge: How Organizations Manage What They Know*. Boston: Harvard Business School Press.
- Droege, S.B. & Hoobler, J.M. (2003). Employee turnover and tacit knowledge diffusion: A network perspective: JMI, *Journal of Managerial Issues*, 15(1), pp.50-64.
- Johannessen, J.-A. (2022) ‘How is tacit knowledge developed?’, *The Philosophy of Tacit Knowledge*, pp. 29–61. doi:10.1108/978-1-80382-677-620221007.
- Kuruppu, K.A. and Egodawele, M.H. (2021) ‘The relationship between knowledge management processes and workforce agility in the Sri Lankan banking sector’, *Wayamba Journal of Management*, 12(2), p. 400. doi:10.4038/wjm.v12i2.7546.
- Muñoz, C.A., Mosey, S. & Binks, M., 2015. The Tacit Mystery: Reconciling Different Approaches to Tacit Knowledge. *Knowledge Management Research & Practice*, 13, pp.289-298. Available at: <https://doi.org/10.1057/kmrp.2013.50> [Accessed : 22 September 2024].
- Nonaka, I. and Takeuchi, H. (1995). *The knowledge-creating company: How Japanese companies create the dynamics of innovation*. New York: Oxford University Press.
- Polanyi, M. (1966). *The Tacit Dimension*. Garden City, New York: Anchor.
- Rathnayake H.D. and Herath D. (2024a) ‘From norms to networks: Investigating the synergy between organizational culture and socialization in implementing knowledge management practices in Sri Lanka’s domestic systematically important banks’, *Sri Lankan Journal of Business Economics*, 13(1). doi:10.31357/sljbe.v13.7510.

Samath, F. (2023). *With an economy in crisis, Sri Lankans migrate out for jobs*. [online] <https://news-decoder.com/>. Available at: <https://news-decoder.com/with-an-economy-in-crisis-sri-lankans-migrate-out-for-jobs/> [Accessed 17 Mar. 2024].

Spender, J.-C. . (1996). Making knowledge the basis of a dynamic theory of the firm. *Strategic Management Journal*, 17(S2), pp.45–62. doi:<https://doi.org/10.1002/smj.4250171106> [Accessed 17 Mar. 2024].

Wenger, E. (1998). *Communities of Practice: Learning, Meaning, and Identity*. Cambridge: Cambridge University Press.

FACTORS AFFECTING TO FINANCIAL LITERACY AND STOCK MARKET PARTICIPATION (WITH SPECIAL REFERENCE TO GAMPAHA DISTRICT)

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Abstract

Well-functioning stock markets significantly impact economic development, with sound knowledge being crucial in the rapidly increasing complexity of financial products. The main objective of this study was to determine the factors affecting to financial literacy and stock market participation. The study used age category, gender difference, educational level and occupation as the independent variables and financial literacy and stock market participation as the dependent variables. The research philosophy, approach and method were positivism, deductive and quantitative respectively. The study involved 107 individuals from Gampaha District, selected using purposive sampling technique. The data was gathered through an online questionnaire and analyzed using SPSS, including frequency, descriptive statistics, correlation, and regression analysis. The study found that, age and occupation significantly influence to the independent variable, while gender differences and education levels were found to be insignificant. The study suggests that, CSE should enhance market participation by offering education and training to increase awareness on stock issues.

Keywords: Financial literacy, Stock issue, Stock market

Introduction

Background of the Study and Research Problem

While market liberalization and structural reforms in Social Security and pensions have caused a continuous shift in decision power away from the government and employers toward private individuals, people have become more involved in the financial markets, and the introduction of new financial products and services has accompanied or even encouraged market participation. However, some of these products are complicated and hard to understand, especially for investors who lack financial expertise (Rooij et al., 2007). There hasn't been much research on this subject, but what little that has been done shows that financial illiteracy is pervasive and that people don't understand even the most fundamental economic concepts. Are people well-equipped to make financial decisions? Do they have adequate financial literacy and knowledge? (Lusardi and Mitchell, 2007). However, there are concerns that households are not utilizing financial innovation, are taking on excessive debt, and are not saving enough for retirement. According to current research, those who lack financial literacy are also less likely to save for retirement, build wealth, and take out high-interest mortgages (Lusardi and Mitchell, 2007).

Since 2003, the Organization for Economic Co-operation and Development has been working on an inter-governmental project to enhance financial literacy, focusing on developing

common principles to improve financial education and literacy standards globally (World Bank, 2012). Financial literacy skills are crucial for effective financial decision-making. 66% of Americans are financially illiterate, lacking basic knowledge of bank accounts, bills, debt, and future planning. Understanding concepts like fixed and variable interest rates, interest compounding, and transaction fees can help make informed decisions. Research shows that those without these skills spend more on transaction fees and higher interest rates (Almenberg and Drebe, 2015).

Experience showed no significant direct impact on investors' intentions; however, it had a significant indirect relationship mediated by the attitude of investors (De Silva and Somathilaka, 2022). Less experienced investors may be less invested in stock markets due to fear of losing money and lack of accurate information. Individual investment decisions are influenced by advocate suggestions and impartial information, leading brokerage firms to provide accurate information to clients.(Indirani, 2021).

Determining whether or not to engage in the stock market depends heavily on an individual's attitude toward financial choices. Perceived behavioral control, subjective norms, and investors' attitudes regarding investing all have a beneficial impact on their behavioral intents to trade stocks (Akhter and Hoque , 2022). The main challenges of the stock markets globally are first, to provide a responsive securities market which mobilizes savings and channels them into productive sectors, secondly to encourage saving cultures that contributes to the country's economic growth, and thirdly to facilitate wider access to resources (Jariwala, 2015).

The individual's participation in the market is of paramount importance the majority of the population does not participate in the stock market as is the case in other parts of the world. The question is therefore, why is it so? This calls for the need to examine the determinants of stock market participation by individuals. The current study intends to cover this gap. The Colombo Stock Exchange is the main stock exchange in Sri Lanka. It has 284 companies representing 20 business sectors as at 30th October 2024, with a market capitalization of Rs. 4,677.87 Bn. (Colombo Stock Exchange, 2024). But still there is a lack of individuals' participation in stock market activities. (De Silva and Somathilaka, 2022).

Therefore, this research study focus to find out what are the factors affecting to financial literacy and stock market participation in Sri Lanka, with special reference to Gampaha District?

Main Research Objective

To find out the factors affecting to financial literacy and stock market participation.

Specific Research Objectives

1. To identify the effect of age category on financial literacy and stock market participation.
2. To find the effect of gender difference on financial literacy and stock market participation.
3. To show the effect of educational level on financial literacy and stock market participation.

4. To illustrate the effect of occupation on financial literacy and stock market participation.

Significance of the Study

Financial literacy is crucial for a country's economic growth, as it helps individuals become self-sufficient and achieve financial stability. It affects all demographics and socio-economic levels, enabling people to manage their own financial decisions. Lack of financial literacy can lead to debt and poor decisions. The study suggests that improving financial literacy can lead to better decision-making, improved stock market participation, and healthier household welfare. Improving financial literacy among households can lead to smoother personal financing and increase the country's overall financial literacy.

Methodology

To identify the factors affecting to financial literacy and stock market participation, the positivism philosophy, deductive approach, quantitative method and cross-sectional time horizon were utilized. For this research study, primary data was obtained from respondents through an online questionnaire, and the gathered data were analyzed using the SPSS. The dependent variables, financial literacy and stock market participation have been identified in previous literature and the independent variables include age category, gender difference, educational level and occupation. The Summary of the variable links can be established and it depicts the support of the variables for the study. The following conceptual framework can be developed based on the identified independent and dependent variables. The Summary of the variable links can be established and it depicts the support of the variables for the study. The following conceptual framework can be developed based on the identified independent and dependent variables.

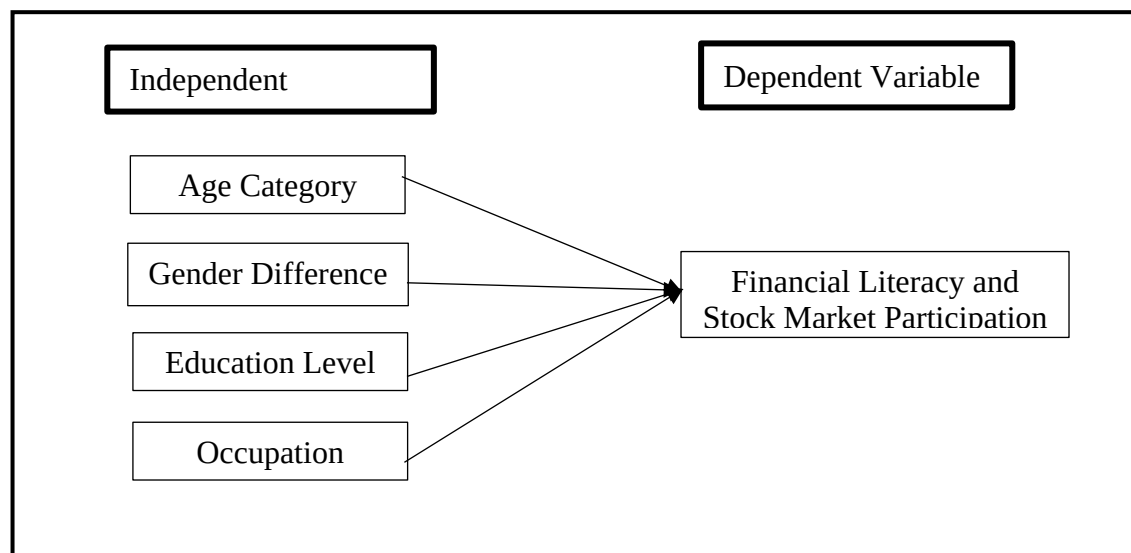


Figure 1: Conceptual Framework

Source: Researcher Constructed (2024)

The following hypotheses can be constructed for testing purposes based on the conceptual framework.

H1: Age category could have a significant effect on financial literacy and stock market participation.

H2: Gender difference could have a significant effect on financial literacy and stock market participation.

H3: Educational level would have a significant effect on financial literacy and stock market participation.

H4: Occupation will have a significant effect on financial literacy and stock market participation.

The population of the study was people living in Gampaha District. The researcher has selected Gampaha district due to several reasons. As per the Department of Census and Statistics (2012), Gampaha is the second largest population city in Sri Lanka approximately 2.2 million and as a percentage it is 11.32%. Furthermore, Gampaha has the highest literate people across the country (Department of Census and Statistics, 2012). The researcher has been selected the sample size as 107 individuals from Gampaha District, based on purposive sampling technique. An online questionnaire with five point Likert scale method was used to gather primary data and the secondary data was gathered from the results of earlier studies that were looked into in reference to this research study.

Results

Following the data analysis, 52% of the respondents were males, and 48% were females. This implies that, males responded much more to the questionnaires than females. The largest response lied on people aged in a group of 20 to 25 years and the smallest responded group lied in the group aged above 40 years. Out of 107 respondents received, 38% had degree or higher educational qualification, diploma holders were 22%, advanced level qualification were obtained by 32% of respondents and rest represent ordinary level qualification, that is 8%. Majority of the respondents represents financial field that is 46.7%.

Table 1: Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Gender Difference	107	1.00	5.00	2.7290	.77484
Education Level	107	3.33	5.00	4.3769	.43937
Age Category	107	3.00	5.00	4.4206	.46149
Occupation	107	2.67	5.00	4.1682	.54441
Financial Literacy & Stock Market Participation	107	2.73	5.00	3.8513	.46412
Valid N (list wise)	107				

Source: SPSS Data (2024)

Minimum and maximum value of the data set shows the lowest (Min) and the highest (Max) value in the data set. Minimum value of the gender variation is 1 and maximum range is 5. Education level distribute to 3.33(minimum) - 5 (maximum), with the mean value of data set 4.3769. For the Age and occupation category. The last independent variable is respondents' occupation. Education level minimum value started from 3.33 and it end up with the 5. The recorded mean value of the data set is 4.3769. By analyzing respondents' answers relating to the occupation related financial literacy questions found that 2.67 minimum value, 5 maximum value and mean value of the data set is 4.1682. The standard deviation is a statistic that measures the dispersion of a dataset relative to its mean. The given data set highest standard deviation is 0.77484 which is gender variation. And the lowest standard deviation is 0.43937 which is for educational level variation.

Table 2: Summary of Correlation Analysis

Independent Variable	R value	P value	Relationship with Dependent Variable
Gender Difference	0.026	0.787	Weakly Positive Correlation
Education Level	-0.088	0.365	Weakly Negative Correlation
Age Category	0.449	0.000	Moderately Positive Correlation
Occupation	-0.078	0.426	Weakly Negative Correlation

Source: SPSS Data (2024)

The study reveals a weak positive correlation between gender, educational level, age category, and occupation category in relation to financial literacy and stock market participation. Gender and age category have a significant level of 0.787, while educational level and occupation have a weak negative correlation of -0.088 and -0.449 respectively. Age category and occupation category have a weak positive correlation of -0.078, indicating no significant relationship between these variables. The study concludes that, gender and age category positively correlate with financial literacy and stock market participation. The study reveals a weakly positive correlation between gender, education level, occupation, and financial literacy and stock market participation. However, the gender difference is not statistically significant. Education level has a weak negative correlation, while occupation has a moderate positive correlation. Age also has a significant effect, with a p value lower than the 0.01 level.

Table 3: Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.510 ^a	.260	.231	.40692

Source: SPSS Data (2024)

Table 4: ANOVA

Model	Sum of Squares	Df	Mean Square	F	Sig.
1 Regression	5.943	4	1.486	8.973	.000 ^b
Residual	16.890	102	.166		
Total	22.833	106			

a. Dependent Variable: Financial Literacy & Stock Market Participation

b. Predictors: (Constant), Occupation, Education Level, Gender Difference, Age Category

Source: SPSS Data (2024)

The value of R^2 of the above model summary of regression analysis table shows the degree to which extend the variances of the dependent variable is explained by the independent variable. Results of this analysis shows that 26% (R^2) of financial literacy and stock market participation is explained by the selected independent (Gender difference, Age category, Education level and occupation). The rest of the 74% of the Financial literacy and stock market participation is depend on the other factors such as family background, Social influence and those factors are not covered by the current study. bAfter analyzing the data set using ANOVA test when the significant value is less than 0.05. It considers that the fitness of the model is good. In the above table ANOVA test significant value is 0.000 and it shows the model fit of the regression model.

Table 5: Coefficients

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
1 (Constant)	1.943	.634		3.067	.003
Gender Difference	.018	.052	.030	.345	.731
Education Level	.085	.096	.080	.886	.377
Age Category	.551	.095	.548	5.824	.000
Occupation	-.227	.080	-.267	-2.830	.006

a. Dependent Variable: Financial Literacy & Stock Market Participation

b. Predictors: (Constant), Occupation, Education Level, Gender Difference, Age Category

Source: SPSS Data (2024)

According to the table 5, following model can be derived for factors affecting Financial Literacy and Stock Market Participation (FLSMP).

$$\text{FLSMP} = 1.943 + 0.018 (\text{Gender Difference}) + 0.085 (\text{Education level}) + 0.551 (\text{Age Category}) - 0.227 (\text{Occupation}) + \mu$$

The significance values for the dimensions of gender difference, education level, age category and occupation were 0.731, 0.377, 0.000 and 0.006 respectively. Variables of age category and occupation were considered statistically significant variables that effect on financial literacy and stock market participation since the ‘P’ values of these two variables were less than 5% of significance. Therefore, H1 and H4 can be accepted. This has been proved by De Silva & Somathilaka (2022). Gender difference and education level were considered statistically insignificant variables on customer satisfaction since the ‘P’ value of these variables were 0.731 and 0.377, respectively, and higher than the level of 5% significance. Therefore, H2 and H3 can be rejected. This has been proved by De Silva & Somathilaka (2022).

Discussion

The study aimed to identify the factors influencing financial literacy and stock market participation among individuals in the Gampaha District. The results indicate that age and occupation significantly affect financial literacy and stock market participation, while gender and education level do not show a statistically significant impact.

The findings reveal a moderate positive correlation between age and financial literacy/stock market participation ($r = 0.449$, $p < 0.01$). This suggests that as individuals grow older, they tend to develop better financial literacy and exhibit higher participation in stock market activities. These results align with previous research by De Silva & Somathilaka (2022), which highlights the role of experience and accumulated financial knowledge in shaping investment behavior. This could be due to increased exposure to financial decisions over time, higher disposable income, and a greater focus on long-term wealth accumulation. Similarly, occupation was found to have a significant effect on financial literacy and stock market participation ($\beta = -0.227$, $p = 0.006$). However, the negative coefficient indicates that individuals in certain occupations may be less likely to engage in stock market investments. A possible explanation is that individuals engaged in non-financial professions might lack the necessary exposure or interest in financial markets. This aligns with findings from Indirani (2021), which suggest that financial education in workplaces significantly influences investment decisions.

Contrary to expectations, gender was not a significant determinant of financial literacy or stock market participation ($\beta = 0.018$, $p = 0.731$). This result suggests that both males and females have similar levels of financial knowledge and participation when other factors such as occupation and age are considered. While previous studies (Almenberg & Dreber, 2015) indicate that gender gaps exist in financial literacy, this study suggests that such differences may not be prominent in the Gampaha District, possibly due to equal access to financial education and employment opportunities. Similarly, education level did not have a statistically significant impact on financial literacy and stock market participation ($\beta = 0.085$, $p = 0.377$). This contradicts conventional wisdom, which suggests that higher educational attainment should lead to better financial knowledge and investment behavior. However, this may indicate that formal

education does not always translate into practical financial skills, emphasizing the need for targeted financial education programs beyond traditional academic settings.

The regression model explains 26% of the variance in financial literacy and stock market participation ($R^2 = 0.260$), implying that 74% of the variation is influenced by other factors not covered in this study. These could include financial socialization, risk tolerance, income levels, or access to financial advisory services, as suggested in prior research (Lusardi & Mitchell, 2007). The ANOVA test ($p < 0.001$) confirms the overall model's significance, reinforcing the validity of the identified relationships.

Conclusion and Recommendation

This study examined the determinants of financial literacy and stock market participation among individuals in the Gampaha District, Sri Lanka. Findings indicate that age and occupation significantly influence stock market participation, while gender and education level do not have a statistically significant impact. The results were supported by Pearson correlation, ANOVA, and coefficient correlation tests, with strong significance values of 0.000 for age and 0.006 for occupation.

Despite the growing emphasis on financial literacy, awareness and participation in the stock market remain low due to limited access to financial education, inadequate exposure to market mechanisms, and a lack of engagement from financial institutions. To address these challenges, the Colombo Stock Exchange (CSE) and regulatory bodies should implement targeted financial literacy programs across social, economic, political, and academic sectors, organize seminars and training to educate both shareholders and non-shareholders, and enhance market transparency by encouraging brokers to provide online financial data while listed companies publish financial statements digitally. Additionally, decentralizing exchange functions through regional offices can make stock transactions more accessible, and revising investment incentives can encourage greater participation from both individual investors and companies. These measures can significantly improve financial literacy levels and strengthen stock market participation, ultimately fostering a more inclusive and robust investment landscape in Sri Lanka.

References

- Akhter, T. and Hoque, M.E., 2022. Moderating effects of financial cognitive abilities and considerations on the attitude–intentions nexus of stock market participation. *International Journal of Financial Studies*, 10(1), p.5.
- Almenberg, J. and Dreber, A., 2015. Gender, stock market participation and financial literacy. *Economics Letters*, 137, pp.140-142.
- Colombo Stock Exchange: <https://www.cse.lk/pages/market-capitalization/market-capitalization.html>

De Silva, K. and Somathilaka, H., 2022. FACTORS AFFECTING STOCK MARKET PARTICIPATION OF INDIVIDUAL INVESTORS IN SRI LANKA. *International Research Symposium on Management*, pp. 27-32.

Indirani, S., 2021. Digitalization of stock markets. Retrieved from.

Jariwala, H.V., 2015. Analysis of financial literacy level of retail individual investors of Gujarat State and its effect on investment decision. *Journal of Business & Finance Librarianship*, 20(1-2), pp.133-158.

Jonsson, S., Söderberg, I.L. and Wilhelmsson, M., 2017. An investigation of the impact of financial literacy, risk attitude, and saving motives on the attenuation of mutual fund investors' disposition bias. *Managerial Finance*, 43(3), pp.282-298.

Lusardi, A. and Mitchell, O.S., 2007. Baby boomer retirement security: The roles of planning, financial literacy, and housing wealth. *Journal of monetary Economics*, 54(1), pp.205-224.

World Bank., 2012

Zhu, M. and Chawanote, C., 2022. The impact of financial literacy on family wealth. *Thammasat Review of Economic and Social Policy*, 8(1), pp.4-48.

**FACTORS AFFECTING THE ONLINE PURCHASING INTENTION OF MOBILE
PHONE ACCESSORIES AMONG MILLENNIALS IN KANDY MUNICIPAL
COUNCIL AREA**

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Abstract

Online shopping has become increasingly popular, with a growing market for mobile phone accessories. However, this growth has slowed recently. This research investigates the factors influencing millennials in the Kandy Municipal Council area to shop online for mobile phone accessories, focusing on the Technology Acceptance Model (TAM). Using a quantitative design, data was collected from 120 millennials through a five-point Likert scale questionnaire assessing perceived usefulness, perceived ease of use, website content, and trust. Analysis used SPSS 26 included descriptive statistics, correlation, and multiple regression analyses.

The findings highlight the significant roles of perceived usefulness and perceived ease of use in driving online shopping intentions. Trust showed a marginal impact, while website content had minimal influence. These insights guide businesses and e-retailers in aligning strategies with millennial preferences, enhancing customer engagement, and boosting online sales of mobile phone accessories.

Keywords: Online Shopping, Perceive Ease of Use, Perceive Usefulness, Trust, Website Content

Introduction

In the modern era, integrating technology into daily life has become essential, especially for effective time management. Especially through online platforms that offer convenience and time-saving benefits (Athapaththu & Kulathunga, 2018). Globally, internet penetration has surged, with Sri Lanka reflecting this trend by recording 10.20 million internet users in 2022, a 4.9% increase from the previous year (Kemp, 2023). Among the many online activities, shopping has become a major focus, reshaping traditional consumer behavior (Shanthi & Kannaiah, 2015). Millennials, a digitally savvy generation born between the early 1980s and late 1990s, are key drivers of this change, particularly in the online market for mobile phone accessories (Dimock, 2019)

The Kandy Municipal Council area, with its significant millennial population, provides a unique opportunity to explore this demographic's online purchasing intentions. Despite the global growth of the mobile accessories market, online sales remain overshadowed by offline channels (GrandViewResearch, 2023). This study seeks to identify factors influencing millennials' online purchasing behavior in Kandy, addressing a research gap and providing insights for businesses to better align with consumer preferences.

In such a context, this study will address the following research questions

- i. Does perceived usefulness impact online purchasing intention for mobile phone

- accessories?
- ii. Does perceived ease of use influence online purchasing intention for mobile phone accessories?
 - iii. Does website content affect online purchasing intention for mobile phone accessories?
 - iv. Does trust play a role in online purchasing intention for mobile phone accessories?

The Aim of the Study

The primary aim of this study is to identify and analyze the factors influencing online shopping intentions for mobile phone accessories among millennials in the Kandy Municipal Council area. Specifically, the study seeks to explore how perceived usefulness, ease of use, website content, and trust shape millennials' decisions to purchase mobile phone accessories online. By focusing on these factors, the research aims to provide valuable insights into the preferences and behaviors of this influential demographic, ultimately helping businesses optimize their online strategies to better cater to millennial consumers.

Literature Review

Online shopping, which refers to the process of purchasing goods or services via the internet, has revolutionized traditional retail by eliminating intermediaries and physical barriers like stores and malls (Shanthi & Kannaiah, 2015). The growth of social media platforms like Facebook, Instagram, and LinkedIn has further contributed to the rise of social commerce, a new form of e-commerce (Liang & Turban, E., 2011). Online shopping is recognized under various names such as e-web stores, virtual stores, and online stores, all of which aim to provide consumers with a comprehensive platform for making purchases with reduced costs for both buyers and sellers (Rahimnia & Hassanzadeh, 2013).

While online shopping offers multiple benefits, including convenience and a broader range of choices, it also presents risks that consumers must consider, such as concerns over product quality and merchant trust (Bansal, et al., 2013). Despite the significant advantages, some customers still exhibit reluctance due to factors such as the inability to physically inspect products, leading to hesitation in making online purchases (Yang, et al., 2010).

Online purchasing intention, defined as a consumer's willingness to buy from an online business, is influenced by various factors, including prior experiences, external information, and personal evaluations of the product (Bukhari, et al., 2013). Research into purchase intention helps explain consumer decision-making processes, particularly since direct measurement of actual behavior can be challenging (Peña-García, et al., 2020). With the rise of e-commerce, many offline activities have shifted to online platforms, making the understanding of online purchase intentions increasingly important for businesses seeking to enhance their customer engagement and sales (Athapaththu & Kulathunga, 2018).

Mobile phones are no longer just communication devices; they offer numerous functionalities, including internet browsing, entertainment, and navigation (Ataei & Abdollah, 2023). As mobile devices have evolved, so too has the market for accessories such as power banks, protective cases, chargers, and headphones, which enhance the functionality and aesthetics of these devices. The mobile phone accessories market has been expanding, with both online and

offline distribution channels playing significant roles. E-commerce platforms, in particular, have gained popularity due to their convenience and broader selection of products. Offline retail stores continue to provide opportunities for consumers to physically interact with products before purchase (GrandViewResearch, 2023).

Several theories and models have been developed to understand consumer behavior in the context of online purchasing. The Theory of Reasoned Action (TRA) proposed by Ajzen and Fishbein (1975) asserts that an individual's intention to perform a behavior is a strong predictor of their actual behavior. This theory focuses on the influence of attitudes and subjective norms—social pressures influencing behavior. Expanding on TRA, Ajzen introduced the Theory of Planned Behavior (TPB), which includes perceived behavioral control (PBC), accounting for external factors that may hinder or facilitate an individual's intention to engage in a behavior.

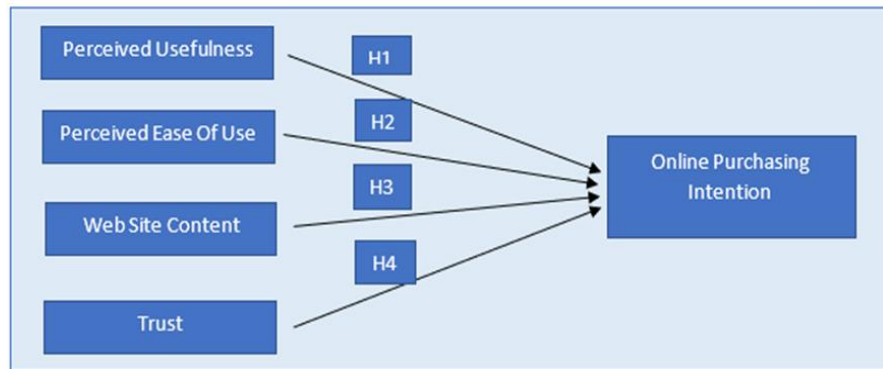
In the context of online shopping, both TRA and TPB provide frameworks for understanding how attitudes, social pressures, and perceived control affect purchasing decisions. The Technology Acceptance Model (TAM), developed by Fred Davis in 1989, is another influential model that focuses on the perceived usefulness (PU) and perceived ease of use (PEOU) of technology in shaping user behavior. TAM has been widely applied to understand online consumer behavior and technology adoption, showing that consumers are more likely to engage in online shopping if they perceive it to be useful and easy to navigate.

Furthermore, the extended TAM model, as studied by Cheema (2018), shows that perceived ease of use (PEOU) plays a crucial role in determining the intention to purchase online. Consumers who find online shopping platforms easy to navigate are more likely to make purchases. Other factors such as website content, customer support, and overall shopping experience also significantly affect purchasing intentions (Athapaththu & Kulathunga, 2018). So Through this literature rivew , the reseacrcher was able to identify online shopping is driven by various psychological, usability, and trust-related factors, which influence the purchasing decisions of consumers. Theories like TRA, TPB, and TAM provide valuable insights into these decision-making processes, helping businesses tailor their strategies to enhance consumer engagement and optimize the online shopping experience.

Methodology

This study adopts a quantitative research design to explore the factors influencing millennials' online purchasing intentions for mobile phone accessories in the Kandy Municipal Council Area. A deductive approach was employed, with hypotheses derived from established theoretical frameworks (Figure 1) and tested against the data collected.

Figure 1: Conceptual Framework: Developed by author using reserch data, 2023



The following hypotheses have been developed to guide the investigation:

H1: There is a positive impact of Perceived Usefulness on online purchasing intention of mobile phone accessories

H2: There is a positive impact of Perceived Ease of Use on online purchasing Intention of mobile phone accessories.

H3: There is a positive impact of Website Content on online purchasing intention of mobile phone accessories.

H4: There is a positive impact of Trust on online purchasing intention of mobile phone accessories.

The study used a structured questionnaire to collect primary data. The questionnaire was designed to measure the variables of interest—Perceived Usefulness, Perceived Ease of Use, Website Content, Trust, and Online Purchasing Intention. Items for each variable were adapted from validated scales in previous studies and adjusted to fit the context of mobile phone accessories. A 5-point Likert scale ranging from "Strongly Disagree" (1) to "Strongly Agree" (5) was used to measure responses.

Table 1: sample profile: Survey data (2023)

Selection Criteria	Sample size	No of Respondents	Response rate
Millenilas in Kandy municipal council area	120	116	96.67%

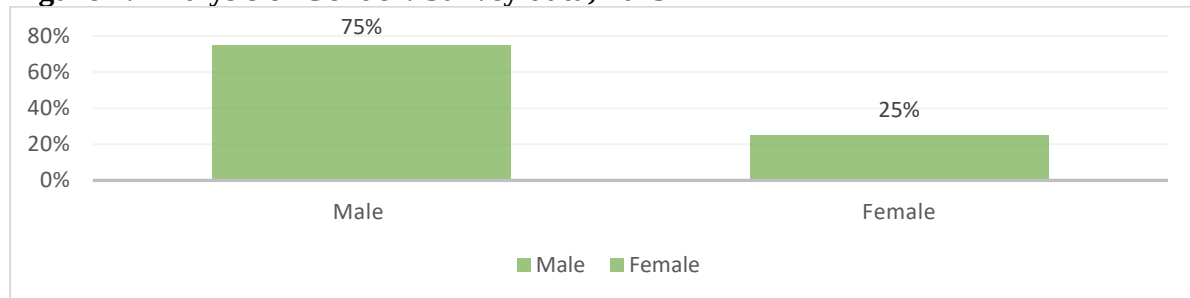
The target population consisted of millennials (aged 27-42) residing in the Kandy Municipal Council Area. The location was selected due to its substantial millennial population, which was estimated at 24,690 in 2022 by the Department of Census and Statistics. Convenience sampling was used, given the practical constraints of reaching the target demographic. Efforts were made to ensure diversity in terms of gender, occupation, and education level to capture a broad perspective within the population. The initial sample size was set at 120 participants, exceeding the calculated minimum sample size of 96 participants (based on a 95% confidence level and a 10% margin of error) to enhance the reliability of findings. The questionnaire was distributed digitally via Google Forms, ensuring accessibility and ease of participation for respondents.

Data analysis involves IBM SPSS version 26, using descriptive statistics, correlation, and multiple regression to test hypotheses and evaluate relationships between variables.

Results and Discussion

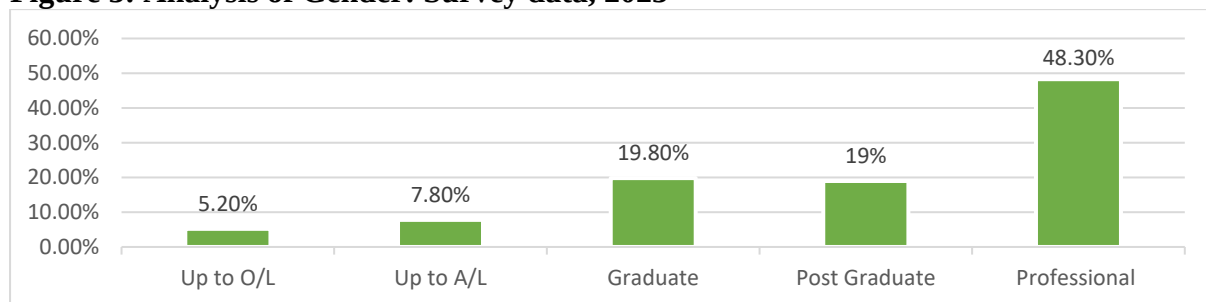
The sample consisted of 75% male participants (87 individuals) and 25% female participants (29 individuals), highlighting a male-dominated respondent pool.

Figure 2: Analysis of Gender: Survey data, 2023



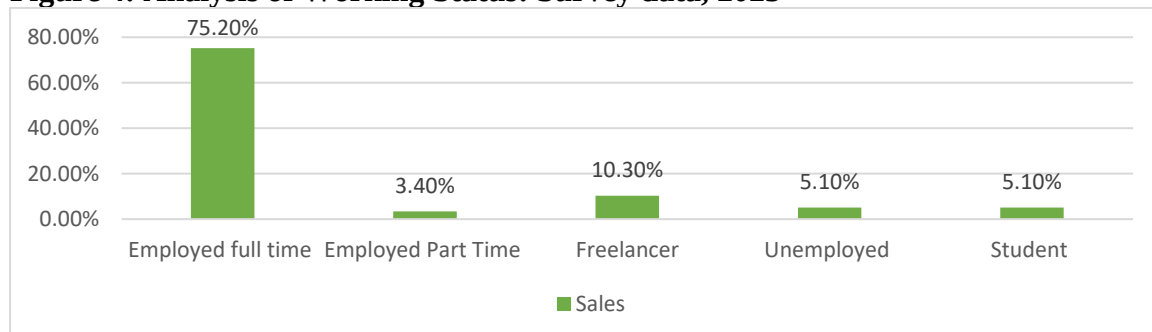
A majority of respondents (48.3%) had completed professional education, while 19.8% were graduates and 19% were post-graduates.

Figure 3: Analysis of Gender: Survey data, 2023



In terms of employment status, 75.2% of the respondents were employed full-time, followed by 10.3% freelancers, 3.4% part-time employees, and 5.1% each being unemployed or students.

Figure 4: Analysis of Working Status: Survey data, 2023



The findings showed that educational background did not significantly influence the perception of online purchasing factors, with all mean values for Perceived Usefulness, Perceived Ease of Use, Website Content, Trust, and Online Purchasing Intention. Regardless of their employment

status, participants displayed positive perceptions towards the online purchasing process, with no significant variation in the responses regarding different employment categories.

Cronbach's Alpha was used to test the reliability of the survey instrument. All variables (PU, PEOU, Website Content, Trust, and Online Purchasing Intention) showed Cronbach's Alpha values above 0.9, indicating a high level of consistency and reliability. The participants generally agreed with the statements regarding the influencing factors, with low standard deviations across the variables, confirming that the responses were consistent.

Variable	No. of items	Cronbach's Alpha Value
Perceived usefulness	3	.962
Perceived ease of use	3	.973
Website content	3	.985
Trust	3	.987
Online purchasing intention	5	.974

Table 2: Analysis of Working Status: Survey data, 2023

The correlation analysis revealed significant relationships between the independent variables and online purchasing intention. Perceived Usefulness (PU) had a moderate positive correlation ($r = 0.588$, $p < 0.001$) with online purchasing intention. Similarly, Perceived Ease of Use (PEOU) had a stronger positive correlation ($r = 0.607$, $p < 0.001$) than other variables. Website Content ($r = 0.521$, $p < 0.001$) and Trust ($r = 0.517$, $p < 0.001$) also had significant positive correlations, but Trust showed the weakest relationship among the factors.

Table 3: Correlation analysis Source: SPSS data, 2023

Variable	Correlation	Significant
Perceived usefulness	.588	<.001
Perceived ease of use	.607	<.001
Website content	.521	<.001
Trust	.517	<.001

Multiple regression analysis indicated that Perceived Usefulness and Perceived Ease of Use were the most significant predictors of online purchasing intention. The R-squared value of 0.462 suggests that 46.2% of the variation in online purchasing intention could be explained by the independent variables.

Table 4: Model Summery Source: SPSS data (2023)

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.680 ^a	.462	.442	.416

a. Predictors: (Constant), T, PU, PEOU, WC

The beta coefficients for PU ($\beta = 0.242$) and PEOU ($\beta = 0.305$) indicated that these factors had the strongest influence on the online purchasing intention of millennials. Trust ($\beta = 0.164$) showed a positive, though weaker, influence, while Website Content ($\beta = 0.009$) had an insignificant impact on purchasing intentions.

Table 5: Analysis of co efficiencies of regression model: SPSS data(2023)

Coefficients ^a						
Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	
	B	Std. Error	Beta			
1	(Constant)	1.254	.330	3.805	<.001	
	PU	.242	.086	.282	2.823	.006
	PEOU	.305	.094	.326	3.246	.002
	WC	.009	.097	.010	.088	.930
	T	.164	.083	.180	1.969	.051

a. Dependent Variable: PI

The regression analysis showing that higher levels of Perceived Usefulness and Ease of Use are associated with increased online purchasing intention (PU: $\beta = 0.282$, PEOU: $\beta = 0.326$). Website Content (WC), on the other hand, did not demonstrate a significant influence on online purchasing intention. Regression coefficient (WC: $\beta = 0.010$) were negligible, suggesting that the content provided on the website does not strongly affect consumers' decision to purchase mobile phone accessories online. Trust (T) exhibited a borderline significant impact on online purchasing intention. The regression analysis yielded a T: $\beta = 0.180$ for Trust. This suggests that while Trust might play a role in influencing online purchasing intention, its effect was not as strong as that of Perceived Usefulness and Ease of Use in this study.

The regression model can be developed as below.

$$YPI = 1.254 + 0.242X_{PU} + 0.305X_{PEOU} + 0.009X_{WC} + 0.164X_T$$

Figure 5: Results of Regression Analysis Source: SPSS data (2023)

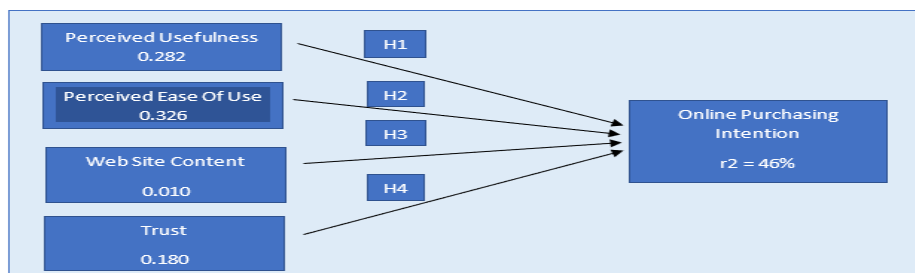


Table 6: Summary of tested Hypothesis: SPSS data (2023)

Hypothesis	Sig.	r	Results
H1: There is a positive impact of Perceived Usefulness on online purchasing intention of mobile phone accessories	.006	0.588	Accepted
H2: There is a positive impact of Perceived Ease of Use on online purchasing Intention of mobile phone accessories.	.002	0.607	Accepted
H3: There is a positive impact of Website Content on online purchasing intention of mobile phone accessories.	.930	0.521	Rejected
H4: There is a positive impact of Trust on online purchasing intention of mobile phone accessories.	.051	0.517	Marginally Accepted

The results underscore the importance of perceived usefulness and ease of use in driving online purchasing intention. Millennials who perceived online shopping for mobile phone accessories as useful and easy to use were more likely to engage in online purchases. While website content and trust did influence purchasing intentions, their effects were comparatively weaker. The findings suggest that online stores should focus on improving the usability and perceived value of their offerings to enhance purchasing intentions among millennial consumers.

Conclusions and Recommendations

In conclusion, the study demonstrates that Perceived Ease of Use (PEOU) and Perceived Usefulness (PU) are the primary factors influencing millennials' online purchasing intention for mobile phone accessories in the Kandy Municipal Council area. These findings align with existing literature suggesting that ease of navigation and perceived benefits significantly shape consumer behavior in e-commerce contexts. While Website Content and Trust showed weaker associations with purchasing intentions, their roles in fostering consumer engagement and confidence cannot be entirely disregarded.

Based on these findings, it is recommended that online retailers prioritize enhancing website usability by simplifying user interfaces and improving the overall user experience. This includes optimizing search functionalities and providing intuitive navigation systems to facilitate seamless shopping experiences. Furthermore, marketers should emphasize the convenience, accessibility, and time-saving benefits of online platforms, as these are key motivators for millennial consumers. Although trust and website content were secondary factors, addressing these elements through secure payment systems, transparent return policies, and high-quality, relevant content will contribute to building a more comprehensive online shopping experience.

Future research should consider expanding the geographical scope to include a wider variety of demographic groups to improve the generalizability of these findings. Moreover, incorporating additional variables such as price sensitivity, brand reputation, and the influence of peer recommendations could provide a deeper understanding of the factors affecting online purchasing intentions. Additionally, exploring external influences such as economic conditions and digital marketing strategies may offer more nuanced insights into consumer behavior in the online marketplace.

References

- Ataei, M. & Abdollah, M., 2023. *ScienceDirect*. [Online]
Available at: <https://www.sciencedirect.com/topics/engineering/cellphone> [Accessed 25 08 2023].
- Athapaththu, J. & Kulathunga, K., 2018. Factors Affecting Online Purchase Intention: A Study of Sri Lankan Online Customers. *International Journal of Scientific & Technology Research*, 7(<https://doi.org/10.5539/ibr.v11n10p111>), pp. 120-128.
- Bansal, R., Gupta, A. & Bansal, A., 2013. Online Shopping: A Shining Future. *International Journal of Techno-Management Research*, Vol. 01(ISSN: 2321-3744).
- Bukhari, F. A. et al., 2013. An investigation of customers to explain the purchase intentions for expensive mobile phone. *Journal of Basic and Applied Scientific Research*, Volume 3(11), pp. 87-96.
- Dimock, M., 2019. *Defining generations: Where Millennials end and Generation Z begins*, s.l.: Pew Research Center.
- GrandViewResearch, 2023. *Mobile Accessories Market Size, Share & Trend Analysis Report By Product (Headphone, Charger, Power Bank, Protective Case, Others), By Distribution Channel (Online, Offline), By Region, And Segment Forecasts, 2023 - 2030*. [Online]
Available at: <https://www.grandviewresearch.com/industry-analysis/mobile-accessories-market>[Accessed 02 09 2023].
- Kemp, S., 2023. *Datareportal*. [Online]
Available at: <https://datareportal.com/reports/digital-2023-sri-lanka#:~:text=The%20state%20of%20digital%20in%20Sri%20Lanka%20in%202023&text=There%20were%2014.58%20million%20internet,percent%20of%20the%20total%20populati on.> [Accessed 01 09 2023].
- Liang, T. & Turban, E., 2011. Introduction to the Special Issue Social Commerce: A Research Framework for Social Commerce.. *International Journal of Electronic Commerce*, 16(<http://dx.doi.org/10.2753/JEC1086-4415160201>), pp. 5-14.
- Peña-García, N., Gil-Saura, I., Rodríguez-Orejuela, A. & Siqueira-Junior, J. R., 2020. Purchase intention and purchase behavior online: A cross-cultural approach. *ScienceDirect*, 6(6).

Rahimnia, F. & Hassanzadeh, J. F., 2013. The impact of website content dimension and e-trust on e-marketing effectiveness: The case of Iranian commercial saffron corporations. *Information & Management*, 50(5)(DOI:10.1016/j.im.2013.04.003), p. 240–247.

Shanthi, D. R. & Kannaiah, D., 2015. Consumers' Perception on Online Shopping. *Journal of Marketing and Consumer Research*, Issue 31 July 2015.

Yang, J.-x., Zhao, H. & Wan, J., 2010. Research on the Advantages and Disadvantages of Online Shopping and Corresponding Strategies. *Business 2010 International Conference on E-Product E-Service and E-Entertainment*, Issue DOI:10.1109/ICEEE.2010.5660278.

IMPACT OF WORK-LIFE BALANCE ON EMPLOYEE TURNOVER INTENTION OF GENERATION Z AND MEDIATING EFFECT OF JOB SATISFACTION

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Abstract

Generation Z (Gen-Z), often known as Digital Natives is now entering the workforce. Multiple studies exposed that Gen-Z prioritizes Work-life balance (WLB) and Job satisfaction (JS). The association of JS with Employee Turnover Intention (ETI) has been established in literature. This study conducted on a sample of Gen-Z employees in Sri Lanka (SL) provide valuable insight regarding WLB, JS and ETI of Gen-Z. This paper intends to identify the effect of WLB and JS of Gen-Z employees on ETI.

The research incorporates primary data accumulated through a structured questionnaire. 118 responses were received and was analysed through IBM SPSS. Results indicate a significant association of WLB, and JS with ETI and identify JS as a partial mediator between WLB and ETI. The recommendations permit employers to improve workplaces and encourage long-term employee well-being.

Keywords: Employee Turnover Intention, Generation Z, Job Satisfaction, Sri Lanka, Work-life balance

Introduction

“Generation” refers to a cohort of individuals sharing a mutual birth-period. While there are disagreements regarding the precise birth years of this group, according to Figure 1, most sources suggest Gen-Z, which represents 30% of the global population, refer to individuals born between 1995 and 2010 (Jayatissa, 2023). Gen-Z are the first generation to grow up with mobile devices, the internet, and other digital tools making them true "digital natives." (Maurer, 2016).

This generation prioritises psychological health and holistic approaches to work (Choughari, 2024). The most crucial consideration when seeking a job for Gen-Z is WLB (Gabrielova & Buchko, 2021). They emphasise JS and resign roles to prioritise working conditions before salary (Syal, et al., 2024). Job switching is not considered negatively by Gen-Z (Fernando, 2023). Compared to predecessors, Gen-Z exhibited the lowest levels of tenure and job commitment (Syal, et al., 2024) with an average of 1-3 months (Hendriana, et al., 2023). GenZ are prone to psychological stress at work (Schroth, 2019). They often exhibit a variety of behavioural and emotional disorders, including paranoia, bipolar disorder, and anxiety (Wattegama, 2022). Consequently, Gen-Z place considerable emphasis on WLB to mitigate distress and enhance their wellbeing (Utomo, et al., 2024).

Birth Years	Author(s)
Born in the early 1990s and early 2000s	Arar & Yuksel (2015)
Born between mid-1990 to mid-2000's	Dwivedula <i>et al.</i> , (2019)
Born between mid-1990 to 2004	Sidorcuka & Chesnovicka, (2017)
Born after 1990	Booz & Company, (2010)
Born after 1995	Chillakuri (2020); Dolot (2018); Chillakuri & Mahanandia (2018); Robak & Albrychiewicz-Słocińska (2019); Berkup (2014)
Born between 1995-2010	Jayathilake & Annuar (2020); Agarwal & Vaghela (2018); Kirchmayer & Fratričová (2017); Bencsik <i>et al.</i> , (2016); Jiri (2016); Fodor & Jaeckel, (2018); Diaconu & Dutu (2020); Kirchmayer & Fratričová (2017); Kirchmayer & Fratričová (2018); Huțanu <i>et al.</i> , (2018); McKinsey & Company (2018)
Born between 1995 – 2009	Cseh-Papp <i>et al.</i> , (2017)
Born between 1995-2012	Stillman & Stillman (2017); Wilson <i>et al.</i> , (2017); Singh (2014); Barhate & Dirani (2021); Deloitte (2018)
Born between 1995 – 2015	Koulopoulos & Keldsen (2014) (as cited by Chareewan <i>et al.</i> , (2020)
Born after 1995	Tang (2019); Agarwal & Vaghela (2018); Maioli (2016); Fratričová, & Kirchmayer (2018); Bulut & Maraba (2021); Bielen & Kubiczek (2020); Hampton & Welsh (2019); Adecco (2015)
Born after 1995 and raised during the 2000s	Wilson <i>et al.</i> , (2017)
Born in 1996 and after	Hameed & Mathur (2019); Bejtkovsky (2016)
Born between 1996 - 2010	Kodithuwakku <i>et al.</i> , (2018); Scott (2016) (as cited by Chareewan <i>et al.</i> , (2020)
Born between 1996 - 2011	Lanier (2017)
Born between 1996 - 2012	Schwieger & Ladwig (2018); n-gen People Performance Inc., (2017)
Born between 1996 – 2013	Grow & Yang (2018)
Born after 1997	Jayathilake (2019)
Born in 1998 - present	Otieno & Nyambegera (2019)
Born before and after 2000	Çora (2019)
Born after 2000	Ozkan & Solmaz (2015)
Mid 1990s to Mid 2000	Lalić <i>et al.</i> , (2020)

Figure 1 - Birth Year of Gen-Z

Source: (Jayatissa, 2023)

WLB is the capacity to maintain a balance between both personal and professional work demands and responsibilities which renders employees' content at a workplace (Duan, *et al.*, 2023). Poor WLB induces depression, exhaustion, elevated blood pressure and cholesterol, besides job and life dissatisfaction (Rajagopalasingam, *et al.*, 2020). JS is the level to which employees have a positive and productive perception regarding their employment (ArunaShantha, 2019). ETI refers to an employee's expressed intention to leave the organization within a specified timeframe (Lazzari, *et al.*, 2022).

The positive and significant impact of WLB and JS has been well-established in literature (Utomo, *et al.*, 2024). It is also recognized that JS and ETI exhibit an inverse relationship (ALMaaitah, *et al.*, 2021). The relationship between WLB and ETI is also documented (Lestaria & Margaretha, 2021). However, there are currently limited literature sources for research regarding how WLB influences Gen-Z employee JS (Waworuntu, *et al.*, 2022) and ETI, especially in the Sri Lankan context. This study intends to reduce said literature limitation.

Main Objective

To explore the relationship between WLB, JS and ETI.

Specific Objectives

- To investigate the association of WLB and JS of Gen-Z employees in SL.
- To explore the relationship of JS and ETI of Gen-Z employees in SL.
- To study the link between WLB on ETI of Gen-Z employees in SL
- To inspect the correlation between WLB and ETI, with JS as a mediator

Methodology

This deductive study intends to authenticate its hypotheses via a quantitative analysis approach. The data was analysed with Descriptive analysis, Correlation and Regression analysis, and Baron and Kenny mediation tests via IBM SPSS version 28 and Sobel test via an online calculator.

The theoretical population of the study is employed Sri Lankan Gen-Z. The specific magnitude of the population was considered ambiguous due to inadequate sources. Considering 5% margin of error and 50% population proportion, the desired sample size was calculated as 385 participants. The sample was selected via Convenience sampling and Snowball sampling. It enabled to select participants available and contiguous to the research (Jager, et al., 2017) and participants that are not contiguous and unfamiliar to the researcher (Leighton, et al., 2021). The questionnaire was distributed via social media and 118 responses from employed individuals born between 1995-2005 were received for analysis.

The questionnaire comprised four sections (Demographic information, Work-Life balance factors, Employee Satisfaction Metrics and Employee turnover likelihood) and included seven 5-point Likert scale questions per WLB, JS and ETI components. WLB was measured by items in (Smeltzer, et al., 2016). ETI was measured with items by (Youcef, et al., 2016). JS was measured with the items by (Kuwaiti & Subbarayalu, 2019) and (Youcef, et al., 2016). The Conceptual framework and hypothesis were developed based on the available literature sources. The schematic diagram is denoted in Figure 2.

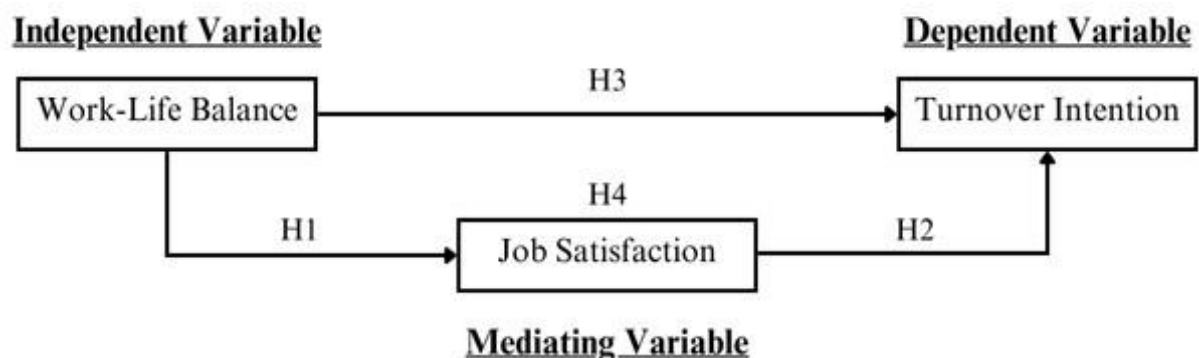


Figure 2 - Conceptual Framework

Research Hypotheses

H₁: There is an association between WLB and JS

H₂: There is a relationship between JS and ETI

H₃: There is a link between WLB and ETI

H₄: There is a correlation between WLB and ETI, with JS as a mediator

Results

Profile of Samples

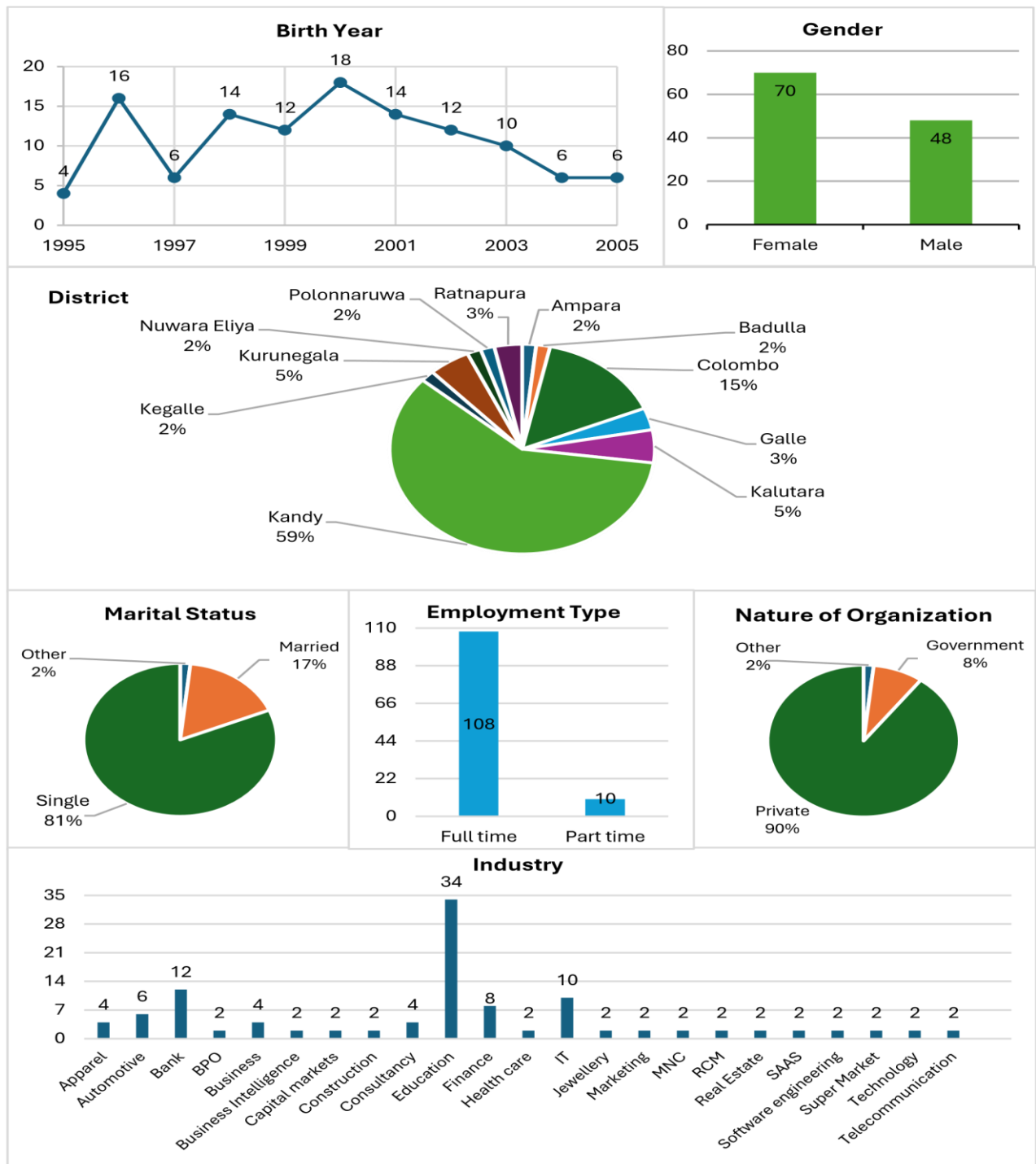




Figure 3 - Demographic Information

Source: (Survey Results, 2024)

Results from 118 respondents from multiple demographics were selected for analysis. According to Figure 3, 59.3% of respondents were females. Majority of respondents were from Kandy, Single and Employed by a private organization. 28.8% of respondents were from the Education sector. 66.1% respondents had ≤3 years of experience, 67% were working on site jobs, 32.2% were from Executive level and 38.9% earned between Rs.50,000 – Rs.100,000. It is evident that a diverse combination of respondents has entered to the study from different districts in SL and from various industries.

Reliability and Validity of Questionnaire

Table 1 - Reliability Analysis

Section	Cronbach's Alpha	N of Items
Work-Life Balance Factors	.760	7
Job Satisfaction Metrics	.886	7
Employee Turnover Intention	.772	6

According to Table 1, the Cronbach's Alpha value for the above sections of the questionnaire ranged from 0.760 – 0.886. A reliability coefficient of $\geq .70$ is deemed acceptable in most social science research (Bujang, et al., 2018). Therefore, the data is acceptable, reliable and indicate strong internal consistency.

Table 2 - Validity Analysis

		Work-Life Balance Factors	Job Satisfaction Metrix	Employee Turnover Intention
Kaiser-Meyer-Olkin Measure of Sampling Adequacy		.756	.839	.773
Bartlett's Test of Sphericity	Approx. Chi-Square	358.289	471.931	255.508
	df	21	21	15
	Sig.	<.001	<0.001	<0.001

As Table 2 presents, the KMO values for each section of the questionnaire is between 0.75 and 0.85 which is higher than the considered acceptable value. The significance value of the Bartlett's test is also <0.005 , indicating the data set is suitable for factor analysis (Shrestha, 2021).

Distribution Analysis

Table 3 - Normality of Distribution

Tests of Normality

	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Avg_WLB	.081	118	.057	.982	118	.121
Avg_JS	.074	118	.160	.973	118	.017
Avg_ETI	.077	118	.086	.973	118	.017

a. Lilliefors Significance Correction

According to Table 3, the p -value of Kolmogorov-Smirnov test is $>.05$, indicating data is normally distributed. The Shapiro-Wilk p -value was disregarded since it is suitable only for $n < 50$ samples (Mishra, et al., 2019).

Univariate Analysis

Table 4 - Univariate Analysis

Descriptive Statistics			
	N	Mean	Std. Deviation
Avg_WLB	118	3.3341	.80925
Avg_JS	118	3.6441	.79917
Avg_ETI	118	2.6780	.83425
Valid N (listwise)	118		

According to Table 3, average WLB (M=3.33, SD=0.81) is above average indicating respondents possess moderate WLB. Average JS (M=3.64, SD=0.80) is also high among respondents. Average ETI (M=2.68, SD=0.83) is below average, indicating respondents are content with their role.

Correlation Analysis

Table 5 - Bivariate Correlation Analysis

		Correlations		
		Avg_WLB	Avg_JS	Avg_ETI
Avg_WLB	Pearson Correlation	1	.428**	-.444**
	Sig. (2-tailed)		<.001	<.001
	N	118	118	118
Avg_JS	Pearson Correlation	.428**	1	-.581**
	Sig. (2-tailed)	<.001		<.001
	N	118	118	118
Avg_ETI	Pearson Correlation	-.444**	-.581**	1
	Sig. (2-tailed)	<.001	<.001	
	N	118	118	118

** . Correlation is significant at the 0.01 level (2-tailed).

The study revealed significant correlations between each variable. A significant moderate negative relationship was identified between WLB and ETI ($r=-.444$, $n=118$, $p<.001$), beside JS and ETI ($r=-.581$, $n=118$, $p<.001$). A significant moderate positive correlation was prevalent between WLB and JS ($r=.428$, $n=118$, $p<.001$).

Regression and Mediation Analysis

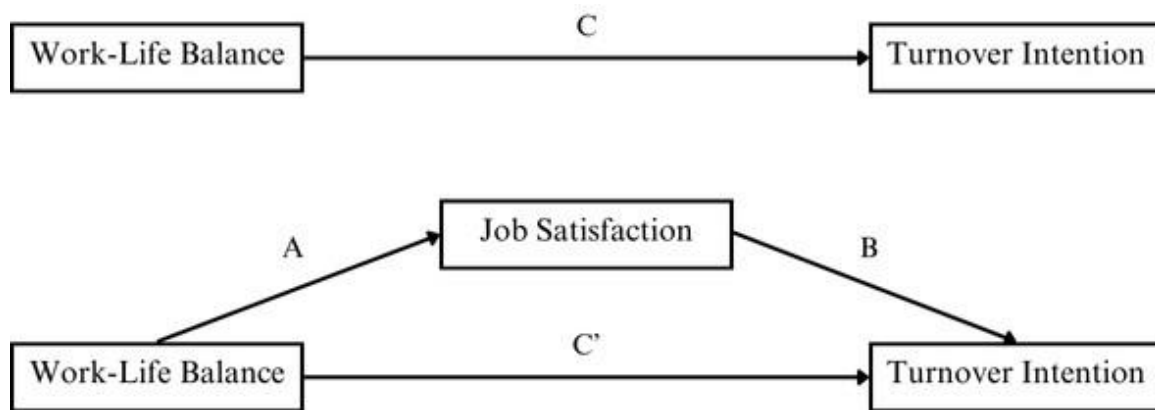


Figure 4 - Paths for Baron and Kenny Analysis

Table 6 - Summary of Regression Analysis

Model	Unstandardized B	Coefficients Std. Error	Standardized Coefficients Beta	Sig.
C	-.458	.086	-.444	<.001
A	.422	.083	.428	<.001
B	-.500	.084	-.479	<.001
C'	-.246	.083	-.239	.004

The significant relationships between each variable have led to the consideration that mediation is possible. According to Table 6, the direct effect of C' (Beta $-.239$, $p=.004$) is weaker in strength than the total effect of C (Beta $-.444$, $p<.001$). The significant C' indicates WLB still exert a direct influence on ETI even after accounting the mediator. Therefore, JS can be considered as a partial mediator between WLB and ETI since $C' \neq 0$ (Dastgeer, et al., 2020). The Sobel test was employed to calculate the mediating effect of JS via an online Sobel test calculator.

Input:		Test statistic:	Std. Error:	p-value:
a	0.422	Sobel test: -3.86599246	0.05457848	0.00011064
b	-0.500	Aroian test: -3.83483034	0.05502199	0.00012565
s _a	0.083	Goodman test: -3.89792682	0.05413134	0.00009702
s _b	0.084	Reset all	Calculate	

Figure 5 - Sobel test results

As per Figure 5, the p -value of the Sobel Test is $<.05$ rendering the mediation statistically significant (Dastgeer, et al., 2020). The negative direction of the indirect effect suggests WLB influence ETI negatively through JS.

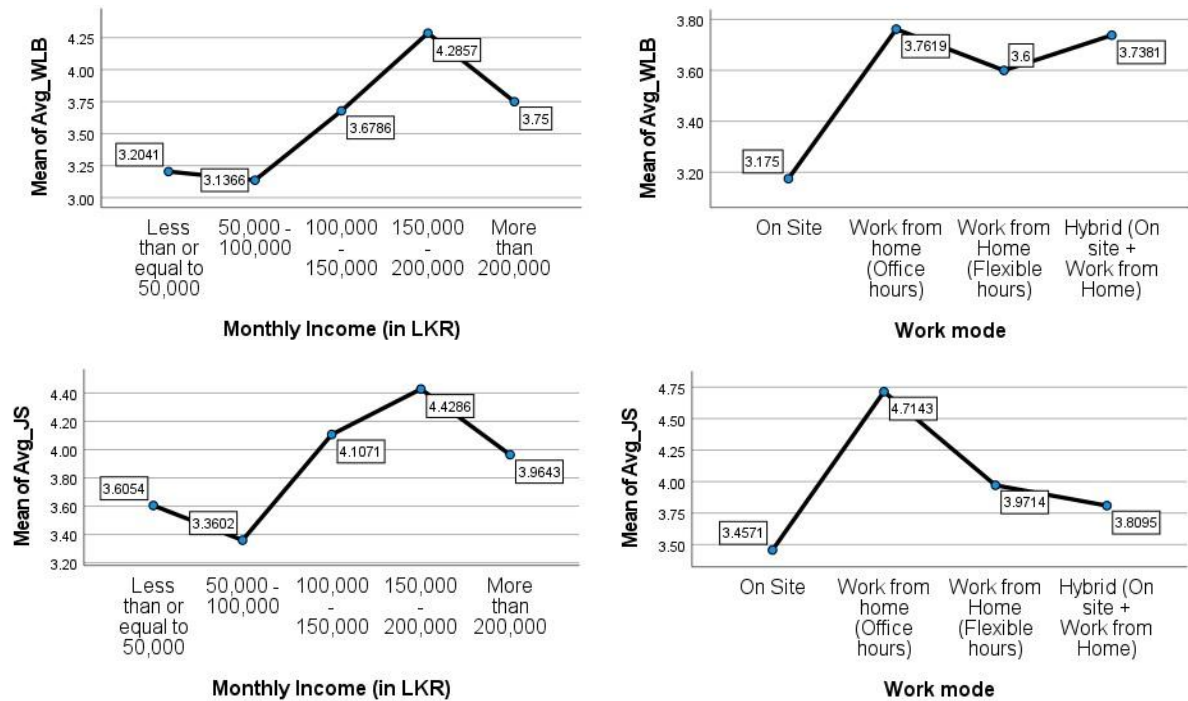


Figure 6 - ANOVA Means Plots According to Figure 6, Gen-Z prefer high salaries and flexible working conditions.

Discussion

The study investigated the relationship between WLB and JS of Gen-Z revealing a moderate positive correlation accepting H_1 of the research. It is consistent with previous literature conducted by (Utomo, et al., 2024) and (Waworuntu, et al., 2022). H_2 of the study was also accepted since a moderate negative relationship was prevalent between JS and ETI. Prior studies such as (AL-Maaitah, et al., 2021) and (Salleh, et al., 2020) also suggests Employees possessing JS exhibit low ETI. WLB and ETI also displayed a moderate negative correlation accepting H_3 and was uniform with results from (Lestaria & Margaretha, 2021) and (Hee & Ann, 2019). Moreover, the mediation analysis results accepted H_4 . This corresponds to findings from (Kumara & Fasana, 2018) and (Lebang & Ardiyanti, 2021). Therefore, all four hypotheses of the study were accepted. Overall, the study's outcomes regarding relationships between WLB, JS and ETI add to the current body of existing knowledge.

Conclusion and Recommendations

Understanding factors influencing ETI of Gen-Z is crucial as they are the foundation of the SL and Global workforce in the ensuing decades. This study contributes to the growing literature by examining the impact of specific factors on Gen-Z in SL and provides localized opinions regarding how to retain Gen-Z in sectors essential to the development of the national economy. Improving WLB and JS reduce turnover expenses of organizations and discourage young employees seeking employment opportunities abroad leading to reduced Brain-Drain.

According to the outcomes, the research proposes following recommendations to minimise ETI of Gen-Z. Flexible work schedules (Remote work and Flexible working hours) should be adopted by organisations to improve workers' WLB. Develop fair salaries and incentive programs that improve benefits according to employee tenure and experiences to enhance JS. Foster a work environment valuing employee well-being by prioritizing employee welfare through non-monetary benefits such as paid leave, maternity/paternity benefits and life insurance to increase JS. Create roles that promote employee involvement and recognizing achievements through awards, public recognition, or incentives to decrease ETI significantly. Following these recommendations allow employers to improve workplaces and encourage long-term employee well-being.

Limitations and suggestions for future research.

The study used non-probability sampling methods and reached limited geographical area (11 districts), receiving only 118 responses due to challenges in gathering information and respondent reluctance, increasing the margin of error to 8.87%. Replicating the study in a diverse sample, exploring moderated mediation, other potential mediators and the interaction between direct and indirect effect is suggested.

References

- AL-Maaitah, D. A. A., Al-Maaitah, T. A. M. & Alkharabsheh, O. H. M., 2021. The impact of job satisfaction on the employees turnover intention at public universities (Northern Border University). *International Journal of Advanced and Applied Sciences*, 8(5), pp. 53-58.
- ArunaShantha, A., 2019. The Impact of Work-Life Balance on Job Satisfaction: With Special Reference to ABC Private Limited in Sri Lanka. *American Journal of Humanities and Social Sciences Research*, 3(6), pp. 97-108.
- Bujang, M. A., Omar, E. D. & Baharum, N. A., 2018. A Review on Sample Size Determination for Cronbach's Alpha Test: A Simple Guide for Researchers. *The Malaysian journal of medical sciences*, 25(6), pp. 85-99.
- Choughari, H., 2024. *The Impact Of Gen-Z In The Workplace*. [Online]
Available at:
<https://www.forbes.com/councils/forbeshumanresourcescouncil/2024/02/05/theimpact-of-gen-z-in-the-workplace/> [Accessed 23 November 2024].

- Dastgeer, G., Rehman, A. u. & Asghar, M. A., 2020. Selection and Use of Mediation Testing Methods; Application in Management Sciences. *Business and Economic review*, 12(3), pp. 71-96.
- Duan, S. X., Deng, H. & Wibowo, S., 2023. Exploring the impact of digital work on work–life balance and job performance: a technology affordance perspective. *Information Technology & People*, 36(5), pp. 2009-2029.
- Fernando, R., 2023. *The Island*. [Online]
Available at: <https://island.lk/understanding-potential-of-generation-z-how-next-wave-ofemployees-will-transform-workforce/> [Accessed 22 November 2024].
- Gabrielova, K. & Buchko, A. A., 2021. Here comes Generation Z: Millennials as managers. *Business Horizon*, Volume 64, pp. 489-499.
- Hee, O. C. & Ann, Y. S., 2019. Factors Influencing Employee Turnover in the Food Manufacturing Industry in Malaysia. *International Journal of Academic Research in Business and Social Sciences*, 9(1), pp. 482-491.
- Hendriana, E., Christoper, A., Zain, H. O. A. & Pricilia, N., 2023. The Role of Employer Branding in Work-life Balance and Employee Retention Relationship among Generation Z Workers: Mediation or Moderation?. *Journal of Theoretical and Applied Management*, 16(1), pp. 124-143.
- Jager, J., Putnick, D. L. & Bornstein, M. H., 2017. More than Just Convenient: The Scientific Merits of Homogeneous Convenience Samples. *Monographs of the Society for Research in Child Development*, 82(2), pp. 13-30.
- Jayatissa, K., 2023. Generation Z – A New Lifeline: A Systematic Literature Review. *Sri Lanka Journal of Social Sciences and Humanities*, 3(2), pp. 179-186.
- Kumara, J. & Fasana, S., 2018. Work life conflict and its impact on Turnover intention of Employees: The Mediation Role of Job satisfaction. *International Journal of Scientific and Research Publications*, 8(4), pp. 478-484.
- Kuwaiti, A. A. & Subbarayalu, A. V., 2019. Health Sciences Teaching Staff's Perception about Quality of Work Life in Saudi Universities: Reliability and Validity of the Questionnaire Instrument. *Hamdan medical Journal*, 12(4), pp. 182-188.
- Lazzari, M., Alvarez, J. M. & Ruggieri, S., 2022. Predicting and explaining employee turnover intention. *International Journal of Data Science and Analytics*, 14(3), p. 279–292.
- Lebang, F. A. & Ardiyanti, N., 2021. The Effect of Work-Life Balance and Work Stress on Turnover Intention with Job Satisfaction as A Mediator at Anti-Corruption Institution in Indonesia. *Advances in Economics, Business and Management Research*, 187(1), pp. 638648.
- Leighton, K., Kardong-Edgren, S., Schneidereith, T. & Foisy-Doll, C., 2021. Using Social Media and Snowball Sampling as an Alternative Recruitment Strategy for Research. *Clinical Simulation in Nursing*, Volume 55, pp. 37-42.

- Lestaria, D. & Margaretha, M., 2021. Work life balance, job engagement and turnover intention: Experience from Y generation employees. *Management Science Letters* , 11(1), p. 165–170.
- Maurer, R., 2016. *What HR Should Know About Generation Z*. [Online]
Available at: <https://www.shrm.org/topics-tools/news/talent-acquisition/hr-know-generation-z> [Accessed 23 November 2024].
- Mishra, P. et al., 2019. Descriptive Statistics and Normality Tests for Statistical Data. *Annals of Cardiac Anaesthesia*, 22(1), pp. 67-72.
- Rajagopalasingam, V., Fernando, R. L. S. & Ramanayake, U. B., 2020. Impacts of Perceived Role Demands on Work-Life Balance and Moderating Effects of Work Ethics: Evidence from Public Sector Professionals in Sri Lanka. *International Journal of Business and Management*, 15(8), pp. 115-131.
- Salleh, A. M. M. et al., 2020. The impact of Career planning and Career satisfaction on Employees Turnover Intention. *Entrepreneurship and Sustainability Issues*, 8(1), pp. 218-232.
- Schroth, H., 2019. Are You Ready for Gen Z in the Workplace?. *California Management Review*, 61(3), pp. 5-18.
- Shrestha, N., 2021. Factor Analysis as a Tool for Survey Analysis. *American Journal of Applied Mathematics and Statistics*, 9(1), pp. 4-11.
- Smeltzer, S. C. et al., 2016. Psychometric Analysis of the Work/Life Balance Self-Assessment Scale. *Journal of Nursing Measurement*, 24(1), pp. 5-14.
- Syal, A. et al., 2024. The influence of reward, work-life balance on employee retention: The mediating effect of Job satisfaction Generation Z employees in West Kalimantan. *Journal of Management Science*, 7(1), pp. 270-279.
- Utomo, S. S. et al., 2024. The Impact of Work-Life Balance on Job Satisfaction, Job Performance, and Workplace Engagement Among Generation Z Employees: A Comprehensive Analysis. *PROSENAMA*, Volume 4, pp. 107-114.
- Wategama, C., 2022. *Six lessons from Gen Z (aka 'Screenagers')*. [Online]
Available at: <https://www.ft.lk/columns/Six-lessons-from-Gen-Z-aka-Screenagers/4-739675> [Accessed 22 November 2024].
- Waworuntu, E. C., Kainde, S. J. R. & Mandag, D. W., 2022. Work-Life Balance, Job Satisfaction and Performance Among Millennial and Gen Z Employees: A Systematic Review. *Society*, 10(2), pp. 384-398.
- Youcef, S., Ahmed, S. S. & Ahmed, B., 2016. The Impact of Job Satisfaction on Turnover Intention by the Existence of Organizational Commitment, and Intent to Stay as Intermediates Variables Using approach PLS in Sample Worker Department of Transport Saida. *Management*, 6(6), pp. 198-202.

**EFFECTS OF EXPECTED AND PERCEIVED QUALITY ON STUDENT
CONTINUATION INTENTION: THE MEDIATING ROLE OF STUDENT
SATISFACTION WITH SPECIAL REFERENCE TO PRIVATE HIGHER
EDUCATION INSTITUTIONS IN SRI LANKA**

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Abstract

This study examines the effects of expected and perceived quality on student continuation intentions in private higher education institutions in Sri Lanka, with student satisfaction as a mediating variable. The research aims to understand how discrepancies between students' expectations and their actual experiences in areas such as teaching quality, infrastructure, and support services influence their overall satisfaction and their intention to continue their education at the same institution. A survey conducted with 381 students from five private universities in Sri Lanka, using a structured questionnaire to collect data. The results indicate a significant gap between expected and perceived quality, particularly in teaching and infrastructure, which negatively impacts student satisfaction. Moreover, student satisfaction was found to mediate the relationship between perceived quality and continuation intentions, highlighting its critical role in retention decisions. The findings suggest that private higher education institutions should focus on aligning expectations with actual experiences to improve satisfaction and retention.

Key words: Expected Quality, Perceived Quality, Student Satisfaction, Continuation Intention

Introduction

Private higher education institutions have become an important part of Sri Lanka's educational system, offering students various opportunities for both academic and professional growth (Perera, 2024). In recent years, these institutions have faced increasing competition to attract and retain students (Bandara et al., 2022). One of the key factors influencing whether students stay or leave is the gap between what they expect from their education and what they actually experience (Al Hassani & Wilkins, 2022). Expected quality refers to the standards students anticipate when they first enroll, influenced by things like promotional materials, the institution's reputation, and the opinions of peers (Chhor et al., 2024). Perceived quality, on the other hand, is based on students' actual experiences with aspects like teaching, infrastructure, and student support services (Del Río-Rama et al., 2021).

There is often a disconnect between students' expectations and their experiences, which can lead to dissatisfaction. When students' experiences do not meet their expectations, it can have a major impact on their overall satisfaction and their decision to continue their studies at the same institution. This dissatisfaction may lead them to transfer or even drop out (Bäulke et al., 2022).

Perceived quality refers to how students view the overall quality of their education based on their experiences and interactions within the university. It includes factors like teaching effectiveness, resources, and campus environment. Expected quality, on the other hand, relates to the standards students anticipate before enrolling, based on factors like reputation or promotional materials. Both impact retention: if perceived quality meets or exceeds expectations, students are more likely to stay, as they feel their needs are being met. However, if perceived quality falls short of expectations, dissatisfaction may lead to higher dropout rates or transfers to other institutions.

This study aims to explore the impact of expected and perceived quality on students' intentions to continue their education, with student satisfaction acting as a key mediator. Specifically, it looks at how discrepancies in teaching quality, infrastructure, and support services affect satisfaction, and how that, in turn, influences whether students decide to remain at their current institution. By examining these relationships, the study hopes to provide insights that can help private higher education institutions improve their offerings and reduce student attrition.

The significance of this research lies in its ability to provide valuable information on what drives student satisfaction and retention in Sri Lanka's private education sector. With rising education costs and more alternative educational options available, ensuring high levels of student satisfaction is critical for the long-term success and sustainability of these institutions. By focusing on the role of student satisfaction as a mediator, this research adds a new perspective to existing studies, emphasizing the importance of aligning student expectations with their actual experiences to improve retention and reduce dropout rates.

Ultimately, the findings of this study could help private higher education institutions in Sri Lanka develop strategies to enhance the student experience, understand the effects of expected and perceived quality on students' decisions to stay, and improve both satisfaction and retention rates.

Objectives

- To examine the relationship between expected quality and student satisfaction in private higher education institutions in Sri Lanka.
- To evaluate the relationship between perceived quality and student satisfaction in private higher education institutions in Sri Lanka.
- To investigate the impact of student satisfaction on continuation intentions in private higher education institutions in Sri Lanka.
- To assess the relationship between expected quality and student continuation intentions in private higher education institutions in Sri Lanka.
- To examine the relationship between perceived quality and student continuation intentions in private higher education institutions in Sri Lanka.
- To examine the mediating role of student satisfaction in the relationship between expected quality and student continuation intentions in private higher education institutions in Sri Lanka.

- To examine the mediating role of student satisfaction in the relationship between perceived quality and student continuation intentions in private higher education institutions in Sri Lanka.

Research questions

1. What is the relationship between expected quality and student satisfaction in private higher education institutions in Sri Lanka?
2. How does perceived quality affect student satisfaction in private higher education institutions in Sri Lanka?
3. What is the impact of student satisfaction on continuation intentions in private higher education institutions in Sri Lanka?
4. How does expected quality influence student continuation intentions in private higher education institutions in Sri Lanka?
5. What is the relationship between perceived quality and student continuation intentions in private higher education institutions in Sri Lanka?
6. Does student satisfaction mediate the relationship between expected quality and student continuation intentions in private higher education institutions in Sri Lanka?
7. Does student satisfaction mediate the relationship between perceived quality and student continuation intentions in private higher education institutions in Sri Lanka?

Methodology

This study uses a deductive research approach to examine the gap between expected and perceived quality in private higher education institutions in Sri Lanka, and how this gap affects student satisfaction. The deductive approach is well-suited to this research because it begins with a theoretical framework about the relationship between expected and perceived quality and student satisfaction, and then tests these ideas empirically using data collected from students at private universities (Thorpe, 2022). The main goal is to test hypotheses related to the factors influencing student satisfaction between expectations and experiences.

The research employs a quantitative strategy, using structured surveys to gather primary data from students. This method allows for systematic analysis and the collection of data on various aspects of expected and perceived quality across multiple private institutions in Sri Lanka. The quantitative nature of the study ensures that the findings are statistically valid, allowing for generalization to the broader population of students in private higher education institutions (Pregoner, 2024).

The study's population consists of students enrolled in private higher education institutions in Sri Lanka. To capture the diversity of these institutions, the sample will be drawn from a range of universities offering undergraduate programs in different fields of study. This approach ensures that the sample reflects a variety of student demographics and educational experiences across different institutions. Annually, over 42,000 students enroll in non-state higher education institutions recognized by the Ministry of Education (Lake House, 2024).

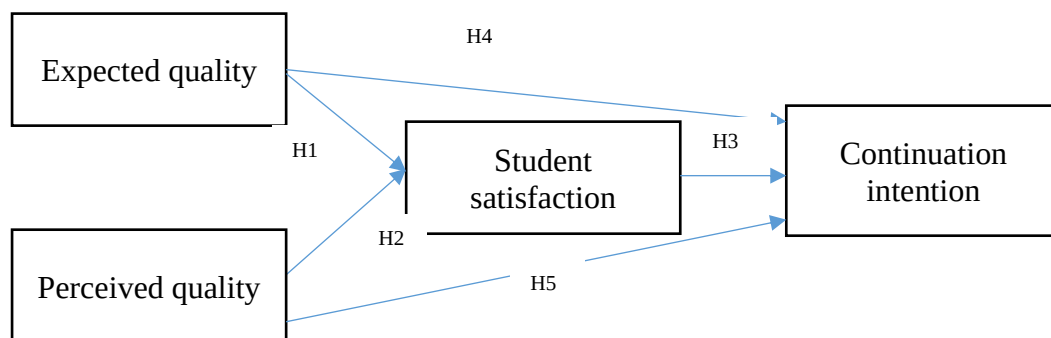
A stratified random sampling technique will be used to select the sample, grouping students by their institution and level of study (e.g., undergraduate). This ensures proportional representation of different student sub-groups, which enhances the reliability and validity of the study's findings (Acharya et al., 2013).

The sample size will be 381 students, selected from approximately five private universities, ensuring a diverse cross-section of the student population. This includes students from various academic programs (e.g., business, engineering, IT) and different year levels (from freshmen to final-year students). This variety will ensure the data captures a comprehensive view of student experiences across disciplines and academic stages.

Data will be collected through a structured questionnaire designed to measure both expected and perceived quality in several areas: faculty competence, teaching quality, infrastructure, support services, and administrative processes. The questionnaire will use a Likert scale (1-5) to allow students to rate their expectations and actual experiences, making it easy to compare the two. The survey will be distributed online to reach a wider audience and ensure anonymity.

The collected data will be analyzed using frequency analysis and descriptive statistics. Additionally, Exploratory Factor Analysis (EFA) will be conducted to explore the structure of the observed variables, and Confirmatory Factor Analysis (CFA) will be used to test the hypotheses and assess the reliability and validity of the data. If there are low response rates or incomplete surveys, the study will implement follow-up strategies to boost participation, such as offering incentives or extending the survey deadline.

Conceptual Framework



Hypothesis:

H1: There is a highly positive relationship between expected quality and student satisfaction.

H2: There is a highly positive relationship between perceived quality and student satisfaction.

H3: There is a highly positive relationship between student satisfaction and continuation intention.

H4: There is a highly positive relationship between expected quality and continuation intention.

H5: There is a highly positive relationship between perceived quality and continuation intention.

H6: Student satisfaction mediate the relationship between expected quality and continuation intention as per this prepare the objective.

H7: Student satisfaction mediate the relationship between perceived quality and continuation intention as per this prepare the objective.

Results and discussion

Exploratory Factor Analysis (EFA) is conducted using the Maximum Likelihood method with Varimax rotation to explore the factor structure and the relationships between the items within the scale. The results from the rotated factor matrix are presented in the following tables.

Table 1:KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.903
Bartlett's Test of Sphericity	Approx. Chi-Square	6240.617
	df	231
	Sig.	.000

The KMO statistic exceeds 0.50, indicating that the sampling adequacy criteria are met. Furthermore, the Bartlett test of sphericity is statistically significant ($p < 0.05$), suggesting that the correlation matrix significantly differs from an identity matrix, which is the desired outcome for factor analysis.

Table 2: Rotated Factor Matrix^a

	Factor			
	1	2	3	4
EQ1		.600		
EQ2		.824		
EQ3		.735		
EQ4		.694		
EQ5		.840		
EQ6		.870		
PQ1				.715
PQ2				.742
PQ3				.632
SS1	.763			
SS2	.790		.306	
SS3	.842			
SS4	.860			
SS5	.836			
SS6	.737			
SS7	.678			
SS8	.734			
CI1			.644	
CI2			.813	
CI3			.871	
CI4			.697	
CI5	.328		.707	

Extraction Method: Maximum Likelihood.

Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 5 iterations.

The results of the exploratory factor analysis (EFA) indicate a four-factor solution, as expected, with all items loading onto their respective factors, except for two items (SS2 and CI5), which show cross-loadings. This four-factor model explains 64.01% of the total variance. These findings suggest a high level of validity for the factors identified. To further validate these results, we proceeded with confirmatory factor analysis (CFA), which will be discussed in the following section.

Figure 1: The initial measurement model

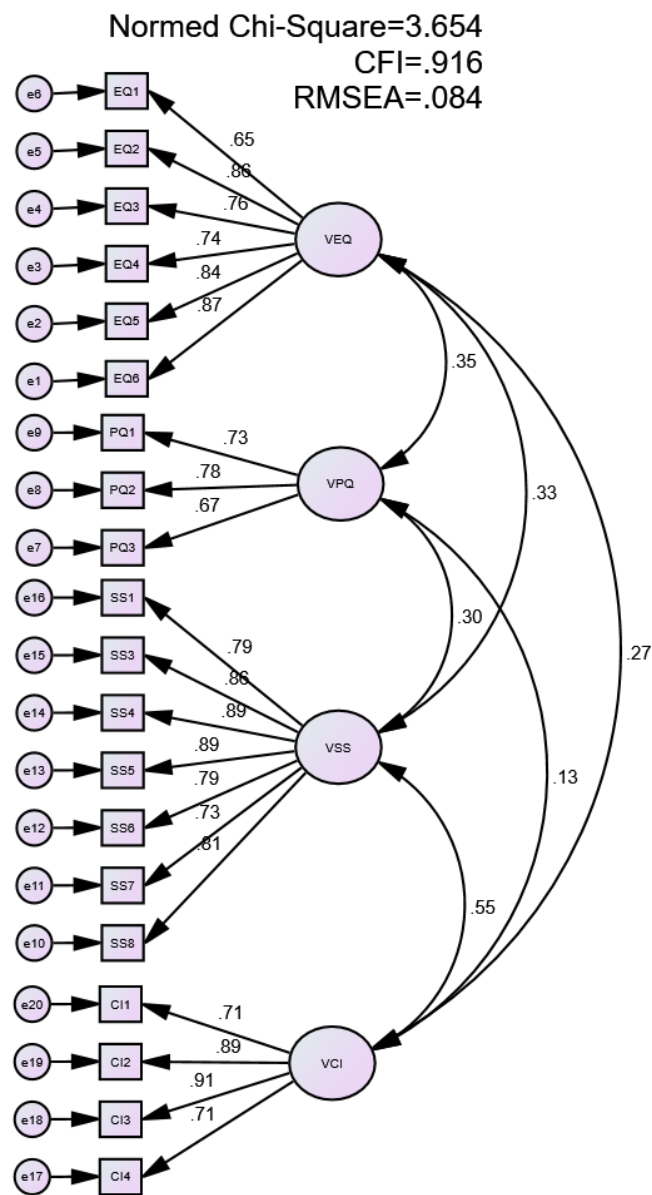


Figure 2: The revised measurement model

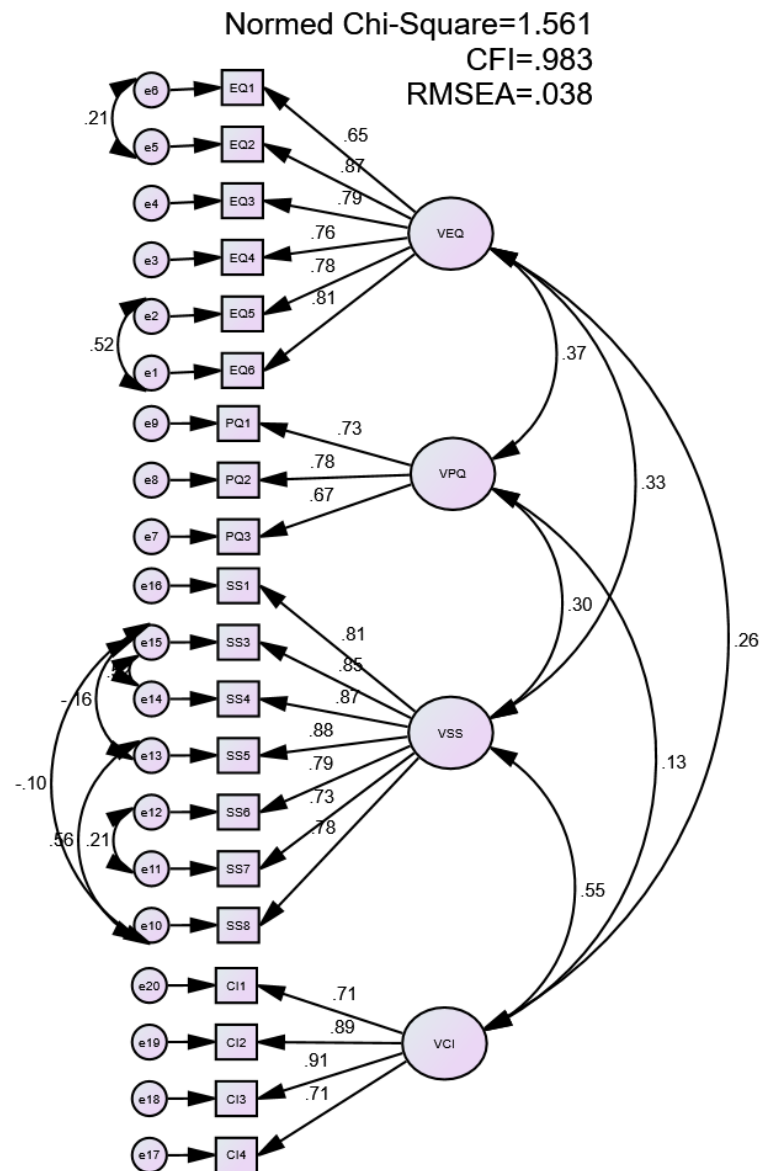


Table 3: Reliability and Convergent Validity

Variables/ Constructs	Items	Standardized Factor Loadings	Cronbach Alpha	Composite Reliability	Average Variance Extracted	Maximum Shared Variance
EQ	EQ1	.651	.907	0.902	0.607	0.135
	EQ2	.873				
	EQ3	.787				
	EQ4	.758				
	EQ5	.780				
	EQ6	.810				
PQ	PQ1	.734	.768	0.771	0.529	0.135
	PQ2	.777				
	PQ3	.667				
SS	SS1	.806	.936	0.933	0.668	0.305
	SS3	.849				
	SS4	.867				
	SS5	.883				
	SS6	.794				
	SS7	.728				
	SS8	.782				
CI	CI1	.705	.874	0.881	0.651	0.305
	CI2	.886				
	CI3	.907				
	CI4	.708				
Initial Model Fitness: X2=599.297, df=164, X2/df= 3.654, RMSEA=.084, RMR=.029, GFI=.862, CFI=.916						
Revised Model Fitness: X2=245.121, df=157, X2/df= 1.561, RMSEA=.038, RMR=.026, GFI=.940, CFI=.983						

The results from the confirmatory factor analysis (CFA) show that the model fits the data very well, with fit statistics: $\chi^2/df = 1.561$, RMSEA = 0.038, RMR = 0.026, and CFI = 0.983. These values align with the recommended thresholds (RMSEA < 0.08, RMR < 0.05, CFI > 0.90). All items exhibited standardized factor loadings greater than 0.52, and the Average Variance Extracted (AVE) was above 0.50, confirming strong convergent validity. Additional support for convergent validity is provided by the fact that the Maximum Shared Variance (MSV) is lower than the AVE for each variable. Moreover, Cronbach's alpha and composite reliability values for all variables exceeded 0.70, indicating strong reliability.

Table 4: Discriminant Validity

	CR	AVE	MSV	MaxR(H))	VSS	VEQ	VPQ	VCI
VSS	0.933	0.668	0.305	0.939	0.817			
VEQ	0.902	0.607	0.135	0.912	0.335	0.779		
VPQ	0.771	0.529	0.135	0.777	0.299	0.368	0.727	
VCI	0.881	0.651	0.305	0.911	0.552	0.265	0.129	0.807

To assess discriminant validity, applied the criteria established. The values in bold along the diagonal represent the square root of the Average Variance Extracted (AVE), while the off-diagonal values indicate the inter-variable correlations. According to the criterion, the bold diagonal values should be greater than the corresponding values in their respective rows and columns. This requirement is met, as shown in the table, confirming that our variables exhibit strong discriminant validity.

To explore the relationships between Expected Quality, Perceived Quality, Student Satisfaction, and Continuation Intention, we employed structural equation modeling (SEM) through AMOS path analysis. The factor scores from the CFA were used as inputs for this analysis. As part of hypothesis testing, we also examined Student satisfaction as a potential mediator. The graphical representation of the structural model, along with the results, is presented below.

Figure 3: Hypotheses Testing (Structural Model)

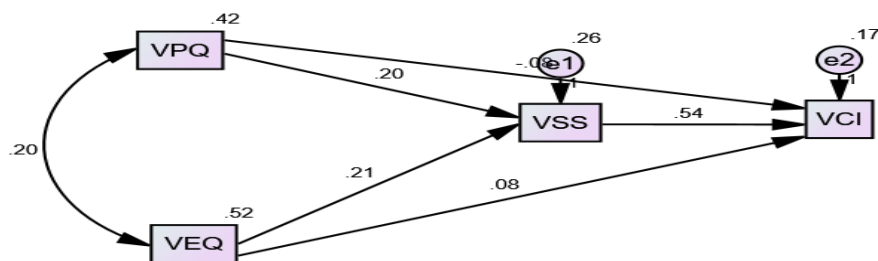


Table 5: Regression Weights

H. No.	Paths	Estimate	S.E.	C.R.	P	Remarks
H1	Expected quality>Student satisfaction	.206	.040	5.164	***	H1 Supported
H2	Perceived quality>Student satisfaction	.201	.045	4.489	***	H2 Supported
H3	Student satisfaction>Continuation intention	.536	.041	13.015	***	H3 Supported
H4	Expected quality>Continuation intention	.085	.033	2.559	.010	H4 Supported
H5	Perceived quality>Continuation intention	-.079	.037	-2.145	.032	H5 Not supported
Model Fitness: X ² =0.000, df=0, X ² /df= -, RMSEA=.374, RMR=.000, GFI=1.000, CFI=1.000						

***<.05, **<.01, *<.001

The results of the structural equation modeling revealed a strong fit for the model, with an RMR of 0.000, a GFI of 1.000, and a CFI of 1.000. However, the RMSEA did not meet the desired threshold, as it should be below 0.08 to indicate satisfactory model fit.

The path analysis results show the following outcomes for the hypotheses:

Expected quality has a positive and significant relationship with student satisfaction ($\beta = 0.206$, $p < 0.05$).

Perceived quality is positively and significantly associated with student satisfaction ($\beta = 0.201$, $p < 0.05$).

Student satisfaction is positively and significantly related to continuation intention ($\beta = 0.536$, $p < 0.05$).

Expected quality also has a positive and significant relationship with continuation intention ($\beta = 0.085$, $p < 0.05$).

However, perceived quality is negatively and significantly related to continuation intention ($\beta = -0.079$, $p < 0.05$).

Based on these findings, hypotheses H1, H2, H3, and H4 are accepted. However, hypothesis H5 is rejected due to the significant p-value and the negative relationship observed, which contradicts the hypothesized direction.

Table 6: Mediation Analysis

H. No.	Path	Total Effects	Direct Effects	Indirect Effects	Remarks
H6	EQ>SS>CI	.195**	.085**	.111**	Hypothesis supported since indirect effects are statistically significant
H7	PQ>SS>CI	.029	-.079	.108**	Hypothesis supported since indirect effects are statistically significant

*<.05, **<.01, ***<.001

The results indicate that student satisfaction partially mediates the relationship between expected quality and continuation intention, with the indirect effect being statistically significant ($\beta = 0.111$, $p < 0.05$). Similarly, student satisfaction also partially mediates the relationship between perceived quality and continuation intention ($\beta = 0.108$, $p < 0.05$). Based on these findings, we can accept hypotheses H6 and H7.

Table 7: Summary of Hypotheses

H.No.	Statement	Status
H1	Expected quality>Student satisfaction	Supported
H2	Perceived quality>Student satisfaction	Supported
H3	Student satisfaction>Continuation intention	Supported
H4	Expected quality>Continuation intention	Supported
H5	Perceived quality>Continuation intention	Not Supported
H6	Student satisfaction mediate the relationship between Expected quality and continuation intention	Supported
H7	Student satisfaction mediate the relationship between perceived quality and Continuation intention	Supported

Conclusion and recommendations

The findings of this study indicate that while expected quality positively influences both student satisfaction and continuation intentions, the hypothesized relationship between perceived quality and continuation intentions was not supported. This suggests that students' actual experiences with the quality of education such as teaching, infrastructure, and support services did not directly impact their intention to remain at the same institution. However, student satisfaction was found to mediate the relationship between expected quality and continuation intentions, highlighting its crucial role in retention decisions.

Based on these findings, several recommendations can be made for private higher education institutions in Sri Lanka. First, institutions should focus on improving expected quality by effectively communicating the standards of teaching, infrastructure, and support services, ensuring that students' expectations align with their actual experiences. While perceived quality may not have a direct impact on continuation intentions, it is essential for institutions to prioritize student satisfaction by enhancing the quality of the actual educational experience. This remains a critical factor in retaining students. By consistently providing a high-quality educational experience, institutions can foster long-term student loyalty and improve retention rates.

References

- Lake House, 2024. *Private Universities: Boon or Drain for Sri Lanka's Higher Education?* Daily News. [Online] 6 February. Available at: <https://www.dailynews.lk/2024/02/06/featured/383019/private-universities-boon-or-drain-for-sri-lankas-higher-education/> [Accessed 6 January 2025].
- Perera, K., 2024. Higher education in contemporary Sri Lanka: Key topics. *Routledge Handbook of Contemporary Sri Lanka*, pp.207-218.
- Bandara, W.B.K., Chandike, B.M.T. and Samaraweera, G.C., 2022. Development of strategies to minimize the student dropout from the alternative higher education sector of Sri Lanka-a case study.
- Al Hassani, A.A. and Wilkins, S., 2022. Student retention in higher education: the influences of organizational identification and institution reputation on student satisfaction and behaviors. *International Journal of Educational Management*, 36(6), pp.1046-1064.
- Chhor, C., Sek, V., Norng, R., Hoeurn, S. and Sam, R., 2024. Factors Influencing Students' Enrollment Decisions in Higher Education Institutions: A Case Study of the National University of Battambang. *European Journal of Contemporary Education and E-Learning*, 2(6), pp.169-186.
- Del Río-Rama, M.D.L.C., Álvarez-García, J., Mun, N.K. and Durán-Sánchez, A., 2021. Influence of the quality perceived of service of a higher education center on the loyalty of students. *Frontiers in Psychology*, 12, p.671407.
- Bäulke, L., Grunschel, C. and Dresel, M., 2022. Student dropout at university: A phase-orientated view on quitting studies and changing majors. *European Journal of Psychology of Education*, 37(3), pp.853-876.
- Thorpe, G.E., 2022. *Relationship Between Perceived Quality of Student Learning Experience, Perceived Quality of Mentoring, and Student Satisfaction* (Doctoral dissertation, Walden University).
- Pregoner, J.D., 2024. Research approaches in education: A comparison of quantitative, qualitative and mixed methods. *IMCC Journal of Science*, 4(2), pp.31-36.
- Acharya, A.S., Prakash, A., Saxena, P. and Nigam, A., 2013. Sampling: Why and how of it. *Indian journal of medical specialties*, 4(2), pp.330-333.

IMPACT OF FACTORS AFFECTING TO EMPLOYEE TURNOVER INTENTION AMONG SEWING MACHINE OPERATORS IN APPAREL INDUSTRY OF SRI LANKA

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Abstract

The development of Sri Lanka's economy depends on the garment sector, which is currently one of the largest in the nation. Approximately 75% of Sri Lanka's job opportunities are supported directly or indirectly by the garment industry, making it the only source of employment in the manufacturing sector. However, finding and retaining the requisite labour is one of the main problems the garment industry faces. Hence, this study was executed to identify the impact of factors affecting employee turnover intention among sewing machine operators in Sri Lanka's apparel industry. The study used a questionnaire to collect primary data for testing the study's hypotheses. It collects data from 317 machine operators among 1800 sewing machine operators in these apparel companies. The IBM SPSS statistical software used to analyze the data showed that variables like job satisfaction, working conditions, work-life balance, and monetary benefits negatively and significantly impact employee turnover among sewing machine operators.

Keywords: Employee Turnover Intention, Job Satisfaction, Sewing Machine Operators, Work-Life Balance

Introduction

The garment industry is vital for Sri Lanka's economy since it has developed into Sri Lanka's primary export industry and a significant contributor to GDP. More than 330,000 direct jobs, or 5% of the total employment in the nation as a whole, are supported by the garment industry (Dheerasinghe, 2009). Meanwhile, employees are the lifeblood and soul of every company, which is not indifferent to the apparel sector. The better the organization's people are qualified, trained, and managed, the more effective and successful it will be (Opatha, 2021). In the current business environment, turnover continues to be one of the most significant challenges facing the apparel industry since it adversely impacts the smooth operation of the daily organization (Boxall, 2003), including a lack of qualified workers and a high incidence of staff turnover (Kelegama & Epaarachchi, 2001). In addition to the indirect, non-financial costs of employee turnover, businesses must cover the direct expenses of exit interviews, new hire training, and compensation (Kesner, 1994). Employee turnover is a cost given the company's investment in these leaving individuals. Organizations will be better able to develop successful retention strategies and address issues that lead to turnover if they can identify the core reasons for high staff turnover. Ensuring that the workforce will react to the company can assist in raising organizational competitiveness.

Further, many female employees quit the industry after their marriages, while a sizable proportion of qualified professionals depart the sector in favour of employment abroad. On average, 60% of workers resign from their jobs each year. When considering internal labour mobility inside the industry, the yearly net quantity of workers leaving the companies is predicted to be 25% (Dheerasinghe, 2009). Hence, this research aims to identify the variables affecting machine operator employee turnover in Sri Lanka's apparel sector. There is a vacuum in the empirical evidence about the turnover of machine operators. The study examines the factors impacting the employee turnover of machine operators in Sri Lanka's textile industry as it relates to the Kandy District by considering the facts above.

Primary research objective

To identify the impact of factors affecting employee turnover intention among sewing machine operators in the apparel industry of Sri Lanka

Secondary research objectives

- To identify the factors affecting employee turnover intention
- To analyze the effect of identified factors in objective one on employee turnover intention
- To develop a model that predicts employee turnover based on specified factors.
- To offer recommendations to overcome the high employee turnover intention of machine operators.

Significance of the study

Employee turnover is significant as new hires must be hired, trained, and given the time they require to be productive by the organization. In addition, the expense of hiring new personnel makes employee turnover costly from the company's standpoint (Holtom and Burch). Understanding the factors that affect employee turnover helps companies develop strategies to avoid them and create an environment conducive to working comfortably and supportively in the organization. Further, employees have an excellent opportunity to express their views about leaving decisions, and employees make company changes.

Methodology

The study used a questionnaire as the primary data-gathering method, as questionnaires are convenient for collecting data from a sample group. Thus, the population for this study comprises Employees of three Apparel factories in the Kandy district. They are Linea Clothing, Smart Shirts (Lanka) Ltd. and Nobelswear (Pvt) Ltd. There are over 1800 sewing machine operators in these apparel companies. So, the population of the study can be accounted for 1800 sewing machine operators in the above three apparel companies. The list of machine operators in the apparel companies is taken, and 317 machine operators are chosen as the sample based on the Morgan sampling table to collect data randomly. The study used a random sampling

method and randomly chosen machine operators from the above population to collect first-hand data. The IBM SPSS statistical software was used to analyze the data gathered from the sample group. The data was presented and analyzed using descriptive statistics, reliability, correlation, and regression analysis. Descriptive analysis was used in the study to show demographic data; consistency of the data set was tested using the reliability technique called Cronbach's alpha; the relationship between four variables and employee turnover was assessed using correlation analysis, the impact of variables Job satisfaction, Working conditions, Work-life balance, and Monetary Benefits on employee turnover among sewing machine operators were examined to test the hypotheses using regression analysis.

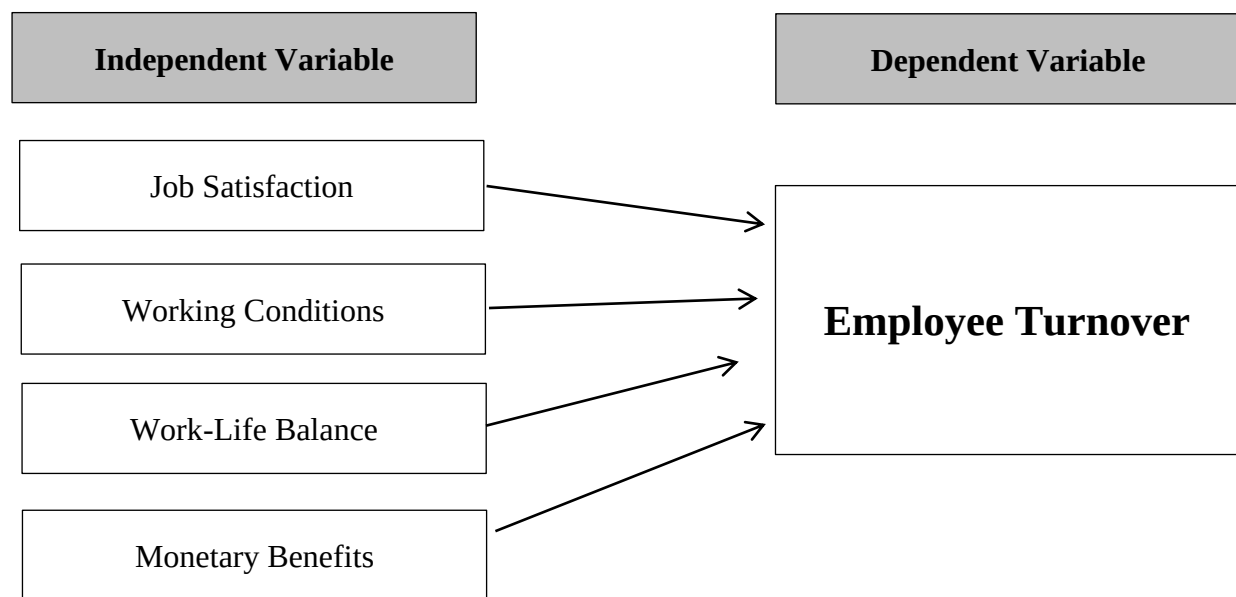


Figure 1: Conceptual Framework

H₁: Job satisfaction have an impact on employee turnover of the sewing machine operators

H₂: Working conditions have an impact on employee turnover of the sewing machine operators

H₃: Work-life balance have an impact on employee turnover of the sewing machine operators

H₄: Monetary Benefits have an impact on employee turnover of the sewing machine operators

Results

Table 1: reliability analysis of variables of the study

Variable	Cronbach's Alpha
Employee turnover	0.567
Job satisfaction	0.518
Working condition	0.629
Work-life balance	0.552
Monetary benefits	0.555

Source: Extracts of SPSS software analysis

Normal P-P Plot of Regression Standardized Residual

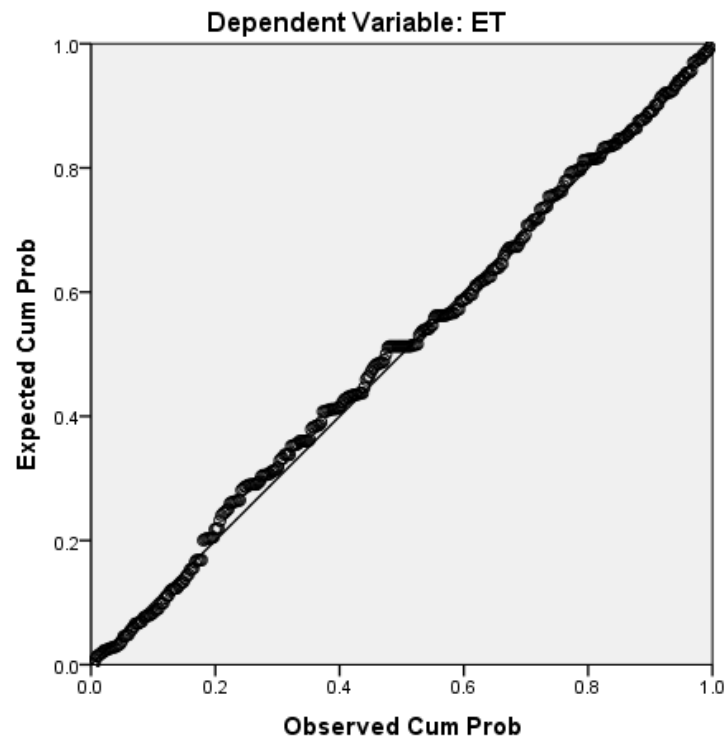


Figure 2: Normality of residuals (Normal P-P Plot)

Source: Extracts of SPSS software analysis

Table 2: correlation analysis of variables

		ET	JS	WC	WLB	MB
ET	Pearson Correlation	1	-.707**	-.788**	-.839**	-.831**
	Sig. (2-tailed)		.000	.000	.000	.000
	N	374	374	374	374	374
JS	Pearson Correlation	-.707**	1	.765**	.697**	.677**
	Sig. (2-tailed)	.000		.000	.000	.000
	N	374	374	374	374	374
WC	Pearson Correlation	-.788**	.765**	1	.799**	.778**
	Sig. (2-tailed)	.000	.000		.000	.000
	N	374	374	374	374	374
WLB	Pearson Correlation	-.839**	.697**	.799**	1	.977**
	Sig. (2-tailed)	.000	.000	.000		.000
	N	374	374	374	374	374
MB	Pearson Correlation	-.831**	.677**	.778**	.977**	1
	Sig. (2-tailed)	.000	.000	.000	.000	
	N	374	374	374	374	374

** . Correlation is significant at the 0.01 level (2-tailed).

Source: Extracts of SPSS software analysis

Table 3: model summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.868 ^a	.753	.750	.23220

a. Predictors: (Constant), MB, JS, WC, WLB

b. Dependent Variable: ET

Source: Extracts of SPSS software analysis

Table 4: Statistical significance of the model

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	60.673	4	15.168	281.324	.000 ^b
	Residual	19.896	369	.054		
	Total	80.569	373			

a. Dependent Variable: ET

b. Predictors: (Constant), MB, JS, WC, WLB

Source: Extracts of SPSS software analysis

Table 5: Regression analysis coefficient table

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	5.704	.113		50.494	.000
	JS	-.145	.043	-.138	-3.361	.001
	WC	-.233	.046	-.247	-5.023	.000
	WLB	-.284	.126	-.286	-2.255	.025
	MB	-.263	.120	-.266	-2.197	.029

a. Dependent Variable: ET

Source: Extracts of SPSS software analysis

Conclusion and recommendations

This study was conducted mainly due to the increasing employee turnover in the apparel sector and the need for sufficient literature related to the topic. Employee turnover has been a critical problem for the apparel sector, as it incurs extra costs for the company to hire employees, and on the other hand, training and development costs for former employees are a waste for the company. Hence, it is critical to identify factors that impact employee turnover intentions in Sri Lanka's apparel sector. Regression analysis, which was used to test the hypotheses, revealed that all the independent variables, namely, job satisfaction, working conditions, work-life balance, and monetary benefits, negatively and significantly impact employee turnover. It suggests that all four alternative hypotheses are accepted, and the null hypotheses are rejected. Thus, the apparel sector can apply the necessary solutions and tactics to enhance these factors and reduce turnover among sewing machine operators. In addition, such tactics will help companies improve their performance and reduce costs associated with hiring and selecting employees.

So, it is recommended to conduct excellent levels of communication to enhance the knowledge of employees and inform them regarding every aspect of the company; fair treatment to all employees, including pay, and due recognition for excellent performance, clearly articulating

the roles and responsibilities of employees to avoid mismatches between jobs and levels. Further, providing adequate training and promotions to make the tasks of employees easy and enhance their skills to get publicity, which is the provision of conducive working environmental factors like proper seating arrangements, ventilation, furniture, machinery, etc., may avoid stress. In addition, providing opportunities to organize recreational activities, fun activities, and trips to avoid boredom, designing an easy job while letting employees have enough time to spend with their families, and provide attractive remuneration packages for each level, considering their job title, cost of living, bonuses, and allotments.

References

- Dheerasinghe, R., 2009. Garment Industry in Sri Lanka. *Staff Studies*, pp. 33-72.
- Kelegama, S. & Epaarachchi, R., 2001. *Productivity, Competitiveness and Job Quality in Garment Industry in Sri Lanka*, s.l.: s.n.
- Opatha, H., 2021. Towards a Generic Model of Human Resource Management. *International Business Research*, 14(7).
- Peter Boxall, J. P., 2003. Strategy and Human Resource Management. *Industrial & Labor Relations Review*, 57(1).

IMPACT OF ONLINE ADVERTISING ON CUSTOMER ENGAGEMENT IN RETAIL FASHION INDUSTRY IN SRI LANKA

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Abstract

Advertising strategy of any organization has the ability, make the positive attitude within customer mind and improve the customer engagement. Therefore, this study has focused on the impact of online advertising on customer engagement with reference to the retail fashion industry in Sri Lanka. Therefore, the research has been proceeding under the deductive approach with the practice of explanatory study as accordance with the research objectives. The study was based on survey research strategy; thus data has been gathered through a structured questionnaire. Data has been analyzed on regression analysis and correlation analysis through the use of SPSS and it has revealed that there is a positive impact of online advertising on customer engagement as mentioned in the published literature. Managerial and academic implications which are uncovered by the researcher, can be applied to improve the performance of future researches.

Key words: Online advertising, customer engagement, retail fashion industry

Introduction

The study has been conducted aiming to identify the impact of online advertising on customer engagement with reference to the retail fashion industry. With the risen of digital era, it has redesigned customer requirements as well as customer engagement with the business firm. With the digitalization of the processes it has been become more convenient and cost effective for both customer and the business firm. Similarly, all the marketing functions has been reshaped as accordance with the digitalized environment. Online advertising refers to attempting to influence the buying behavior of the customers by providing a persuasive selling message about the product and services through websites and social media platforms. With the regular online advertising it is possible to improve the customer engagement towards to the products and brands due to the high customer reachability of the available platforms. Therefore, this research study has been conducted aiming to identify the level of strength of online advertising strategies practiced by the retail fashion business firms to improve the customer engagement.

Methodology

Considering the nature of research objectives, the study has been based on deductive approach, which enables to researcher to analyze the applicability of pre-developed theory or model. Mark Saunders et al (2011), has defined deductive research approach as the research approach involving the testing of a theoretical proposition by the employment of a research strategy specifically designed for the purpose of its testing. In the deductive approach, the research

starts with hypotheses and continues with empirical examination in order to confirm or reject them; therefore, it is connected with positivist paradigm (Bryman and Bell, 2011).

As accordance with the deductive strategy, the study has been proceeded as per the quantitative research approach (Collis and Hussey, 2009). Quantitative researches study objective theories by investigating the relationships among variables (Creswell, 2009) which has been applied to test the impact of quality of online advertising on customer engagement. Thus following main hypothesis has been tested from this particular research study.

H₁ - Online advertising has a significant positive impact on customer engagement in retail fashion industry

Population of this study consisted of all the consumers using online websites and social media to get information on different fashion brands. Sample has been selected based on snow ball sampling technique which enables to reach to respondents easily. Data has been gathered through a structured questionnaire prepared as a google form based on the requirement of structure of the research. Gathered data has been analyzed with the support of SPSS.

Results

A sample of the study consisted of 200 participants, combination of 79% female respondents and 21% male respondents. This indicates that female consumers are more likely to interact with retail fashion brands on social media. Age demographics of the sample indicates that 72.1% of respondents were in between 20-30 years old. Sample has been consisted of 83% of urbanized respondents while 16% of respondents live in sub urban areas. With reference to the employability of the sample, Majority of the respondents are employed which was 66% while one third of respondents (33%) of the sample are non-employed. Next it has tested the respondents' behavior of using social media and online shopping websites, since those are the major available online advertising strategies. Majority of the respondents have surfed in social media which is 83% and least number of respondents were checking for dresses on online shopping websites.

It has proceeded a reliability analysis to check the consistency of the gathered information. Here it has considered the Cronbach's alpha value of the variables.

Table 1: Reliability Test

Variable	Number of Dimension	Cronbach's Alpha
Quality of online advertising strategy	3	0.831
Customer engagement	4	0.929

As a result, it can be observed that the items assess the variables and structures mentioned in an effective manner, which qualifies them for further analysis. A high degree of internal consistency is suggested by the positive Cronbach's alpha values, which also show that the data collected from survey respondents is with highly reliability.

Table 2: Validity Test

Variable	KMO Measure of Sampling Adequacy	Bartlett's Test of Sphericity
online advertising strategy	0.818	0.000
Customer engagement	0.898	0.000

Validity is the measure of the accuracy and reliability of information within a dataset or database. Since KMO and Bartlett's Test value of all the variables was more than 0.8, the validity of the data set is at the accepted level and it can be identified the adequacy of the data set. Bartlett's test of Sphericity was employed in this study to assess if the correlation matrix of the observed variables differs significantly from an identity matrix. Hence both values are lower than 0.05 there is a significance correlation in between variables.

Table 3: Correlation analysis

No	Independent variables (Dimensions of advertising value)	Dependent variable (Customer engagement)	p-value
1	Informativeness	0.852**	0.000
2	Entertainment	0.898**	0.000
3	Credibility	0.823**	0.000

Above table demonstrates the results of correlation analysis for online advertising strategy and customer satisfaction. Pearson correlation coefficients suggest that there is strong positive relationship between all the dimensions of service quality variable and customer satisfaction. Among all the service quality dimensions' entertainment has the highest positive correlation with customer engagement.

Regression analysis

The R-value denotes a strong correlation, with a value of approximately 95%. This indicates a high level of correlation between online advertising and customer engagement. The R-square value indicates the proportion of variance in the dependent variable (customer engagement) that can be accounted for by the independent variable (online advertising).

The F-ratio, which compares two mean square values, serves as an indicator of whether the variation among group means exceeds what would be expected by chance. A higher F-ratio indicates a more pronounced relationship between the variables. In this study, the F-value of 202.111, with 5 and 139 degrees of freedom (df), and a probability of occurrence by chance of less than 0.001 ($F = 202.111$, $P = <0.001$), indicates a statistically significant relationship between social media marketing and customer engagement. Consequently, the findings suggest that online advertising positively and significantly influences the enhancement of customer engagement.

Moving to the co-efficient table of regression analysis, it can be observed that, the P value of informativeness, entertainment and credibility is lesser than 0.05 (informativeness =0.000,

entertainment = 0.000 and credibility = 0.001); thus there is a significance relationship between online advertising and customer engagement.

Discussion

Successful online advertising strategy encourage positive customer behavior with an attractive content (Mishra & Mahalik, 2017) which can be similarly applicable in this study as well. Further Liang & Chen (2009) have argued that a good quality website always lead to strong customer relationships which leads to positive customer engagement. As discussed earlier, social media advertising can be identified as one form of online advertising. Published literature argued that there is a positive relationship between social media marketing and customer engagement (Wanigasekara et al., 2024) Persuasive content of an advertisement such as emotional and philanthropic content, has a positive impact on customer engagement (Hosanagar et al., 2013). Comparatively this study has identified informative content can increase the customer engagement.

Conclusion and Recommendations

Based on the results generated through data analysis, it is possible to observed that there is a significance positive impact of online advertising on customer engagement in retail fashion industry of Sri Lanka based on the significant level of 0.05. The testing hypothesis shows that customer engagement can be increased through an advertisement with quality and credible information and entertaining content. It has suggested fashion retailers should present their contents on social media platforms regularly and need to focus on trending strategies of online advertising such as short video contents as future managerial implications. Further future studies are possible to base on single online advertising strategies with the expansion of social media platforms and websites with the utilization of alternative sampling strategies as academic implications.

References

- Bryman, A. and Bell, E. (2011) Business Research Methods. 3rd Edition, Oxford University Press, Oxford
- Collis, J. and Hussey, R. (2009) Business Research: A Practical Guide for Undergraduate and Postgraduate Students. 3rd Edition, Palgrave Macmillan, Basingstoke.
- Creswell, J. W. (2009). Research Design: Qualitative, Quantitative, and Mixed Methods Approaches (3rd ed.). Thousand Oaks, CA: Sage Publications.
- Lee, D., Hosanagar, K. & Nair, H., 2013. The Effect of Advertising Content on Consumer Engagement; s.l.: Research Gate.
- Liang, C. J., & Chen, H. J. (2009). A Study of the Impacts of Website Quality on Customer Relationship Performance. Total Quality Management & Business Excellence, 20, 971-988. <https://doi.org/10.1080/14783360903181784>

Mahalik, D. K. & Mishra, A., 2017. IMPACT OF ONLINE-ADVERTISING ON CONSUMERS.. International Journal of Advanced Research , 5(10.21474/IJAR01/4615), pp. 1935-1939.

Saunders, M.N., Saunders, M., Lewis, P. and Thornhill, A. (2011) Research Methods for Business Students. 5th Edition, Pearson Education, Essex.

Wanigasekara, I., Yasara, I. & Abeysekara, N., 2024. Impact of Social Media Marketing on Customer Engagement in an. International Journal of Research and Scientific Innovation, XI(ISSN No. 2321-2705), pp. 968-987.

**DETERMINANTS OF USER PREFERENCE TOWARDS DIGITAL ACCOUNTING
INSTRUMENTS: A STUDY ON SMALL-SCALE ENTERPRISES IN THE
THIMBIRIGASYAYA DIVISIONAL SECRETARIAT AREA**

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Abstract

Purpose of this study was to investigate the determinants of user preference towards the digital accounting instruments (DAI) in the small scale enterprises. This study was carried out complying with positivism research philosophy and employed deductive approach using the quantitative method. Population of the study consists of 538 small scale enterprises located in Thibirigasyaya divisional secretariat area of Sri Lanka. The study was carried out based on a sample and sample size was decided as 217 based on Morgan's table. Sample was drawn using simple random sampling technique. A survey questionnaire was administered among the sample respondents to gather primary data. Data presentation and analysis were carried out using descriptive statistics, correlation analysis and multiple regression analysis with the support of SPSS (version 27). This study concluded that trust towards the digital accounting instruments and financial capability make a significant impact on the user preference towards digital accounting instruments of the small scale enterprises. This also concluded that proficiency in digital accounting, technology orientation and customer expectations are insignificant in predicting user preference towards digital accounting instruments. The present study recommends the suppliers of digital accounting instruments to take actions to enhance their customer's trustworthiness towards the digital accounting instruments and to provide their products at reasonable price. This further recommends the government entities which involves in small business development to provide awareness programs to increase trust towards digital accounting systems among the small enterprises and to provide them a financial support to install digital accounting instruments.

Keywords: Digital accounting instruments, User preferences

Introduction

Digital accounting instruments (DAI) are technological advancements that offer comprehensive solutions beyond traditional bookkeeping methods (Velasco, 2024). These tools provide businesses with improved capabilities for financial record-keeping, real-time data analysis, and strategic decision-making (Smith, 2024). Billing machines, cash registers, electronic invoicing systems, Point of Sale (POS) systems, and accounting software are widely used to optimize financial processes (Bouchrika, 2025).

The small and medium enterprise sector (SME) represents over 75% of Sri Lanka's total businesses, contributing approximately 52% to the nation's Gross Domestic Product (GDP) of the nation (Kulasinghe, 2018). However, as concluded by Kulasinghe (2018) despite the advantages of DAI are popular, they are remain underutilized, particularly among small-scale enterprises (Kulasinghe, 2018). In contrast, the supply arm of digital accounting solutions for the SME sector has been gradually increasing since recent past (Dissanayake, 2022). But these suppliers are lacking with a clear understanding about what factors determine the user preference (UPN) towards DAI. This lacuna has created some difficulties and drawbacks to the DAI suppliers in effectively approaching the small scale enterprises with their standard and customized DAIs (Bouchrika, 2025).

The current study investigates the determinants of UPN towards DAI of small scale enterprises in Thimbirigasyaya Divisional Secretariat area of Colombo, Sri Lanka, where small-scale businesses experience challenges in transitioning from traditional manual methods to digital accounting systems. Findings of this study provide a significant insight to the suppliers of DAI on what determinants determine the UPN towards DAI of small scale enterprises. This knowledge can be used by the DAI suppliers to customize their products and promote the products complying with their customers' UPN. Further, findings of the study are significant for the government entities that cater the small business sector to take policy decisions to motivate the small enterprises to move towards DAI. Finally, findings of this study will provide an opportunity to the small-scale enterprises to identify key determinants which shape their preference towards DAI.

Research Question

- What are the determinants of user preferences towards the digital accounting instruments in the small-scale enterprises of Thibirigasyaya Divisional Secretariat Areas, Sri Lanka?

Research Objectives

Main Objective

- To examine the determinants of user preferences towards the digital accounting instruments in the small-scale enterprises of Thibirigasyaya Divisional Secretariat Areas, Sri Lanka.

Secondary Objectives

- To study the impact of trust towards the digital accounting instruments on user preferences towards the digital accounting instruments in the small-scale enterprises.
- To study the impact of proficiency in digital accounting on user preferences towards the digital accounting instruments in the small-scale enterprises.
- To study the impact of technology orientation on user preferences towards the digital accounting instruments in the small-scale enterprises.
- To study the impact of financial capability on user preferences towards the digital accounting instruments in the small-scale enterprises.
- To study the impact of customer expectations on user preferences towards the digital accounting instruments in the small-scale enterprises.

Methodology

Sampling and Data collection

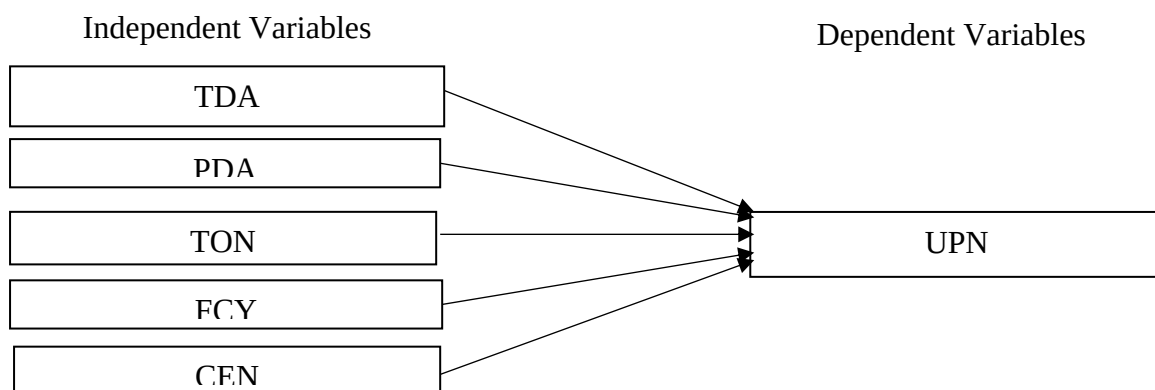
This research was conducted complying with positivism research philosophy. Deductive approach was employed and quantitative method was used. The study targeted small-scale enterprises of Thimbirigasyaya divisional secretariat area of Sri Lanka with a total population of 538 enterprises (BNR, 2024). The study carried out on sample basis and the sample size was determined as 217 respondents with guidance of Morgan's Table (Krejcie and Morgan, 1970). Simple random sampling technique was used to draw the sample from the population by giving them an equal opportunity for being selected for the sample. Primary data were collected by administering a survey questionnaire among the respondents and the questionnaire consists of closed end questions to gather demographic data of the respondents and Five Point Likert Scale question statements to gather data on the perceived status of the respondents on the research variables. Cronbach alpha analysis was conducted to test the data reliability. Sampling adequacy was tested using KMO analysis. Pearson correlation analysis was employed for test the relationship between the independent variables and the dependent variable whilst the impact of independent variables on the dependent variable was tested by multiple regression analysis.

Conceptual Framework

As concluded by Dissanayake (2022); Vaidyanathan (2017) trust in accounting instruments (TDA) is a significant predictor of user preference (UPN) towards DAI. Proficiency in digital accounting (PDA) makes a significant impact on UPN (Kitchil, 2024); Balasuriya, 2018). As empirically proved by Kumarasinghe, (2020); Abeygunasekara, (2023) technology orientation (TON) is a strong determinant of UPN. UPN is further affected by financial capability (FCY) (Wided Dafri, 2023); (Masaar, 2024) and customer experience (CEN) (Zanat, 2024); (Broløs, 2024).

Conceptual framework illustrates the logical relationship exist between the independent variables of a scientific study (Sekaran, 2016). As shown by Figure 1, TDA, PDA, TON, FCY and CEN are the independent variables of the study. UPN is recognized as the dependent variable.

Figure 1: Conceptual Framework



Source: Author Construct (2024)

Hypotheses

H1: Trust towards digital accounting instruments makes an impact on user preferences towards the digital accounting instruments in the small-scale enterprises of Thibirigasyaya Divisional Secretariat Areas, Sri Lanka

H2: Proficiency in digital accounting makes an impact on user preferences towards the digital accounting instruments in the small-scale enterprises of Thibirigasyaya Divisional Secretariat Areas, Sri Lanka

H3: Technology orientation makes an impact on user preferences towards the digital accounting instruments in the small-scale enterprises of Thibirigasyaya Divisional Secretariat Areas, Sri Lanka.

H4: Financial capability makes an impact on user preferences towards the digital accounting instruments in the small-scale enterprises of Thibirigasyaya Divisional Secretariat Areas, Sri Lanka

H5: Customer expectations make an impact on user preferences towards the digital accounting instruments in the small-scale enterprises of Thibirigasyaya Divisional Secretariat Areas, Sri Lanka.

Results and Discussion

Reliability

Reliability of the data set was measured with Cronbach's Alpha analysis. Pallant (2020) pointed out that the data set is reliable if the Cronbach's Alpha value is greater than 0.7. As shown by Table 1, Cronbach's Alpha values of all the research constructs are greater than 0.7. This confirms that the dataset used for the study is reliable.

Table 1: Reliability of research variables

Variable		Cronbach's Alpha values	N of Items	Reliability status
Independent	TDA	0.977	05	Reliable
	PDA	0.950	05	Reliable
	TON	0.979	05	Reliable
	FCY	0.963	05	Reliable
	CEN	0.713	05	Reliable
Dependent	UPN	0.963	08	Reliable

Source: Author Construct (2025)

Validity

Apart from reliability, validity of the data set is needed for further analysis. The Kaiser-Meyer-Olin (KMO) method gives a significant understanding about data validity. KMO value gets between 0.0-1.0 and if this value gets between 0.8- 1.0 sampling is adequate for factor analysis and it gives an idea about data validity Pallant (2020). As shown by Table 2, the KMO value of the data set of the current study is 0.972. This confirms the sampling adequacy and it gives an idea about data validity.

Table 2: Sample adequacy

KMO and Bartlett's Test		
Kaiser-Meyer-Olin Measure of Sampling Adequacy.		.972
Bartlett's Test of Sphericity	Approx. Chi-Square	12986.861
	df	528
	Sig.	.000

Source: Author Construct (2025)

Demographic profile of the respondents

As per the descriptive analysis 72.8% of the sample respondents are male entrepreneurs whilst the rest of them i.e. 27.2% are females. Majority of the respondents i.e. 31.3% belongs to the age range of 35-44 years whilst 29.5% are in the age range of 25-34%. 54.8% of the respondents have completed their secondary education and 99% of the sample have completed at least their secondary education. Only 17.2% of the respondents have less than 1 year entrepreneurial experience. Majority of the business i.e. 31.3% are having with 1-3 years of entrepreneurial experience whilst 54% of the sample respondents possess more than four years of experience in their own businesses.

Correlation analysis

Correlation analysis was conducted to show the relationships exist between the independent variables and the dependent variables (Table 3).

Table 3: Correlation between independent and dependent variables

No	Independent variables	Dependent variable (UPN)
1	TDA	.922**
2	PDA	.875**
3	TON	.906**
4	FCY	.921**
5	CEN	.762**

** . Correlation is significant at the 0.01 level (2-tailed).

Author Construct (2025)

As per table 3, Correlation values between TDA and UPN gets 0.922 whilst the correlation between TON and UPN gets 0.906 at the significance level of 0.01. Further, correlation between FCY and UPN gets 0.921 at the significant level of 0.01. These statistical figures demonstrate that TDA, TON and FCY have strong positive relationships with UPN. Correlation between PDA and UPN gets 0.875 and this also denotes that there is a strong positive relationship between them. The lowest correlation values exist between CEN and UPN i.e. 0.762. This figure shows that there is a significant positive relationship between the variables.

Regression analysis

Multiple regression analysis was carried out to show the impact of independent variables on the dependent variables. Regression outcomes were summarized in Table 4.

Table 4: Summary of the regression analysis

Method		Linear		
Adjusted R Square		0.891		
F		350.402 at sig level of 0.000		
B-Constant		0.059		
Independent Variable	B	Beta	t	Sig
TDA	0.405	0.398	5.854	0.000
PDA	0.070	0.077	1.315	0.190
TON	0.097	0.100	1.401	0.163
FCY	0.346	0.358	5.258	0.000

CEN	0.059	0.050	1.28	0.200

Source: Author Construct (2025)

As demonstrated by Table 4, adjusted R square of the regression model is 0.891 whilst F= 350.402 at $p=0.000 < \alpha = 0.01$. This confirms that 89.1% variation of dependent variable i.e. user preferences is explained by the five determinants i.e. TON, PDA, TDA, CEN and FCY hence the multiple regression model is fit to explain the impact of independent variables on the dependent variable.

Multiple regression model is as follows.

$$UPN = 0.059 + 0.405_{TDA} + 0.07_{PDA} + 0.097_{TON} + 0.346_{FCY} + 0.059_{CEN}$$

As per the regression model beta coefficient of TDA is 0.398 at $p = 0.00 < \alpha = 0.05$ and $t = 5.854$ and these statistical evidence prove that TDA is a significant predictor of UPN. This support to accept the hypothesis 01 which stipulates that trust towards digital accounting instruments makes an impact on user preferences towards the digital accounting instruments in the small-scale enterprises. Further, beta coefficient of FCY is 0.346 at $p = 0.00 < \alpha = 0.05$ and $t = 5.258$ and these statistical evidence also prove that FCY is a significant predictor of UPN. Accordingly, the 04th hypothesis i.e. financial capability make an impact on user preferences towards the digital accounting instruments is also accepted. However, beta coefficient of PDA is 0.077 at $p = 0.190 > \alpha = 0.05$ and $t = 1.315$ whilst beta coefficient of TON gets 0.100 at $p = 0.163 > \alpha = 0.05$ and $t = 1.104$. What these statistical figures emphasize is that neither PDA nor TON are significant predictors of UPN. This does not support to accept 2nd and 3rd hypotheses. Furthermore, beta coefficient of CEN gets 0.050 at $p = 0.200 > \alpha = 0.05$ and $t = 1.28$. These statistical figures confirm that CEN is insignificant in predicting UPN. Accordingly, this statistical analysis does not support to 5th hypothesis which stipulates that customer expectations make an impact on user preferences towards the digital accounting instruments in the small-scale enterprises. Summary of hypotheses testing is shown by Table 5.

Table 5: Summary of hypotheses testing

Independent Variable	Dependent Variable	Hypothesis	
		H ₀	H ₁
TDA	UPN	Rejected	Accepted
PDA		Accepted	Rejected
TON		Accepted	Rejected
FCY		Rejected	Accepted
CEN		Accepted	Rejected

Source: Author construct (2025)

Discussion

As revealed by this study trust towards digital accounting instruments makes a significant impact on user preferences towards digital accounting instruments in the small-scale enterprises. This finding is compatible with the previous findings of (Dissanayake, 2022) and (Vaidyanathan, 2017). Accordingly, (Kitchil, 2024); (Balasuriya, 2018) proficiency in digital accounting makes an impact on user preferences towards the digital accounting instruments in the small-scale enterprises. However, the findings of current study are contradicted with these previous literature as it statistically proved that proficiency in digital instruments is insignificant in determining user preference. As denoted by (Kumarasinghe, 2020); (Abeygunasekara, 2023) technology orientation of the small-scale enterprises makes significant impact on user preferences towards digital accounting instruments. However, the current study statistically found that technology orientation does not make a significant impact on user preference towards digital accounting system. According to (Dafri, 2023) and (Masaar, 2024) financial capability makes an impact on user preferences towards the digital accounting instruments in the small-scale enterprises. This study also statistically found that financial capability of small enterprises is a significant predictor of user preference towards digital accounting instruments. The current study does not agree with (Sbm, 2021) and (Sarawagi, 2024) who have concluded that customer expectations make an impact on user preferences towards the digital accounting instruments in the small-scale enterprises.

Conclusions and Recommendations

This study concludes that trust towards digital accounting instruments and financial capability make a significant impact on user preferences towards the digital accounting instruments in the small-scale enterprises of Thibirigasyaya Divisional Secretariat Area, Sri Lanka. However, proficiency in digital accounting, technology orientation and customer expectations do not make a significant impact on user preferences towards the digital accounting instruments in the small-scale enterprises of this areas. Based on the conclusions, this study recommends the

suppliers of digital accounting instruments to take whatever possible actions to improve the trust towards the digital accounting instruments to attract more small scale enterprises to their products. This study also recommends the digital accounting instruments suppliers to offer their products at a reasonable price as the user preference is highly affected by the financial capability of small scale customers. This also recommends the government entities that involves in small business development to conduct awareness programs to motivate small scale enterprises to move towards efficient digital accounting instruments. This study finally recommends such government institutes to provide financial support services to introduce digital counting instruments to the small scale business. The conclusions of this study were drawn focusing on a single divisional secretariat area of Colombo, District Sri Lanka. However, this study suggests the future researchers to do a comprehensive study on the same topic focusing on a much broader geographical area Such as Colombo District, Western Province or entire country as a whole.

References

- Abeygunasekara, N. R., 2023. *Impact of Digital Transformation on the Performance of SMEs*. [Online]
Available at: <http://ir.lib.ruh.ac.lk/bitstream/handle/iruor/14835/75%20%28247-262%29.pdf?sequence=1&isAllowed=y>
[Accessed 10 12 2024].
- Balasuriya, M., 2018. *Taking accountancy into the digital age*. [Online]
Available at: <https://www.ft.lk/Special-Report/Taking-accountancy-into-the-digital-age/22-664428>
[Accessed 10 12 2024].
- BNR, 2024. *Department of Business Names Registration, Western Province*. [Online]
Available at: <https://bnr.wp.gov.lk/>
[Accessed 10 12 2024].
- Bouchrika, I., 2025. *18 Best Accounting Software in 2025*. [Online]
Available at: <https://research.com/software/best-accounting-software>
[Accessed 07 01 2025].
- Dafri, W., 2023. *Challenges and opportunities to enhance digital financial transformation in crisis management*. [Online]
Available at: <https://www.sciencedirect.com/science/article/pii/S259029112300267X>
[Accessed 10 12 2024].
- Dissanayake, C. T. G., 2022. *Factors affecting the intention to use cloud accounting among Sri Lankan accounting professionals*. [Online]
Available at: <https://ijabf.sljol.info/articles/10.4038/ijabf.v8i1.119>
[Accessed 10 12 2024].

Educational and Psychological Measurement.

Sekaran, U. and Bougie, R. 2016. *Research Methods for Business: A Skill-Building Approach*. 7th ed. West Sussex: Wiley & Sons.

Kitchil, N., 2024. *A New Era for Aspiring Accountants: Equipping Students with Skills*. [Online]

Available at: <https://www.sundaytimes.lk/241215/education/a-new-era-for-aspiring-accountants-equipping-students-with-skills-580646.html>

[Accessed 10 12 2024].

Krejcie, R.V. and Morgan, D.W. 1970. *Determining Sample Size for Research Activities*.

Kulasinghe, S., 2018. *Catalyzing Small and Medium-sized Enterprise Venture Capital in Sri Lanka*. [Online]

Available at: <https://www.adb.org/publications/catalyzing-sme-venture-capital-sri-lanka>

[Accessed 04 12 2024].

Kumarasinghe, H. A., 2020. *The Impact Of Digitalization On Business Models With Special Reference To Management Accounting In Small And Medium Enterprises In Colombo District*. [Online]

Available at: https://www.researchgate.net/publication/340461003_The_Impact_Of_Digitalization_On_Business_Models_With_Special_Reference_To_Management_Accounting_In_Small_And_Medium_Enterprises_In_Colombo_District

[Accessed 10 12 2024].

Masaar, 2024. *Digital Technology: New Opportunities, Persistent Challenges in Developing and Poor Countries*. [Online]

Available at: <https://masaar.net/en/digital-technology-new-opportunities-persistent-challenges-in-developing-and-poor-countries/>

[Accessed 10 12 2024].

Pallant, J. 2020. *SPSS survival manual: A step-by-step guide to data analysis using IBM SPSS*. Routledge. Available at: <https://doi.org/10.4324/9781003117452> [Accessed 28 January 2025].

Sarawagi, A. G. D. M. S. S. S. B., 2024. *Evaluating the effectiveness of digital accounting applications for small and medium enterprises: A user-centric approach*. [Online]

Available at: https://www.researchgate.net/publication/382059670_Evaluating_the_effectiveness_of_digital_accounting_applications_for_small_and_medium_enterprises_A_user-centric_approach

[Accessed 10 12 2024].

Sbm, 2021. *"Small Businesses' Obstacles & Opportunities with Digital Accounting Software"*. [Online]

Available at: https://smallbusinessmajority.org/sites/default/files/research-reports/small-businesses-obstacles-opportunities-digital-accounting-software.pdf?utm_source=chatgpt.com

[Accessed 10 12 2024].

Smith, D., 2024. *How Has Technology Impacted Bookkeeping Practices: Modern Accounting Evolved*. [Online]

Available at: <https://accountingforeveryone.com/how-has-technology-impacted-bookkeeping-practices/>

[Accessed 04 12 2024].

Vaidyanathan, N., 2017. *Ethics and Trust in the Digital Age*. [Online] Available at: https://www.accaglobal.com/content/dam/ACCA_Global/Technical/Future/pi-ethics-trust-digital-age.pdf

[Accessed 10 12 2024].

Velasco, C., 2024. *Virtual Accountants vs Traditional Bookkeepers*. [Online] Available at: <https://insboss.net/virtual-accountant-vs-bookkeeper/>

[Accessed 04 12 2024].

IMPACT OF DIGITAL BANKING ON FINANCIAL PERFORMANCE OF ABC BANK

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Abstract

To better understand how digital banking affects ABC Bank's financial performance, this study looks at important performance metrics such the rate of digital adoption, operational effectiveness, and customer happiness. It is essential to comprehend how digital transformation is affecting conventional financial organizations as it changes the banking landscape.

The implementation of digital banking services has improved ABC bank's profitability, decreased operating expenses, and raised client engagement, according to the findings of the study. Aside from that, the study emphasizes how important user experience is and how cutting-edge technology like AI and machine learning can be integrated to improve service delivery.

By offering insights for policymakers and banking executives to effectively strategize in an increasingly digital environment, this study adds to the expanding body of literature on digital banking. The results highlight the need for banks to continuously innovate and adjust for shifting customer preferences to maintain a competitive edge in the digital era.

Keywords: Digital banking, financial performance, customer experience, customer satisfaction, operation, efficiency, Artificial intelligence

Introduction

Digital banking has transformed the financial services sector, compelling institutions like ABC Bank to rethink strategies. To assess the impact of ABC's strategic investments in digital platforms, the research focusses on the firm's revenue growth, cost-to-income ratio and ROE. The significance of this study is that it contributes to the knowledge about how the change in banking sector towards digital banking affects the financial performance of legacy or incumbent of ABC Bank. By addressing the challenges of increasing competition, operational costs, and changing customer needs, the research aims to inform ABC's strategy for achieving sustained growth.

ABC has revealed equalization of definitive performance indicators like ROE and NIM in the last three years; high operational charges and digital platform fee revenue are to be blamed. Despite the bank's attempt to enhance digital customer contacts, it has not registered significant positive changes in financial performance that elicits questions the efficacy of its digital transformation plan (ABC, 2022). The study undertaken by McKinsey (2023) reveals that more than 65% of banking customers prefer to go digital and ABC is behind its peers such as JP

Morgan, Chase and Barclays where digital customer base is above 70%. By 2023, ABC's global revenues shrank by 4% due to slow digital adoption acts in core regions; Asia, and Europe where digital-first entrants have taken market share at great speed. ABC's cost-to-income ratio, a KPI of operational efficiency, remains above 60%, compared to the industry average of 55%, indicating inefficiency in leveraging digital technology (Weng, 2024). According to Gurumurthy et al (2024), banks that invest in digital technologies experience a 30% increase in revenue growth and a 25% reduction in operational costs within three years of implementation. ABC's underperformance in this regard suggests a gap in its digital strategy.

Research Questions

1. How does the digital adoption rate among ABC's customers influence the bank's overall financial performance, particularly in terms of revenue growth and profitability?
2. To what extent does operational efficiency, as driven by ABC's digital banking transformation, impact on its financial performance indicators such as cost-to-income ratio and net profit margin?
3. What is the relationship between customer experience and satisfaction with ABC's digital banking services and the bank's financial performance, including customer retention and overall profitability?

Objectives of the Study

1. To evaluate the impact of digital adoption rates among ABC's customers on the bank's financial performance, focusing on key metrics such as revenue growth and profitability.
2. To evaluate the influence of operational efficiency, driven by digital banking initiatives, on ABC's financial performance, particularly in terms of the cost-to-income ratio and net profit margin.
3. To evaluate the relationship between customer experience and satisfaction with ABC's digital banking services and its impact on financial performance, including customer retention and profitability.

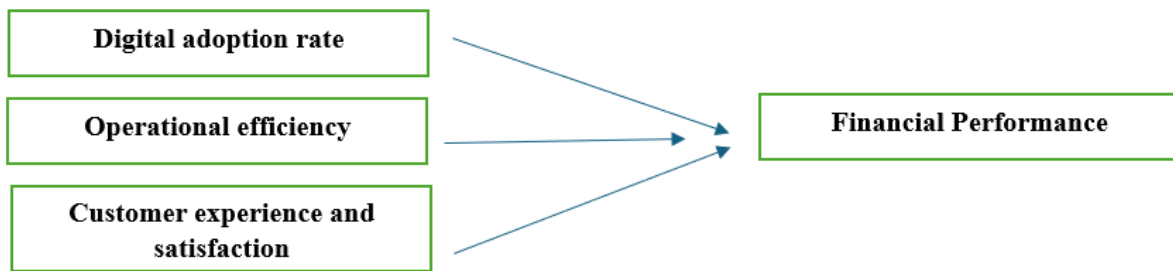
Methodology

To measure financial performance from the customers' point of view, the study has considered determining factors like savings, transactions, trust and access. Cost effectiveness, security and convenience determine the financial viability of an investment clients' point of view.

Through online transactions and broadening access to financial services digital banking contributes to better financial performance as experienced by customers in turn determines how well or bad-off bank financially.

Conceptual Framework

Figure 1: Conceptual Framework



Statement of Hypothesis

H0a: There is no impact between digital adoption rate and financial performance.

H1a: There is an impact between digital adoption rate and financial performance.

H0b: There is no impact between operational efficiency and financial performance.

H1b: There is an impact between operational efficiency and financial performance.

H0c: There is no impact between customer experience, satisfaction and financial performance.

H1c: There is an impact between customer experience, satisfaction and financial performance.

This study adopted positivism as its research philosophy, quantitative data to ensure systematic and objective analysis. Deductive research approach was used to develop hypotheses from existing theories which were then tested using empirical data (Gilgun, 2019). A survey approach through a structured Likert-scale questionnaire (1-5) was used to gather data, all which have been designed to facilitate systematic collection of quantitative information. The study employed a cross-sectional time horizon to gather information within a specific period to assess how digital banking services were currently used and alleged relevance on financial performance (Tsang, 2016). The information analyzed via IBM SPSS that both descriptive and inferential statistics obtained.

Sampling Design

The sampling technique used was non-probability convenience sampling where participants recruited were ABC customers who engaged in both mobile banking and internet banking.

Population

ABC's customers as the population are justified for the following reasons:

1. Customer transactions and behavior influence financial performance.
2. Digital banking adoption is a KPI.
3. Operational improvements from customer perspective impact on financial performance.
4. Customer satisfaction as a mediator of financial performance.

Sample Selection Procedure

ABC's customers were done through convenience sampling on a voluntary basis.

Sample Size

A sample of 384 respondents arrived using Morgan's Table to have a statistical representation of the wide customer base which allowed for conclusions regarding the influence associated with digital banking towards financial performance.

Results

Actual Sample Description

Table 1: Actual sample

Selected sample size	Actual standard responds	Response rate
385	380	94.6%

Reliability Analysis

Table 2: Summary of reliability

The Variable	Cronbach's Alpha	Reliability	Conclusion
Digital adoption rate	.736	.736>0.7	Reliable
Operational efficiency	.833	.833>0.7	Reliable
Customer experience and satisfaction	.706	.706>0.7	Reliable
Financial performance	.738	.738>0.7	Reliable

Descriptive Analysis

Table 3: Descriptive analysis

Statistics					
		Digital adoption rate	Operational efficiency	Customer experience and satisfaction	Financial performance
N	Valid	380	380	380	380
	Missing	0	0	0	0
Mean		4.5382	4.4750	4.5217	4.4053
Median		4.5000	4.5000	4.7500	4.5000
Mode		5.00	5.00	5.00	4.00
Std. Deviation		.41316	.52261	.41733	.36490
Minimum		3.50	3.00	3.50	3.75
Maximum		5.00	5.00	5.00	5.00

Demographic Characteristics Analysis

Gender

Table 4: Gender

Gender					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	104	27.4	27.4	27.4
	Female	276	72.6	72.6	100
	Total	380	100	100	

Number of Years Being an ABC Customer

Table 5: Number of years being an ABC customer

Years of being a customer					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Less than 1 year	3	0.8	0.8	0.8
	1-3 years	248	65.3	65.3	66.1
	4-6 years	86	22.6	22.6	88.7
	7-10 years	36	9.5	9.5	98.2
	More than 10 years	7	1.8	1.8	100
	Total	380	100	100	

How often do you use ABC'S Digital Banking Services?

Table 6: Digital Banking Services usage

ABC's digital banking services					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Daily	176	46.3	46.3	46.3
	Weekly	99	26.1	26.1	72.4
	Monthly	105	27.6	27.6	100
	Total	380	100	100	

Which Digital Banking Platforms of ABC Do You Use the Most?

Table 7: Digital Banking Platforms of ABC

Digital banking platforms of ABC					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Digital Wallets Integration	40	10.5	10.5	10.5
	Online Banking via Desktop	89	23.4	23.4	33.9
	ATM Services	91	23.9	23.9	57.9
	Mobile App	160	42.1	42.1	100
	Total	380	100	100	

Testing hypothesis

Regression Analysis

Table 8: Model Summary

Model Summary^b					
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.394 ^a	.155	.148	.33677	1.935
a. Predictors: (Constant), Customer Experience and Satisfaction, Digital Adoption Rate, Operational Efficiency					
b. Dependent Variable: Financial Performance					

Table 9: Coefficient

Coefficients^a						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	3.859	.209		18.442	.000
	Digital Adoption Rate	.214	.068	.229	2.675	.009
	Operational Efficiency	.322	.060	.462	5.351	.000
	Customer Experience and Satisfaction	.554	.068	.634	8.152	.000
a. Dependent Variable: Financial Performance						

Table 10: Summary of Hypothesis

H#	Hypotheses	T Value	P value	Status
H1 _a	There is a significant positive relationship between the digital adoption rate and financial performance	2.675	0.009	Accepted
H1 _b	There is a significant positive relationship between operational efficiency and financial performance	5.351	0	Accepted
H1 _c	There is a significant positive relationship between customer experience and satisfaction and financial performance	8.152	0	Accepted

Correlation Analysis

Table 11: Correlation between digital adaptation rate and financial performance

Correlations			
		Digital Adoption Rate	Financial Performance
Digital Adoption Rate	Pearson Correlation	1	.737
	Sig. (2-tailed)		.000
	N	380	380
Financial Performance	Pearson Correlation	.737	1
	Sig. (2-tailed)	.000	
	N	380	380

Table 11, digital adoption rate: higher adoption is tied to better financial outcomes because there is a high positive correlation ($r=0.737$) with financial performance.

Table 12: Correlation between operational efficiency and financial performance

Correlations			
		Operational Efficiency	Financial Performance
Operational Efficiency	Pearson Correlation	1	.779
	Sig. (2-tailed)		.000
	N	380	380
Financial Performance	Pearson Correlation	.779	1
	Sig. (2-tailed)	.000	
	N	380	380

Table 12, operational efficiency: financial performance was most affected by operational efficiency ($r=0.779$), which involved cutting costs and using resources efficiently.

Table 13: Correlation between customer experience and financial performance

Correlations			
		Customer Experience and Satisfaction	Financial Performance
Customer Experience and Satisfaction	Pearson Correlation	1	.729**
	Sig. (2-tailed)		.000
	N	380	380
Financial Performance	Pearson Correlation	.729**	1
	Sig. (2-tailed)	.000	
	N	380	380
**. Correlation is significant at the 0.01 level (2-tailed).			

Table 13, customer satisfaction: correlation coefficient ($r=0.729$) shows to retain clients and be profitable, ABC Bank should adopt user-friendly and secure digital platforms.

Table 14: Overall correlation

Correlations					
		Digital Adoption Rate	Operational Efficiency	Customer Experience and Satisfaction	Financial Performance
Digital Adoption Rate	Pearson Correlation	1	.769**	.705**	-.037
	Sig. (2-tailed)		.000	.000	.470
	N	380	380	380	380
Operational Efficiency	Pearson Correlation	.769**	1	.774**	-.070
	Sig. (2-tailed)	.000		.000	.171
	N	380	380	380	380
Customer Experience and Satisfaction	Pearson Correlation	.705**	.774**	1	.186**
	Sig. (2-tailed)	.000	.000		.000
	N	380	380	380	380
Financial Performance	Pearson Correlation	-.037	-.070	.186**	1
	Sig. (2-tailed)	.470	.171	.000	
	N	380	380	380	380
**. Correlation is significant at the 0.01 level (2-tailed).					

Discussion

Impact of Digital Adoption Rates on Financial Performance

The locations of digital adoption rates and company performance are coherent. Nguyen-Thi-Huong et al. (2023) who argued that there is better customer response and efficient operations in the digital space. It was noted by Madusanka and Kumari (2021) that an increase in digital maturity by only 10% may lead to increased profits ranging between 2% - 4%. The adoption of mobile applications and internet services by ABC bank has increased the number of customer transactions while at the same time decreasing operating expenses, which in turn cut across client satisfaction. Through digital adoption, ABC can offer uniform cost-efficient services and hence improve its financial position in general.

Impact of Operational Efficiency on Financial Performance

The analysis shows that the level of operational efficiency exerts significant influence on the financial performance for ABC. According to Bahl et al. (2022) financial performance is affected by operational efficiency, with special reference to the role played by automation on decreasing costs while increasing both effectiveness and efficiency. ABC has been able to optimize its resources by lowering the cost related to income; this is supported by Mor and Gupta (2021) who stated that technology raises efficiency levels by 15%. Through big data analytics, there is improved streamlined operational risk management due to better understanding of individual clients' behaviors.

Impact of Customer Experience and Satisfaction on Financial Performance

According to Lohano et al. (2024) customer experience and satisfaction have a positive relationship with financial performance. It pointed out that usability, security, and service reliability contribute towards customer loyalty. The modern technologies such as AI chatbots and individual digital solutions have led to an increased customer base within different organizations; this is evidenced by Huseynov (2023) which shows that AI increased retention by 20%. ABC bank has been able to increase its market share and the loyalty of customers through strategies which include focusing on user-friendly interfaces, making transactions safe and offering quick support services.

Conclusions and Recommendations

The researcher concluded that financial performance should serve as the key dependent variable. Digital adoption rate, operational efficiency, and customer experience and satisfaction should also be considered as dependent variables of the study. The research indicates the following:

1. Digital adoption rate has a significant impact on financial performance, hence the H1a hypothesis was accepted.
2. Digital operational efficiency rate has a significant impact on financial performance, hence the H1b hypothesis was accepted.
3. Customer experience and satisfaction have had a significant impact on financial performance, hence the H1c hypothesis was accepted.

The goals of this study could be attained because its hypotheses were tested. The objective was accomplished by establishing links between possible causes.

ABC should prioritize digital transformation to enhance customer satisfaction and corporate performance. Key recommendations include increasing digital adoption by improving user-friendly, secure mobile apps and online platforms, integrating AI and big data for better engagement. Operational efficiency can be boosted through advanced technologies and automation, optimizing back-office processes, and reducing costs. Enhancing customer experience through robust feedback mechanisms and personalized digital services is crucial for retention and satisfaction.

References

- ABC. (2022). ABC in Sri Lanka. *ABC* [Online] Available at: <https://www.about.hsbc.lk/hsbc-in-sri-lanka> [Accessed: 19 August 2024].
- Bahl, K., Kiran, R. and Sharma, A. (2022) Impact of drivers of change (digitalization, demonetization, and consolidation of banks) with mediating role of nature of training and job enrichment on the banking performance. *SAGE Journals* [Online]. Available at: <https://doi.org/10.1177/21582440221097393> [Accessed: 31 August 2024].
- Calculater.net (2024) Morgon online calculation tool. *Calculater.net* [Online]. Available at: <https://www.calculator.net/sample-size-calculator.html> [Accessed: 12 October 2024].
- Gilgun, J. F. (2019) Deductive qualitative analysis and grounded theory: sensitizing concepts and hypothesis-testing. *The SAGE Handbook of Current Developments in Grounded Theory*, pp.107–122. SAGE [Online]. Available at: DOI: <https://doi.org/10.4135/9781526485656.n7> [Accessed: 28 August 2024].
- Gurumurthy, R., Schatsky, D. and Camhi, J. (2024) Uncovering the connection between digital maturity and financial performance. *How Digital Transformation Can Lead To Sustainable High Performance*. Deloitte [Online]. Available at: <https://www2.deloitte.com/us/en/insights/topics/digital-transformation/digital-transformation-survey.html> [Accessed: 18 August 2024].
- Huseynov, F. (2023) Chatbots in digital marketing: enhanced customer experience and reduced customer service costs. *Contemporary Approaches of Digital Marketing and the Role of Machine Intelligence*. IGI-Global [Online]. Available at: 10.4018/978-1-6684-7735-9.ch003 [Accessed: 31 August 2024].
- Lohano, N. R., Jariko, N. M. A. and Memon, N. M. (2024) The influence of digital banking services on financial performance: a focus on customer experience. *Progressive Research Journal of Arts & Humanities (PRJAH)*, 6(1), pp. 88–100. *Prjah* [Online]. Available at: <https://doi.org/10.51872/prjah.vol6.Iss1.311> [Accessed: 2 September 2024].
- Madusanka, K. A. E. and Kumari, D. A. T. (2021) Antecedents of customer adoption on digital banking with special reference to non-banking financial institutes in Sri Lanka. *South Asian*

Journal of Finance, 1(1), pp. 61–79. *SAJF* [Online]. Available at: DOI: 10.4038/sajf.v1i1.28 [Accessed: 31 August 2024].

McKinsey & Company (2023) Banking profits are up, thanks to rising interest rates, but financial institutions globally need to reinvent themselves in the face of major structural and macroeconomic shifts. McKinsey [Online]. Available at: <https://www.mckinsey.com/industries/financial-services/our-insights/global-banking-annual-review> [Accessed: 17 August 2024].

Mor, S. and Gupta, G. (2021) Artificial intelligence and technical efficiency: The case of Indian commercial banks. *Strategic Change*, 30(3), pp. 235–245. Wiley [Online]. Available at: <https://doi.org/10.1002/jsc.2406> [Accessed: 2 September 2024].

Nguyen-Thi-Huong, L., Nguyen-Viet, H., Nguyen-Phuong, A., and Van Nguyen, D. (2023). How does digital transformation impact bank performance? *Cogent Economics & Finance*, 11(1).

Tsang, E. W. K. (2016) *The Philosophy of Management Research*. 01st ed. Taylor and Francis [Online]. Available at: <https://www.taylorfrancis.com/books/mono/10.4324/9781315463216/philosophy-management-research-eric-tsang> [Accessed: 5 September 2024].

Weng, W. (2024) Qatari banks most efficient worldwide with 21.5% average cost-to-income ratio. *Tabinsights* [Online]. Available at: <https://tabinsights.com/article/qatari-banks-most-efficient-worldwide-with-215-average-cost-to-income-ratio> [Accessed: 18 August 2024].



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Chapter 02:
CONSTRUCTION

CHARACTERIZE AND ANALYZE FEASIBILITY OF THE MEGA SCALE PROJECTS IN THE INFRASTRUCTURE SECTOR IN SRI LANKA

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Abstract

Transportation is a major aspect of infrastructure building in Sri Lanka, and railways are one of those important public transport modes. Considering this fact, there are two railway projects at a national level taken into consideration in the present research work: one is the Colombo Light Rail Transit System, and the other one is a new railway line from Matara to Katharagama. The comparison and analyses are based on their shortcomings and benefits. These are assessed mainly from the perspective of environmental impact, socioeconomic effects, cost-benefit considerations, and transit implications. From these main variables, 18 sub-factors were identified through the various literature reviews. Refinement of benefits and costs of the projects were further assessed through semi-structured interviews with experts in infrastructure. It also enumerates that the comparison of the identified factors in projects and constraints, and the setting for future research into balancing achievements against goals for subsequent initiatives into infrastructure projects are needed.

Keywords: Cost- Benefit Analysis, Economic Impact, Environmental Analysis, Feasibility Analysis, Infrastructure Projects.

Introduction

Sri Lanka, given its strategic position in the Indian Ocean, contemplates ambitious infrastructure development programs put into place, which would aim at economic growth and regional connectivity. Mega-scale infrastructure development projects involve port development, energy facilities, and transport networks, among others, that are very much needed in socio-economic objectives. However, detailed feasibility studies must be conducted on whether these mega-projects can generate profits and are sustainable, in keeping with the national priorities in development. A feasibility evaluation should be done in terms of various factors, such as financial, technical, economic, environmental, social, and regulatory aspects. The study analyzes the complexities of project feasibility evaluation in the Sri Lankan context and seeks to understand approaches, challenges, and best practices involved in the same. The main objective is to present a definition and examination of mega-scale infrastructure projects executed in Sri Lanka, identifying the balance between advantages and disadvantages concerning impacts on the environment and the community. It also covers two railway infrastructure development projects at the national level by weighing their respective benefits and drawbacks.

Literature Review

Infrastructure Development Project in the World

In developing countries, infrastructure development is a determining factor in the process of economic progress and improvement in livelihood. Yet, inadequacies persist due to poor maintenance, inefficiency, and misallocated investment. These challenges demand better policymaking, mechanisms of incentive compatibility, and prioritizing infrastructure maintenance over high-profile projects.

Large-Scale Infrastructure Development Projects in the World

Large infrastructure plans are set for East Africa, primarily in the transport sectors, to improve tourism and environmental sustainability. The challenges include procedures, large territories, and high selection costs. Effective stakeholder management will ensure that any port development is done sustainably.

Feasibility Analysis of the Projects

Indonesia also plans to cooperate with Google regarding the distribution of equal internet access, including feasibility study activities. Such feasibility studies include expressions of techniques for understanding the Internet. Every investment project requires a socio-economic feasibility study.

Light Rail Transit Infrastructure Development Projects in the World

The project of Hamilton Light Rail is zero-emission and environment-friendly, not like what this history-based city of Hamilton has ever considered; the building process should not be carried on without considering the challenges and implications of a neoliberal ideology that it brings with it.

Railway Infrastructure Development Projects in the World

According to Kovacevic et al. 2016, Croatian railway infrastructure shows a tendency to deteriorate due to an absence of appropriate maintenance, whereas Irandu & Owilla 2020 stated that Africa can benefit from BRI investments.

Methodology

Mathara- Katharagama New Railway Line

The Mathara-Katharagama New Railway Line and the Colombo LRT Project are other infrastructural projects in Sri Lanka. Mathara-Katharagama New Railway Line, belonging to the Ministry of Transportation, was laid from Mathara to Katharagama with a length of 114.5 kilometers. This is a project sponsored by the Export-Import Bank of China and China National Machinery Export and Import Cooperation; it aims to make rail and road transport more competitive, facilitate community travel in rural areas, and bring in more visitors in the haunted locations within Southern Province.

Figure 1: Mathara – Katharagama Railway Extension Project Proposal Route



Colombo Light Rail Transit Project (Lrt)

The Light Rail Transit Colombo project, under construction in Sri Lanka, is a mass rapid light rail system that will uplift the urban environment and help in the social and economic development of the Western Region. The project covers a length of 75 km with seven lines and will be implemented in seven phases. These will minimize congestion in traffic, air pollution, and the use of private vehicles. This will increase the riding skills of the people and reduce the rate of accidents. The project covers two geographical locations, which include the main depot in the Central Business District of Colombo and connected suburbs. Light rail is operated on fixed rails powered by electricity connected with a pole or rod. The cities to be covered in the project are those within the Western Region.

Figure 2: Colombo LRT Project



Consist of Methodology

Data from both primary and secondary sources were extracted to analyze the factors that influence acceptable quality in construction. Primary data would include information from a survey, interview, experiment, and questionnaire, while the secondary source includes websites, reports, and documents on infrastructure projects precisely related to railway development. The analysis was based on questionnaires and interviews with project managers, engineers, consultants, environmental officers, local authority officials, and users of public transport. Qualitative data from semi-structured interviews will be interpreted through content analysis, hence providing input from specialists in the construction industry.

Results and Discussion

To accomplish the goals, the study's findings were covered in the chapter. Statistical data analysis and quantification of qualitative data approaches were used to assess the data obtained from 35 respondents in a questionnaire survey and three semi-structured interviews. To help with understanding the outcomes and comparing the findings in order to meet the research goals, the data were displayed in tables and graphs.

An analysis of demographic data to give a clear image of the makeup and characteristics of the chosen sample with the target population, demographic data analysis was conducted. Here is a breakdown of the sample group's demographic values.

In the survey carried out to assess workability and feasibility in mega-scale projects, 35 professionals in the Sri Lankan infrastructure industry responded.

They comprised 45.7% contractors, 28.6% clients, and 25.7% consultants. The majority were civil engineers, amounting to 45.7%, whereas 57.1% had 1-5 years of experience.

The statement that the Colombo LRT Project affects livelihoods was agreed to by 54.3%, with a mean rating of 3.91, in comparison with 57.1% with a mean of 3.89 for Mathara-Katharagama Railway Line.

The impact of travel in Colombo agreed to by 45.7% with a mean of 4.31, while for Mathara it was 62.9% agreed to with a mean of 3.94.

The other responses that follow in sequence are health and safety, where 57.1% agreed for Colombo, with a mean of 3.86, and 54.3% for Mathara. Responses on job creation were 51.4% for Colombo with a mean of 4.37 and 54.3% for Mathara with a mean of 4.09.

Also, improvement in infrastructure saves travel time in Colombo, where 65.7% agreed with a mean of 4.29, while in Mathara 71.4% agreed with a mean of 3.97.

Other impacts, like accident costs, emissions, vehicle operating costs, traffic, noise, air quality, and water and soil quality, had favorable implications for the Colombo project.

High agreement was received for improving public transport in both questionnaires: 60% for Colombo responded to the mean of 4.40, while 62.9% for Mathara made a statement that corresponded to the mean of 4.03. Overall, data characterizes quite positive perceptions in both projects, often rating a little higher for the Colombo LRT.

Conclusion and Recommendation

The proposed LRT in Colombo will be constructed along the main artery roads, while other socio-economic impacts include loss of jobs as a result of disruptions of corporate operations. While this saves many workers and passengers due to reduced travel time, experts warn of health risks and safety hazards associated with the project such as noise and dust. This is costlier than the expansion at the new railway line in Matara-Kataragama. Yet, the LRT project has immense benefit to develop the economy of Sri Lanka and influence South tourism. The advantages of the project are improved road infrastructure and public transit. The disadvantages will be increased travel times, noise, air quality, and accident costs while reduced vehicle operating costs.

Conclusion

The infrastructural projects under discussion in the study are two major ones in Sri Lanka, namely the Matara-Kataragama new railway line extension project and the Colombo Light Rail Transit Project. The study was conducted under four main variables: environmental impact, socioeconomic impact, cost-benefit impact, and transport impact. So many sub factors have been identified primarily through literature reviews pertaining to these variables, and the study compares and contrasts these factors between the projects. To ensure assimilation of a wide range of perceptions and experiences, semi-structured interviews were conducted on professionals dealing in infrastructure construction regarding the advantages and disadvantages of such projects.

References

- Adama, O., 2017. Urban imaginaries: funding mega infrastructure projects in Lagos, Nigeria. *CrossMark*, 83(Springerlink.com), pp. 257-274.
- Aswicahyono, H. & Friawan, D., 2008. *Infrastructure Development in Indonesia*, s.l.: s.n.
- Ayogut, M., 2006. *Infrastructure Development in Africa: Prospects and Challenges*, s.l.: Economic Development in the Millennium.
- Budiyanto, S., Jamil, M. & Rahayu I. M., F., 2019. Feasibility Analysis of the Application of Project Loon as an Equitable Effort for Communication Infrastructure Development in Indonesia. *Journal Telekomunikasi dan Komputer*, 9(InComTech).
- Dooms, M., Verbeke, A. & Haezendonck, E., 2013. Stakeholder management and path dependence in large- scale transport infrastructure development ; the port of Antwerp case. *Journal of Transport Geograpy*, 27(Elsevier), pp. 14-25.
- Enns, C. & Bersaglio, B., 2019. *On the Coloniality of "new" Mega - Infrastructure Projects in East Africa*, s.l.: Research at Birmingham portal.
- Ingram, G. & Kessides, C., 1994. *Infrastructure for Development*, s.l.: Finance & Development.

Irandu, E. M. & Owilla, H. H., 2020. *The Economic Implications of Belt and Road Initiative in the Development of Railway Transport Infrastructure in Africa: The case of the Standard Gauge Railway in Kenya*, s.l.: Brill.

Kovacevic, M. S., Gavin, K., Oslakovic, I. S. & Bacic, M., 2016. A new methodology for assessment of railway infrastructure condition. *6th Transport Research Arena*.

Kristain, O., 2020. Infrastructure imaginaries. *The politics of Light Rail Projects in the age of Neoliberalism*, pp. 1811-1826.

Sheth, A. & Sarkar, D., 2020. Socio - Economic Feasibility Analysis for Sustainable Mass Rapid Transit Project in Western India. *Journal of Construction in Developing Countries*, Volume 25, pp. 129-151.

Topalovic, P., Carter, J., Topalovic, M. & Krantzberg, G., 2012. Light Rail Transit in Hamilton: Health, Environment and Economic Impact Analysis. *P. Topalovic e tal.*, pp. 329-350.

PRIORITISING DELAY FACTORS IN FIBER-REINFORCED CONCRETE PROJECTS IN SRI LANKA: A DUAL-METHOD ANALYSIS

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Abstract

Efficient delay management is considered vital in the performance of projects at construction sites, particularly in the projects of fiber-reinforced precast concrete-based developments. This research represents the delay factors in Sri Lankan projects by employing two analyses: Relative Importance Index and DEMATEL-ANP methods. According to the RII method, the most crucial delay is the shortage of skilled labour; on the other hand, DEMATEL-ANP finds poor project management in the contractor dimension. Comparing these methods, RII was straightforward to understand how the factors can be rated to immediately assess those factors, while there is depth in mapping interdependencies of factors by DEMATEL-ANP. Labour upskilling, proper project management, stakeholder coordination, and resource control could mitigate delay that was suggested. This adds to the present knowledge on delay determinants in Sri Lankan fiber-reinforced precast concrete construction and offers a base for strategic improvement of projects.

Keywords: Construction Delays, DEMATEL-ANP, Fiber-Reinforced Concrete, Project Management, RII

Introduction

Fiber-Reinforced Precast Concrete (FRPC) is a technology that gained significant prominence in the construction field with its enhanced mechanical performance, including high strength, ductility, and durability. All these make FRPC a viable alternative for both structural and environmentally friendly construction (Garcez et al., 2019). Due to increased demand for efficient and environmentally friendly construction worldwide, new techniques such as FRPC exhibit cost-saving and efficient use of resources in providing a project (Hampson et al., 2014). With its use in precast concrete, durability is increased and significant savings in materials can be attained with a sustained use of traditional precast sections (Plizzari and Mindess, 2019). Despite its many potentials, constructions related to FRPC in developing countries, including in Sri Lanka, face significant delays. Inadequacies in availability of resources, logistic ineffectiveness, and excessive controls through laws and legislation cause long-term timelines for a project (Perez and Mauricio, 2018). All these become impediments in widespread use of FRPC in the construction field in Sri Lanka. Hence, it is significant to detect and counteract key factors for delayed projects in order to maximize use of FRPC and timely delivery of a project.

Aim & Objectives

Aim

This research aims to identify and prioritize the critical delay factors in FRPC projects, based in Sri Lanka.

Objectives

The main objectives of this research are to:

1. Identify key delay factors in fiber-reinforced precast concrete construction projects in Sri Lanka.
2. Analyze interrelationships among delay factors across various dimensions (e.g., construction techniques, workforce, and resources).
3. Prioritize delay factors based on their impact on project delays.
4. Compare findings from DEMATEL-ANP and RII methods for a comprehensive understanding.
5. Provide recommendations to mitigate delays and improve project management practices.

Significance of the Study

The current research fills the existing knowledge gap in construction delay analysis by using a dual-method approach: the clear prioritization technique of RII and in-depth causal analysis using DEMATEL-ANP. The present study thus provides an intimate understanding of delay factors specific to FRPC projects in Sri Lanka and is, therefore, particularly relevant to stakeholders operating under similar developing contexts. Insights from this study are expected to help project managers, engineers, and policy-makers design specific initiatives through targeted interventions such as manpower training programs and improved resource planning that cut delays and improve FRPC project outcomes.

Scope and Limitations

This study covers only FRPC construction projects in Sri Lanka, and for that, the results may be of contextual relevance but could not have implications for other socio-economic and regulatory environments. Further research may also extend these findings onto other developing regions or use alternative methodologies that contribute to the further development of delay factor analysis.

Methodology

Research Strategy

The paper follows a quantitative approach for systematically evaluating and prioritizing delay factors in Sri Lankan FRPC projects. However, quantitative methods are chosen for capability to measure factor importance and analyze the interrelationships statistically (Ong and Puteh, 2017). RII is integrated with DEMATEL-ANP to obtain a direct ranking as well as a causal-network perspective. DEMATEL, in particular, demonstrates the cause-effect relationship

among the factors by constructing and normalizing a direct relation matrix while ANP extrapolates the Analytic Hierarchy Process to include interdependencies and feedback loop (Quezada et al., 2018). Combining these methods provides the analysis with an ability to understand the intricacies of causal delays structures, going beyond simple ranking to uncover the causal relationships between the factors and the rate of overall project performance.

Sample Selection

Professionals from different fields (e.g., team leaders, engineers, contractors) having FRPC experience in Sri Lanka were purposively sampled. In this regard, the respondents are sampled in such a way that they have the required knowledge and expertise to give valid and reliable information regarding FRPC construction projects, something that is specific to the project (Etikan et al., 2016).

Data Collection Methods

Data collection was carried out through an online structured questionnaire administered on selected participants. The design of the questionnaire was through a critical review related to literature and comprised closed-ended questions with the aim of applying ranking and rating of each factor's interdependency, as many delay factors were identified in the earlier studies.

Table 1. Structure of the Questionnaire.

Section	Description
Demographic Information	- Participants provided details such as role (e.g., engineer, project manager), years of experience, and involvement in FRPC projects.
	- This data helped validate respondents' expertise and contextualize their perspectives.
Influence of Each Delay Factor	- Participants rated the impact of delay factors (e.g., "Shortage of skilled labor") on FRPC project timelines in Sri Lanka.
	- A Likert scale ("No influence" to "Very high influence") was used.
	- Ratings were used to calculate the Relative Importance Index (RII) for ranking factors.
Pairwise Ranking of Delay Factors	- Respondents compared delay factors' direct influence on one another using a Likert scale.
	- Data was analyzed using the DEMATEL approach to determine cause–effect relationships among factors.

Based on this, the further response was done statistically using RII & DEMATEL-ANP method. For data analysis, MS Excel SPSS and SuperDecision software is used.

Results and Discussion

Results of Data Analysis

The data analysis of this study was conducted using the Relative Importance Index (RII), DEMATEL, and ANP methods to prioritize and understand the relationships between identified delay factors (Table) in fiber-reinforced precast concrete (FRPC) projects in Sri Lanka.

Table 2. Identified Delay Factors

Category	Delay factors
Construction Techniques (D1)	Inadequate design and detailing (F11)
	Inefficient modularization and prefabrication strategy (F12)
	Improper lifting operations (F13)
	Insufficient quality control and testing during production (F14)
Workforce (D2)	Shortage of skilled and experienced labour (F21)
	Inadequate training and upskilling of the workforce (F22)
	Workforce safety and health issues (F23)
Resources (D3)	Delayed delivery of materials (F31)
	Insufficient financial resources (F32)
	Inefficient logistics and supply chain management (F33)
Machinery (D4)	Breakdown or unavailability of specialized machinery (F41)
	Inefficient utilization of machinery (F42)
	Inadequate maintenance and repair of machinery (F43)
Clients (D5)	Unclear or changing project requirements (F51)
	Inadequate communication between clients and contractors (F52)
	Delays in client decision-making (F53)
Contractor (D6)	Incompetence or lack of experience of contractors (F61)
	Inadequate project management (F62)
	Inefficient communication and coordination among the project team (F63)
External Conditions (D7)	Adverse weather conditions (F71)
	Environmental factors such as natural disasters, pollution, and soil conditions (F72)
	Political instability and regulatory changes (F73)

DEMATEL Analysis

DEMATEL analysis provided a clear overview of interrelationships between identified delay factors.

Table 3 represents the Average Direct Relation Matrix, showing relations of one factor directly influencing another. From Normalized Direct Relation Matrix (

Table 4) and Total Relation Matrix (Table 5), F62 ("Inadequate project management") was determined as the most powerful cause factor, which had the highest value to influence other factors. Other critical influencers in the project ecosystem were: "Incompetence or lack of experience of contractors" F61, "Insufficient financial resources" F32, and "Delayed delivery of materials" F31.

Table 3. Average Direct Relation Matrix

	Average																						
	F11	F12	F13	F14	F21	F22	F23	F31	F32	F33	F41	F42	F43	F51	F52	F53	F61	F62	F63	F71	F72	F73	
F11	0.00	1.84	1.23	2.19	0.77	0.42	1.23	1.74	1.65	1.26	0.52	0.61	0.32	1.90	0.74	2.29	1.10	1.77	1.87	0.29	1.06	0.61	
F12	0.65	0.00	2.26	2.13	1.19	1.29	2.58	2.29	1.52	1.13	1.10	1.19	0.35	0.42	0.52	0.45	1.97	2.10	0.81	0.45	0.52	0.45	
F13	0.42	1.97	0.00	1.94	0.65	0.77	3.55	1.29	0.65	1.10	1.35	0.71	0.39	0.52	0.52	0.42	1.74	1.32	0.48	0.58	0.35	0.32	
F14	0.90	2.06	2.16	0.00	0.84	1.26	1.16	1.26	0.77	0.90	0.71	0.52	0.97	0.55	0.55	1.03	1.55	1.90	0.61	0.45	1.13	0.35	
F21	0.81	2.55	3.03	2.06	0.00	1.42	1.65	2.94	1.10	1.55	0.48	1.03	1.81	0.35	0.42	0.48	1.90	1.97	1.10	0.32	0.35	0.39	
F22	1.10	2.52	2.97	2.26	2.58	0.00	2.03	1.71	1.00	1.19	0.68	1.26	1.39	0.32	0.48	0.45	2.23	1.81	1.06	0.32	0.35	0.35	
F23	0.35	1.23	3.06	0.77	0.90	0.97	0.00	1.26	0.68	0.77	0.45	0.42	0.42	0.23	0.32	0.48	1.06	1.55	0.58	0.58	0.68	0.32	
F31	0.39	1.32	1.61	1.84	1.00	0.55	0.84	0.00	2.29	1.65	0.58	0.74	0.48	0.48	0.74	1.45	1.42	2.32	0.71	0.35	0.42	0.52	
F32	2.48	2.48	2.71	2.42	2.94	1.87	2.06	3.00	0.00	2.74	2.06	0.48	2.81	0.55	0.55	0.52	1.00	1.94	0.71	0.42	0.35	0.35	
F33	0.39	1.26	1.16	0.94	0.55	0.32	0.68	2.68	1.74	0.00	0.90	0.55	1.52	0.39	0.61	1.23	0.97	2.06	0.87	0.29	0.29	0.42	
F41	0.39	2.52	3.39	1.81	0.77	0.65	2.06	2.94	1.39	1.58	0.00	1.61	0.68	0.52	0.45	0.45	0.74	1.68	0.71	0.35	0.42	0.42	
F42	0.32	2.00	2.77	0.74	0.68	0.45	1.90	2.16	0.94	1.06	1.19	0.00	0.45	0.29	0.39	0.39	1.23	1.90	0.84	0.29	0.26	0.32	
F43	0.35	1.52	2.58	1.42	0.58	0.35	1.81	2.45	0.94	1.39	2.52	0.87	0.00	0.45	0.42	0.52	1.03	2.10	0.55	0.32	0.29	0.39	
F51	3.00	1.23	0.35	1.90	0.84	0.74	1.03	2.03	2.10	1.35	0.61	0.71	0.26	0.00	1.29	2.39	0.87	2.10	2.06	0.39	0.48	0.42	
F52	3.42	1.06	0.68	2.52	0.68	0.52	1.48	2.16	2.97	1.55	0.55	0.68	0.48	2.29	0.00	2.81	0.68	2.45	1.84	0.32	0.39	0.42	
F53	2.71	0.81	0.48	1.35	0.74	0.35	0.55	2.16	2.16	1.42	0.45	0.58	0.29	1.58	2.42	0.00	0.32	1.74	1.81	0.29	0.26	0.35	
F61	2.71	3.61	3.61	3.26	2.55	2.23	2.74	2.90	2.32	2.10	1.23	2.19	1.39	0.71	2.19	0.61	0.00	2.23	2.55	0.52	0.68	0.55	
F62	1.81	2.58	2.23	2.58	3.06	2.42	2.19	3.16	3.23	2.26	1.68	2.48	1.65	0.77	2.55	0.94	1.29	0.00	2.65	0.39	0.48	0.35	
F63	1.87	1.94	0.97	1.90	2.03	1.26	1.71	2.55	1.68	2.42	1.06	1.39	1.77	0.90	1.74	1.06	1.55	2.32	0.00	0.35	0.35	0.26	
F71	0.94	2.16	3.00	2.13	1.74	0.48	2.55	2.58	0.94	1.81	0.42	1.19	0.87	0.84	0.42	1.32	0.35	1.16	0.39	0.00	1.35	0.35	
F72	1.94	0.97	1.06	1.77	0.87	0.39	2.13	1.58	1.13	1.00	0.55	0.81	0.55	1.68	0.45	2.00	0.39	1.26	0.71	0.87	0.00	0.52	
F73	2.16	0.35	0.32	1.16	0.55	0.52	0.48	1.58	1.97	1.03	0.32	0.32	0.35	1.74	0.55	1.42	0.42	1.16	0.55	0.35	0.35	0.00	

Table 4. Normalize Direct Relation Matrix

	Normalize Direct Relation Matrix (D)																						
	F11	F12	F13	F14	F21	F22	F23	F31	F32	F33	F41	F42	F43	F51	F52	F53	F61	F62	F63	F71	F72	F73	
F11	0.00	0.04	0.03	0.05	0.02	0.01	0.03	0.04	0.04	0.03	0.01	0.01	0.01	0.04	0.02	0.05	0.02	0.04	0.04	0.01	0.02	0.01	
F12	0.01	0.00	0.05	0.05	0.03	0.03	0.06	0.05	0.03	0.02	0.02	0.03	0.01	0.01	0.01	0.01	0.04	0.05	0.02	0.01	0.01	0.01	
F13	0.01	0.04	0.00	0.04	0.01	0.02	0.08	0.03	0.01	0.02	0.03	0.02	0.01	0.01	0.01	0.01	0.04	0.03	0.01	0.01	0.01	0.01	
F14	0.02	0.04	0.05	0.00	0.02	0.03	0.03	0.03	0.02	0.02	0.02	0.01	0.02	0.01	0.01	0.02	0.03	0.04	0.01	0.01	0.02	0.01	
F21	0.02	0.05	0.07	0.04	0.00	0.03	0.04	0.06	0.02	0.03	0.01	0.02	0.04	0.01	0.01	0.01	0.04	0.04	0.02	0.01	0.01	0.01	
F22	0.02	0.05	0.06	0.05	0.06	0.00	0.04	0.04	0.02	0.03	0.01	0.03	0.03	0.01	0.01	0.01	0.05	0.04	0.02	0.01	0.01	0.01	
F23	0.01	0.03	0.07	0.02	0.02	0.02	0.00	0.03	0.01	0.02	0.01	0.01	0.01	0.00	0.01	0.01	0.02	0.03	0.01	0.01	0.01	0.01	
F31	0.01	0.03	0.03	0.04	0.02	0.01	0.02	0.00	0.05	0.04	0.01	0.02	0.01	0.01	0.02	0.03	0.03	0.05	0.02	0.01	0.01	0.01	
F32	0.05	0.05	0.06	0.05	0.06	0.04	0.04	0.06	0.00	0.06	0.04	0.01	0.06	0.01	0.01	0.01	0.02	0.04	0.02	0.01	0.01	0.01	
F33	0.01	0.03	0.03	0.02	0.01	0.01	0.01	0.06	0.04	0.00	0.02	0.01	0.03	0.01	0.01	0.03	0.02	0.04	0.02	0.01	0.01	0.01	
F41	0.01	0.05	0.07	0.04	0.02	0.01	0.04	0.06	0.03	0.03	0.00	0.03	0.01	0.01	0.01	0.01	0.02	0.04	0.02	0.01	0.01	0.01	
F42	0.01	0.04	0.06	0.02	0.01	0.01	0.04	0.05	0.02	0.02	0.03	0.00	0.01	0.01	0.01	0.01	0.03	0.04	0.02	0.01	0.01	0.01	
F43	0.01	0.03	0.06	0.03	0.01	0.01	0.04	0.05	0.02	0.03	0.05	0.02	0.00	0.01	0.01	0.01	0.02	0.05	0.01	0.01	0.01	0.01	
F51	0.06	0.03	0.01	0.04	0.02	0.02	0.02	0.04	0.05	0.03	0.01	0.02	0.01	0.00	0.03	0.05	0.02	0.05	0.04	0.01	0.01	0.01	
F52	0.07	0.02	0.01	0.05	0.01	0.01	0.03	0.05	0.06	0.03	0.01	0.01	0.01	0.05	0.00	0.06	0.01	0.05	0.04	0.01	0.01	0.01	
F53	0.06	0.02	0.01	0.03	0.02	0.01	0.01	0.05	0.05	0.03	0.01	0.01	0.01	0.03	0.05	0.00	0.01	0.04	0.04	0.01	0.01	0.01	
F61	0.06	0.08	0.08	0.07	0.05	0.05	0.06	0.06	0.05	0.05	0.03	0.05	0.03	0.02	0.05	0.01	0.00	0.05	0.05	0.01	0.01	0.01	
F62	0.04	0.06	0.05	0.06	0.07	0.05	0.05	0.07	0.07	0.05	0.04	0.05	0.04	0.02	0.05	0.02	0.03	0.00	0.06	0.01	0.01	0.01	
F63	0.04	0.04	0.02	0.04	0.04	0.03	0.04	0.05	0.04	0.05	0.02	0.03	0.04	0.02	0.04	0.02	0.03	0.05	0.00	0.01	0.01	0.01	
F71	0.02	0.05	0.06	0.05	0.04	0.01	0.05	0.06	0.02	0.04	0.01	0.03	0.02	0.02	0.01	0.03	0.01	0.03	0.01	0.00	0.03	0.01	
F72	0.04	0.02	0.02	0.04	0.02	0.01	0.05	0.03	0.02	0.02	0.01	0.02	0.01	0.04	0.01	0.04	0.01	0.03	0.02	0.02	0.00	0.01	
F73	0.05	0.01	0.01	0.03	0.01	0.01	0.01	0.03	0.04	0.02	0.01	0.01	0.01	0.04	0.01	0.03	0.01	0.03	0.01	0.01	0.01	0.00	

Table 5. Total Relation Matrix

	Total Relation Matrix (T)																						
	F11	F12	F13	F14	F21	F22	F23	F31	F32	F33	F41	F42	F43	F51	F52	F53	F61	F62	F63	F71	F72	F73	
F11	0.036	0.086	0.076	0.095	0.051	0.036	0.071	0.093	0.077	0.066	0.037	0.039	0.032	0.060	0.041	0.075	0.056	0.087	0.070	0.017	0.036	0.024	
F12	0.045	0.051	0.103	0.093	0.061	0.055	0.101	0.104	0.072	0.063	0.049	0.052	0.034	0.027	0.035	0.034	0.075	0.092	0.046	0.021	0.025	0.020	
F13	0.034	0.081	0.047	0.080	0.042	0.039	0.112	0.073	0.047	0.054	0.049	0.037	0.029	0.026	0.030	0.029	0.064	0.068	0.034	0.022	0.019	0.016	
F14	0.047	0.086	0.092	0.043	0.048	0.050	0.066	0.075	0.052	0.053	0.038	0.034	0.042	0.028	0.033	0.044	0.061	0.082	0.039	0.019	0.036	0.017	
F21	0.050	0.107	0.123	0.096	0.038	0.060	0.087	0.122	0.067	0.075	0.040	0.051	0.065	0.027	0.034	0.037	0.077	0.094	0.054	0.019	0.022	0.020	
F22	0.057	0.108	0.124	0.101	0.092	0.031	0.096	0.098	0.065	0.068	0.044	0.056	0.057	0.027	0.036	0.036	0.085	0.092	0.055	0.019	0.023	0.019	
F23	0.029	0.060	0.101	0.050	0.043	0.039	0.034	0.065	0.042	0.043	0.028	0.027	0.026	0.018	0.023	0.027	0.046	0.065	0.032	0.020	0.024	0.014	
F31	0.039	0.071	0.081	0.082	0.053	0.037	0.059	0.051	0.085	0.070	0.036	0.039	0.034	0.027	0.038	0.053	0.059	0.091	0.042	0.017	0.021	0.020	
F32	0.090	0.117	0.129	0.114	0.105	0.074	0.104	0.137	0.053	0.108	0.078	0.045	0.092	0.036	0.041	0.044	0.066	0.105	0.053	0.023	0.026	0.022	
F33	0.035	0.065	0.067	0.059	0.040	0.029	0.051	0.102	0.071	0.033	0.041	0.033	0.053	0.024	0.033	0.046	0.046	0.082	0.042	0.015	0.017	0.018	
F41	0.037	0.100	0.123	0.084	0.049	0.040	0.090	0.115	0.068	0.071	0.026	0.059	0.038	0.028	0.032	0.033	0.049	0.083	0.042	0.019	0.022	0.019	
F42	0.032	0.082	0.102	0.056	0.043	0.032	0.079	0.091	0.053	0.054	0.047	0.022	0.030	0.021	0.027	0.028	0.053	0.079	0.041	0.015	0.016	0.016	
F43	0.034	0.076	0.103	0.073	0.043	0.032	0.080	0.101	0.056	0.064	0.076	0.042	0.022	0.026	0.030	0.033	0.051	0.087	0.037	0.017	0.018	0.018	
F51	0.100	0.076	0.061	0.091	0.055	0.044	0.068	0.102	0.089	0.071	0.040	0.042	0.033	0.023	0.054	0.080	0.052	0.096	0.076	0.019	0.025	0.020	
F52	0.114	0.079	0.074	0.110	0.056	0.043	0.082	0.113	0.113	0.080	0.042	0.044	0.041	0.073	0.031	0.093	0.052	0.110	0.076	0.020	0.025	0.022	
F53	0.090	0.061	0.056	0.074	0.048	0.032	0.052	0.098	0.086	0.067	0.033	0.036	0.030	0.054	0.073	0.028	0.037	0.083	0.067	0.016	0.018	0.018	
F61	0.108	0.156	0.164	0.148	0.110	0.091	0.135	0.153	0.115	0.108	0.069	0.088	0.071	0.047	0.083	0.056	0.057	0.128	0.101	0.029	0.037	0.029	
F62	0.089	0.131	0.132	0.131	0.118	0.093	0.119	0.155	0.131	0.110	0.077	0.092	0.076	0.046	0.089	0.060	0.081	0.079	0.100	0.025	0.031	0.025	
F63	0.079	0.100	0.087	0.100	0.085	0.059	0.091	0.123	0.087	0.099	0.055	0.061	0.069	0.043	0.066	0.055	0.073	0.109	0.037	0.021	0.024	0.019	
F71	0.050	0.093	0.116	0.092	0.069	0.036	0.100	0.109	0.060	0.076	0.035	0.050	0.043	0.037	0.031	0.054	0.041	0.073	0.036	0.011	0.043	0.018	
F72	0.070	0.061	0.067	0.078	0.047	0.031	0.083	0.081	0.060	0.055	0.033	0.038	0.032	0.053	0.031	0.066	0.036	0.069	0.041	0.028	0.012	0.020	
F73	0.071	0.041	0.042	0.059	0.036	0.029	0.040	0.073	0.072	0.050	0.025	0.024	0.026	0.052	0.029	0.051	0.031	0.059	0.034	0.015	0.018	0.008	

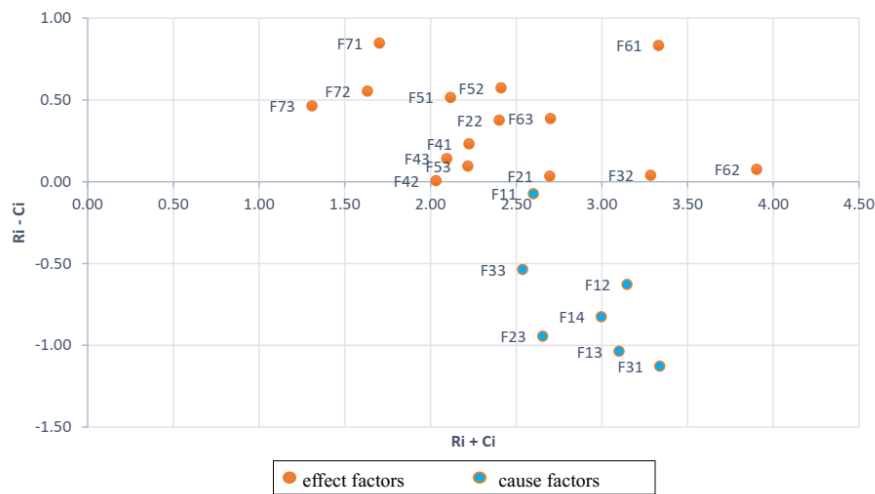
This would be further established in the sum of influences table,

Table 6, which classifies factors into causes or effects depending on values $R_i - C_i$. Furthermore, the diagram of causality, Figure 1, visualizes a mapping of this interdependence, with influences propagating out into a complex network in FRPC project delays. DEMATEL emphasises that any delay minimization must address basic management and resource issues.

Table 6. Sum of influences given to & received from other factors.

Factor	R_i	C_i	$R_i + C_i$	$R_i - C_i$	Identify
F11	1.2633	1.3369	2.6002	-0.0736	Effect
F12	1.2597	1.8875	3.1472	-0.6278	Effect
F13	1.0319	2.0686	3.1004	-1.0367	Effect
F14	1.0852	1.9113	2.9966	-0.8261	Effect
F21	1.3643	1.3306	2.6949	0.0337	Cause
F22	1.3885	1.0126	2.4011	0.3759	Cause
F23	0.8554	1.8001	2.6554	-0.9447	Effect
F31	1.1049	2.2337	3.3386	-1.1287	Effect
F32	1.6617	1.6218	3.2835	0.0399	Cause
F33	1.0007	1.5372	2.5379	-0.5365	Effect
F41	1.2282	0.9961	2.2243	0.2322	Cause
F42	1.0192	1.0127	2.0319	0.0065	Cause
F43	1.1184	0.9762	2.0945	0.1422	Cause
F51	1.3159	0.8003	2.1162	0.5156	Cause
F52	1.4929	0.919	2.4119	0.5739	Cause
F53	1.1563	1.0613	2.2176	0.095	Cause
F61	2.0819	1.249	3.3309	0.8329	Cause
F62	1.9893	1.9137	3.903	0.0756	Cause
F63	1.5426	1.1564	2.699	0.3862	Cause
F71	1.2744	0.4273	1.7017	0.8472	Cause
F72	1.0932	0.5392	1.6323	0.554	Cause
F73	0.8858	0.4224	1.3083	0.4634	Cause

Figure 1. Causal diagram for delay factors in Fiber reinforced prefabricated construction



ANP Analysis

The ANP analysis, by using the SuperDecisions software, realized detailed rankings of the delay factors by taking into consideration the dependences between the different dimensions. In Table 7: "Inadequate project management" F62 appeared as the most influential factor with a weight of 0.1907 and thus is of critical importance to construction delays.

Figure 2: Network showing interactions; the connections among the dimensions—like workforce and resources—are shown. The limiting matrix in Table 8 further reiterates the prioritization of factors based on the cumulative influence within the decision network, giving further strength to targeted improvements that must be carried out in project management and

Group	Delay Factor	Influential Weight	Rank
D1	F11	0.0084	17
	F12	0.0568	5
	F13	0.1254	4
	F14	0.0456	7
D2	F21	0.0235	11
	F22	0.0031	18
	F23	0.1520	3
D3	F31	0.1716	2
	F32	0.0532	6
	F33	0.0113	15
D4	F41	0.0085	16
	F42	0.0303	9
	F43	0.0220	12
D5	F51	0.0010	19
	F52	0.0392	8
	F53	0.0119	14
D6	F61	0.0153	13
	F62	0.1907	1
	F63	0.0301	10
D7	F71	0.0000	20
	F72	0.0000	21
	F73	0.0000	22

resource allocation for mitigating major delay risks effectively.

Table 7. Influential weights of delay factors in fibre reinforced prefabricated construction.

Figure 2. Interrelationship between dimensions

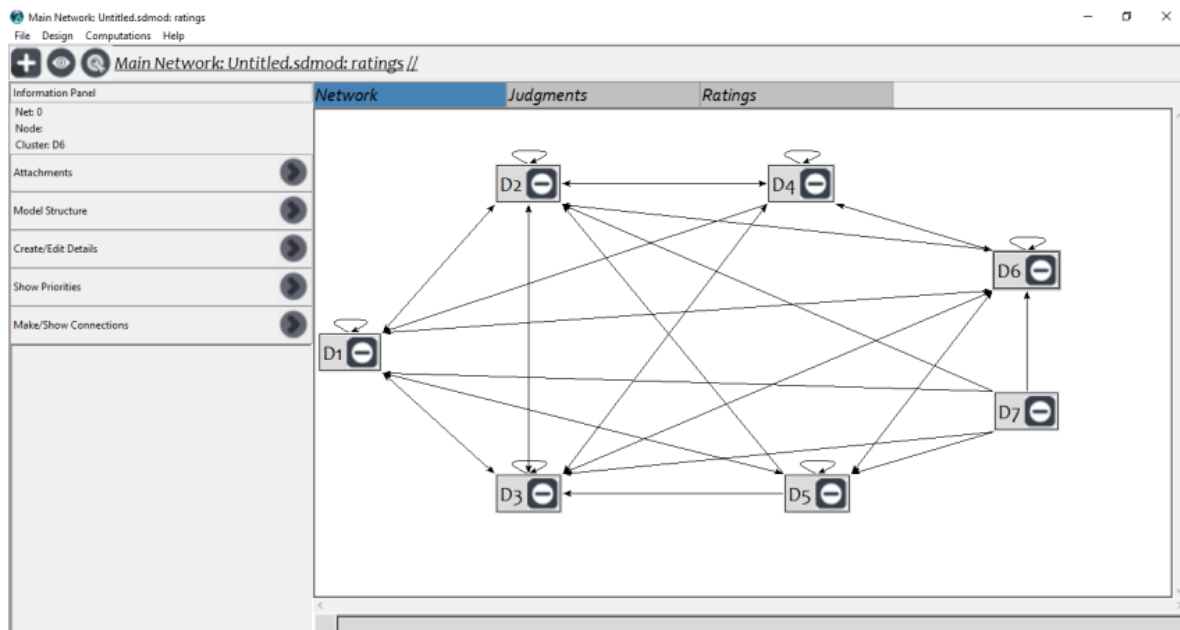


Table 8. Limit Matrix

Clus...	Nodes	F11	F12	F13	F14	F21	F22	F23	F31	F32	F33	F41	F42	F43	F51	F52	F53	F61	F62	F63	F71	F72	F73
D1	F11	0.008364	0.008364	0.008364	0.008364	0.008364	0.008364	0.008364	0.008364	0.008364	0.008364	0.008364	0.008364	0.008364	0.008364	0.008364	0.008364	0.008364	0.008364	0.008364	0.008364	0.008364	0.008364
	F12	0.056781	0.056781	0.056781	0.056781	0.056781	0.056781	0.056781	0.056781	0.056781	0.056781	0.056781	0.056781	0.056781	0.056781	0.056781	0.056781	0.056781	0.056781	0.056781	0.056781	0.056781	0.056781
	F13	0.125378	0.125378	0.125378	0.125378	0.125378	0.125378	0.125378	0.125378	0.125378	0.125378	0.125378	0.125378	0.125378	0.125378	0.125378	0.125378	0.125378	0.125378	0.125378	0.125378	0.125378	0.125378
	F14	0.045621	0.045621	0.045621	0.045621	0.045621	0.045621	0.045621	0.045621	0.045621	0.045621	0.045621	0.045621	0.045621	0.045621	0.045621	0.045621	0.045621	0.045621	0.045621	0.045621	0.045621	0.045621
D2	F21	0.023546	0.023546	0.023546	0.023546	0.023546	0.023546	0.023546	0.023546	0.023546	0.023546	0.023546	0.023546	0.023546	0.023546	0.023546	0.023546	0.023546	0.023546	0.023546	0.023546	0.023546	0.023546
	F22	0.003141	0.003141	0.003141	0.003141	0.003141	0.003141	0.003141	0.003141	0.003141	0.003141	0.003141	0.003141	0.003141	0.003141	0.003141	0.003141	0.003141	0.003141	0.003141	0.003141	0.003141	0.003141
	F23	0.152029	0.152029	0.152029	0.152029	0.152029	0.152029	0.152029	0.152029	0.152029	0.152029	0.152029	0.152029	0.152029	0.152029	0.152029	0.152029	0.152029	0.152029	0.152029	0.152029	0.152029	0.152029
D3	F31	0.171618	0.171618	0.171618	0.171618	0.171618	0.171618	0.171618	0.171618	0.171618	0.171618	0.171618	0.171618	0.171618	0.171618	0.171618	0.171618	0.171618	0.171618	0.171618	0.171618	0.171618	0.171618
	F32	0.053213	0.053213	0.053213	0.053213	0.053213	0.053213	0.053213	0.053213	0.053213	0.053213	0.053213	0.053213	0.053213	0.053213	0.053213	0.053213	0.053213	0.053213	0.053213	0.053213	0.053213	0.053213
	F33	0.011313	0.011313	0.011313	0.011313	0.011313	0.011313	0.011313	0.011313	0.011313	0.011313	0.011313	0.011313	0.011313	0.011313	0.011313	0.011313	0.011313	0.011313	0.011313	0.011313	0.011313	0.011313
D4	F41	0.008544	0.008544	0.008544	0.008544	0.008544	0.008544	0.008544	0.008544	0.008544	0.008544	0.008544	0.008544	0.008544	0.008544	0.008544	0.008544	0.008544	0.008544	0.008544	0.008544	0.008544	0.008544
	F42	0.030268	0.030268	0.030268	0.030268	0.030268	0.030268	0.030268	0.030268	0.030268	0.030268	0.030268	0.030268	0.030268	0.030268	0.030268	0.030268	0.030268	0.030268	0.030268	0.030268	0.030268	0.030268
	F43	0.022007	0.022007	0.022007	0.022007	0.022007	0.022007	0.022007	0.022007	0.022007	0.022007	0.022007	0.022007	0.022007	0.022007	0.022007	0.022007	0.022007	0.022007	0.022007	0.022007	0.022007	0.022007
D5	F51	0.000950	0.000950	0.000950	0.000950	0.000950	0.000950	0.000950	0.000950	0.000950	0.000950	0.000950	0.000950	0.000950	0.000950	0.000950	0.000950	0.000950	0.000950	0.000950	0.000950	0.000950	0.000950
	F52	0.039159	0.039159	0.039159	0.039159	0.039159	0.039159	0.039159	0.039159	0.039159	0.039159	0.039159	0.039159	0.039159	0.039159	0.039159	0.039159	0.039159	0.039159	0.039159	0.039159	0.039159	0.039159
	F53	0.011923	0.011923	0.011923	0.011923	0.011923	0.011923	0.011923	0.011923	0.011923	0.011923	0.011923	0.011923	0.011923	0.011923	0.011923	0.011923	0.011923	0.011923	0.011923	0.011923	0.011923	0.011923
D6	F61	0.015280	0.015280	0.015280	0.015280	0.015280	0.015280	0.015280	0.015280	0.015280	0.015280	0.015280	0.015280	0.015280	0.015280	0.015280	0.015280	0.015280	0.015280	0.015280	0.015280	0.015280	0.015280
	F62	0.190732	0.190732	0.190732	0.190732	0.190732	0.190732	0.190732	0.190732	0.190732	0.190732	0.190732	0.190732	0.190732	0.190732	0.190732	0.190732	0.190732	0.190732	0.190732	0.190732	0.190732	0.190732
	F63	0.030132	0.030132	0.030132	0.030132	0.030132	0.030132	0.030132	0.030132	0.030132	0.030132	0.030132	0.030132	0.030132	0.030132	0.030132	0.030132	0.030132	0.030132	0.030132	0.030132	0.030132	0.030132
D7	F71	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	F72	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	F73	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

RII Method Results

The ranking of delay factors given by the RII method was, therefore, straightforward from the survey responses. F21 was the most critical factor causing delay, while F62 and F31 in second and third ranks, respectively in Table 9. This simple ranking supports the results of DEMATEL and ANP methods but with a stronger emphasis on labour shortage.

Table 9. RII value of delay factors in prefabricated construction.

Group	Delay Factor	No influence	Low influence	Medium influence	High influence	Very high influence	RII	Rank
D1	F11	0	0	8	16	7	0.79355	9
	F12	0	0	7	17	7	0.80000	8
	F13	1	12	16	2	0	0.52258	22
	F14	0	12	15	3	1	0.55484	21
D2	F21	0	1	1	5	24	0.93548	1
	F22	0	0	8	22	1	0.75484	13
	F23	0	2	23	5	1	0.63226	18
D3	F31	0	1	4	10	16	0.86452	2
	F32	0	0	3	15	13	0.86452	2
	F33	0	1	6	17	7	0.79355	9
D4	F41	0	0	5	18	8	0.81935	7
	F42	0	0	17	13	1	0.69677	16
	F43	0	0	12	17	2	0.73548	15
D5	F51	0	0	9	19	3	0.76129	11
	F52	1	1	6	19	4	0.75484	13
	F53	0	1	10	14	6	0.76129	11
D6	F61	0	0	6	13	12	0.83871	5
	F62	0	1	2	15	13	0.85806	4
	F63	0	2	2	16	11	0.83226	6
D7	F71	0	2	14	15	0	0.68387	17
	F72	0	5	21	5	0	0.60000	19
	F73	0	10	17	3	1	0.56774	20

Discussion of Findings

These findings of the research indicated some key facts on delay factors that affect FRPC projects in Sri Lanka. The outcomes from DEMATEL, ANP, and RII offer complementary and contrasting standpoints on the issues of causality and severity of delays, developing a multi-dimensional explanation of the problem.

Comparison with Previous Studies

The identification of shortage of skilled labour as a critical delay factor is consistent with prior research. Such studies as conducted by Safwah Mohd Yusoff et al. (2021) and Akomah et al. (2020) have also reiterated that the shortage of skilled labour is one of the most persistent problems in construction projects within developing countries. However, this research shades into the nuance by emphasizing poor project management as a factor of equal importance, for which there was substantial support from findings by Zidane and Andersen (2018). This is contrary to earlier studies that were focused on the identification of delays due to resource-type factors; hence, FRPC construction projects require highly skilled managers.

Interdependencies of Delay Factors

One of the strong points of this research is showing how the delay factors are interdependent. The RII method identifies the ranking of the factors in terms of their perceived importance. However, DEMATEL and ANP analyses show much deeper and actual causal relationships

between factors. For instance, the poor management of the project is ranked high not only regarding its direct importance but also in influencing other critical issues such as logistical delays and material shortages. These results emphasize the need for a holistic approach to delay management, as many other delay factors are reduced by the addressing of mere management inefficiencies.

Practical Implications

These findings have important implications for stakeholders in the Sri Lankan construction industry. First, since most of the workforce issues are highlighted, workforce development programs seem urgent in nature and should specifically target workers. Upskilling workers with technical training may help to resolve or reduce the shortage of skilled labour, as noted by Akomah et al. (2020). Secondly, project management practices, especially at contractor firms, need special attention. In fact, better project planning, effective communication, and proper resource utilization may help alleviate delays. This study also recommended bringing this into the framework of the project management to account for logistics improvement. Ineffective supply chain management, in terms of material delivery, is one of the significant causes. This supports the findings of Panova and Hilletoft (2018), where it is suggested that by integrating coordinated logistics and material handling at the construction project site, delays can be prevented.

Conclusion

This study identified and prioritized the key delay factors affecting fiber-reinforced precast concrete (FRPC) projects in Sri Lanka using the Relative Importance Index (RII) and DEMATEL-ANP methods. The main findings revealed that the shortage of skilled labour (F21) (RII = 0.935) and inadequate project management (F62) (IW = 0.1907) were the most critical causes of delays, both directly and through their influence on other factors like logistics inefficiencies. The above insights underline the need for customized workforce development programs and better practices of project management, which are crucial in mitigating delays. Interdependency analysis underlines the integrated solution for those core issues that are necessary for the improvement of overall project performance. The present research provides practical recommendations to stakeholders; it furthers the understanding of delay management in FRPC projects.

References

- Akomah, B.B., Ahinaquah, L.K. and Mustapha, Z., (2020) Skilled Labour Shortage in the Building Construction Industry Within the Central Region. *Baltic Journal of Real Estate Economics and Construction Management*, 81, pp.83–92.
- Etikan, I., Musa, S.A. and Alkassim, R.S., (2016) Comparison of convenience sampling and purposive sampling. *American journal of theoretical and applied statistics*, 51, pp.1–4.

- Garcez, E.O., Kabir, M.I., Subhani, M., MacLeod, A., Fehervari, A., Hall, M. and Moulton, P., (2019) Development of high strength self-compacting fibre reinforced concrete for prefabricated concrete industry. In: *MATEC Web of Conferences*. EDP Sciences, p.02011.
- Hampson, K.D., Kraatz, J.A. and Sanchez, A.X., (2014) The global construction industry and R&D. In: *R&D investment and impact in the global construction industry*. Routledge, pp.4–23.
- Ong, M.H.A. and Puteh, F., (2017) Quantitative data analysis: Choosing between SPSS, PLS, and AMOS in social science research. *International Interdisciplinary Journal of Scientific Research*, 31, pp.14–25.
- Panova, Y. and Hilletoft, P., (2018) Managing supply chain risks and delays in construction project. *Industrial Management and Data Systems*, 1187, pp.1413–1431.
- Perez, F.J. and Mauricio, O., (2018) Verification of a simple model for the lateral-load analysis and design of unbonded post-tensioned precast concrete walls. *PCI Journal*.
- Plizzari, G. and Mindess, S., (2019) Fiber-reinforced concrete. In: *Developments in the Formulation and Reinforcement of Concrete*. Elsevier, pp.257–287.
- Quezada, L.E., López-Ospina, H.A., Palominos, P.I. and Oddershede, A.M., (2018) Identifying causal relationships in strategy maps using ANP and DEMATEL. *Computers & Industrial Engineering*, 118, pp.170–179.
- Safwah Mohd Yusoff, N., Azli Mohd Rahim, F. and Siaw Chuing, L., (2021) *The Relationship of Skilled Labour Shortages and Project Performance in Construction Industry: A Conceptual Framework*. *Journal of Project Management Practice*, .
- Zidane, Y.J.T. and Andersen, B., (2018) The top 10 universal delay factors in construction projects. *International Journal of Managing Projects in Business*, 113, pp.650–672.

CASE STUDY OF CAUSE AND EFFECTS OF DELAYS IN SYSTEM REHABILITATION FOR NON-REVENUE WATER REDUCTION

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Abstract

This study aims to explore the primary factors causing delays in a system rehabilitation construction project, examining their impact on the project timeline, budget, and quality. By identifying delay contributors such as weather disruptions, supply chain setbacks, and workforce shortages, we can better understand how these challenges increase costs and compromise project quality. Additionally, the study evaluates the project management team's efforts to mitigate these delays, assessing the effectiveness of strategies like revised scheduling and resource allocation. The findings will culminate in recommendations to enhance the management of similar future projects, focusing on proactive planning, risk management, and efficient resource deployment. Data analysis was performed using regression “ $R^2 = 0.519$ ” analysis to quantify the causes of these delays and the effects on the project time line and cost.

Key words: ADB- Asian Development Bank, CMC- Colombo Municipal Council, DMA- District Metered area, NRW- Non-Revenue Water, NWSDB National Water Supply and Drainage Board.

Introduction

Non- Revenue Water (NRW) can be calculated considering the difference between the total volume inflow from the main flow meter and consumers’ used volume of the water (Kesavan, 2017). The selected rehabilitation water project design is based on non-revenue water (NRW) in the Colombo area which was funded by ADB. Non-Revenue water of more than 45% exceeds the total amount of water supplied by Colombo city. The majority of the CI and GI pipes in the city of Colombo's current network were installed around 70 years ago. Given the severity of the aforementioned issue, Colombo city was divided into 52 District Metered Areas (DMA) and categorized into four packages (I, II, III, and IV), and system rehabilitation projects were implemented in order to reduce NRW valves there (Perera & Halwatura, 2012). Recent observations show that major water project delays occur for variety of causes in Sri Lanka.

Due to the nature of some projects, delays can occur, and water projects fall into this category. These considerations include the fact that the projects are carried out on public streets and roads, where special safety measures are needed to take, and the high degree of uncertainty that these considerations entail (Perera & Halwatura, 2012). The next section enunciates the Significance of the Study as a carrier of new research-based insights into the management of construction projects and their capacity to enhance project performance and results. In project management, it is important to be aware of and minimize project delays which are always an aspect of any given project undertaking. Chronicling the delays to the system rehabilitation

project for non-revenue water reduction in Colombo, Sri Lanka, this research establishes the causes and the effects and outlines potential strategies for the prevention of future delays thereby enriching theory and practice among project planners and managers. (Fashina et al., 2021).

The Research Aims

1. To investigate and analyze the causes and effects of delays in the construction of the system rehabilitation project for non-revenue water reduction in the west part of the city of Colombo, Sri Lanka.
2. To understand the factors contributing to delays, assess their impact on the project timeline, budget, and quality, evaluate mitigation measures implemented by the project management team.

The Research Objectives.

1. To identify the factors contributing to delays in the construction of the system rehabilitation project.
2. To examine the impact of delays on the project timeline, budget and quality.
3. To analysis the effects of delays on the quality of the system rehabilitation project.
4. To evaluate the measures taken by the project management team to mitigate delays and assess their effectiveness.
5. To provide recommendations for improving the management of similar construction projects in the future.

Methodology

The research methodology determined that the delay in the non-revenue water project had 10 independent variables, which included `7 causes for delay factors and 3 effects for delay. In order to assess how often delays occur, a questionnaire was created. This section outlines the methodology employed to investigate the causes and effects of delays in the construction of the system rehabilitation project for non-revenue water reduction in the west part of the city of Colombo, Sri Lanka. The aim of this research is to gain a comprehensive understanding of the factors contributing to delays, assess their impact on the project timeline, budget, and quality, evaluate mitigation measures implemented by the project management team, and provide recommendations for future improvement in managing similar projects.

Conceptual Frame Work

Figure 1: Conceptual Frame (developed by author based on the past literatures)

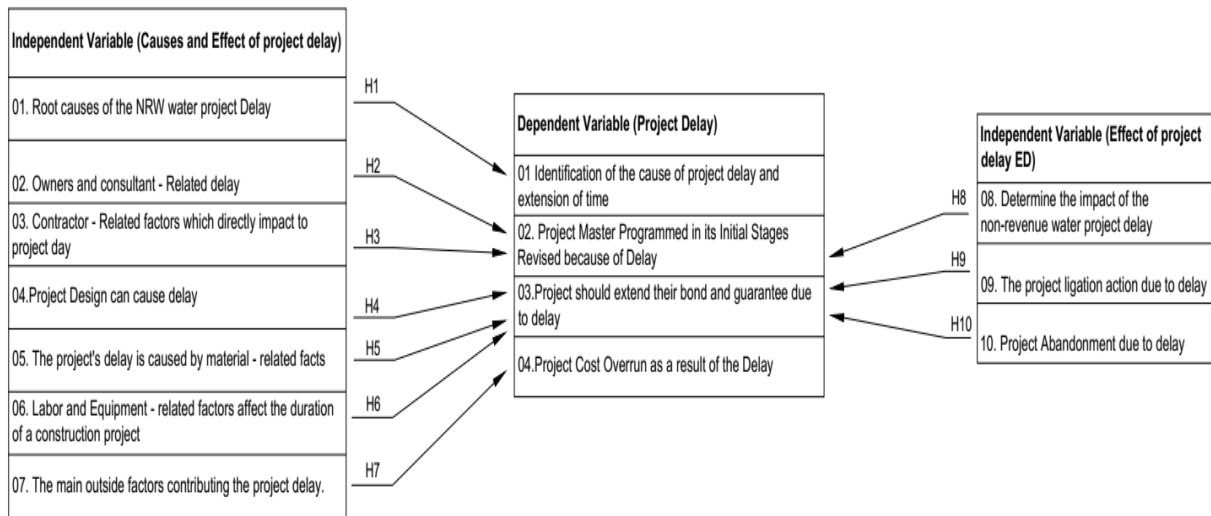


Figure 2: Independent Variable

Independent Variable	Causes of Delay & Effect of Delay
01. Root causes of the NRW water project Delay	CD1
02. Owners and consultant - Related delay	CD2
03. Contractor - Related factors which directly impact to project delay	CD3
04. Project Design can cause delay	CD4
05. The project's delay is caused by material - related facts	CD5
06. Labor and Equipment - related factors affect the duration of a construction project	CD6
07. The main outside factors contributing the project delay.	CD7
08. Determine the impact of the non-revenue water project delay	ED1
09. The Project Litigation Action due to Delay.	ED2
10. Project Abandonment due to delay	ED3

Dependent Variable

Figure 3: Dependent Variable

Project Delay	Project Delay
01 Identification of the cause of project delay and extension of time	PD1
02. Project Master Programmed in its Initial Stages Revised because of delay	PD2
03.Project should extend their bond and guarantee due to delay	PD3
04.Project Cost Overrun as a result of the delay	PD4

Results

Table 1: Model Summary

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.721 ^a	.519	.466	.36471
a. Predictors: (Constant), ED3, CD1, CD4, ED2, CD5, CD3, CD7, CD6, ED1, CD2				

R Squared value 0.519

$$R^2 = 0.519 = (51.9\%)$$

According to result $R^2 0.519$ It Imply that out of total variability (51.9%) of variabilities are explained by this regression model interpretation of the Anova table.

Table 2. Anova data

ANOVA ^a						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	13.070	10	1.307	9.826	.000 ^b
	Residual	12.104	91	.133		
	Total	25.175	101			
a. Dependent Variable: PD1						
b. Predictors: (Constant), ED3, CD1, CD4, ED2, CD5, CD3, CD7, CD6, ED1, CD2						
Regression Sig =0.000						
H ₀ : The model is not adequate						
H ₁ : The model is Adequate						

According to result sig valve is (0.000) which is less than (0.05). There is enough evidence to reject null hypotheses at 5% level. It implies that the model is adequate.

Discussion

According to the final results, the NRW water project's CD1 Root Causes are Labour and Equipment. CD6, Examine the results of the water project's delay that isn't bringing in money Project abandonment because of delay ED3, project litigation because of delay ED2, and ED1 all have a significant relationship. determining the cause of the project's delay and lengthening Some of their elements are in direct agreement with research findings (Rashid, 2020). There are more delay factors describes in the (*Project Management Body Of Knowledge*, 2017) align with the final outcome. More that the research reinforces that factor of effect to delay construction projects. There are 38 delay factors reinforced to contribute the result (Gordon, 2023). The 84 delay factors looked into Iran's issue with water construction and agreed with the result (Matin, 2016). The 17 delay factors were identified in Tehran and those result aligned with the result of the projects.

The objectives of this study were to identify factors causing delays in the construction of the system rehabilitation project, examine their impact on the project timeline and budget, analyze their effects on project quality, evaluate mitigation measures taken by the project management team, and provide recommendations for future improvements in project management. On the other hand, factors such as owners and consultant-related delays (CD2), contractor-related factors impacting project delays (CD3), project design delays (CD4), and delays caused by material-related issues (CD5) were rejected as significant contributors to the delays. These findings imply that focusing efforts on labor, equipment management, and addressing project abandonment and litigation concerns should be prioritized over these rejected factors(Mpofu et al., 2017).

Recommendation

Learning from past projects: Develop and sustain a database of construction project experience. Standardize how to record exercises, positive experiences, and the problems encountered with a view to promoting documentation of lessons learned. It is important to revisit and scrutinize these findings during the course of the project to inform changes and use the details in consequent projects. (Arantes & Ferreira, 2023).

Embrace technology and innovation: Identify and incorporate innovation in using technology in construction project management. As such, integrate such application as project management software, BIM, and others in order to facilitate the best practices, share knowledge, and optimize project delivery. Current development related to technologies and tools used in project management should be followed to enhance the practice (Abbas et al., 2019).

Stakeholder partnership development leads to better construction project results. By setting up open dialogue systems and meeting with stakeholders plus creating ways to address disagreements the project's targets will better sync with everyone involved. A transparent decision policy plus equal participation by all project partners helps teams stay connected and avoid confusion at work. A team environment of joint responsibility helps projects run better and reach deadlines faster while making stakeholders happier with results.

Conclusion

Construction delays and design updates arise most often from coordination problems, contractor struggles, and the difficulty of building complex design plans. Both legal obligations and non-revenue water problems worsen project delays and design changes which push projects beyond their schedules and increase expenses. Taking effective steps like bettering how we find the real causes of problems plus better project planning and communication will help us manage legal challenges and supply chain quality more thoughtfully while also setting up strong monitoring systems. Creating project-specific actions helps projects reach deadlines while keeping costs down and making clients happy. By taking action early and working together as a team project managers deliver better results and control risks better in construction projects.

References

- Abbas, A., Choi, M., Seo, J. O., Cha, S. H., & Li, H. (2019). Effectiveness of Immersive Virtual Reality-based Communication for Construction Projects. *KSCE Journal of Civil Engineering*, 23(12), 4972–4983. <https://doi.org/10.1007/s12205-019-0898-0>
- Arantes, A., & Ferreira, L. M. D. F. (2023). Development of delay mitigation measures in construction projects: a combined interpretative structural modeling and MICMAC analysis approach. *Production Planning and Control*, 0(0), 1–16. <https://doi.org/10.1080/09537287.2022.2163934>
- Fashina, A. A., Omar, M. A., Sheikh, A. A., & Fakunle, F. F. (2021). Exploring the significant factors that influence delays in construction projects in Hargeisa. *Heliyon*, 7(4). <https://doi.org/10.1016/j.heliyon.2021.e06826>
- Gordon, P. (2023). Investigating the Causes of Project Delay and Its Effects on the Project Management in Construction Projects. *International Research Journal of Modernization in Engineering Technology and Science*, 02, 349–359. <https://doi.org/10.56726/irjmets33417>
- Kesavan, M. (2017). *Analysis of Factors Contributing Civil Engineering Project Delays in Sri Lanka - (Proceedings of the Session on ...* 5(December), 40–46.
- Matin, D. M. (2016). Identifying The Effective Factors for Cost Overrun and Time Delay in Water Construction Projects. *Engineering Technology & Applied Science Research*, 6(4), 1062–1066.
- Mpofu, B., Ochieng, E. G., Moobela, C., & Pretorius, A. (2017). Profiling causative factors leading to construction project delays in the United Arab Emirates. *Engineering, Construction and Architectural Management*, 24(2), 346–376. <https://doi.org/10.1108/ECAM-05-2015-0072>
- Perera, W. D. A., & Halwatura, R. U. (2012). Causes and Effects of Delays in Construction of Medium Scale Drinking Water Supply Projects in Sri Lanka. *Annual Transactions of Institution of Engineers, Sri Lanka*, June, 151–159.
- project management Body Of Knowledge. (2017).
- Rashid, Y. (2020). Analysis of delay factors and their effects on construction projects. *Management Science Letters*, 10(6), 1197–1204. <https://doi.org/10.5267/j.msl.2019.11.039>

MATERIAL COST VOLATILITY AND LABOUR MARKET DYNAMICS IN KANDY ASPHALT ROAD CONSTRUCTION DURING 2023

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Abstract

This research assesses variability in material costs and wages of labour in asphalt road construction projects in Kandy for 2023. In quantitative research, structured questionnaires were administered to the 95 participants in the industry. The results indicate that the price of construction materials such as bitumen has increased by an average of 35.2% above the world average cost and skilled labour cost by 18.5%. Project delays and workforce issues proved to have a high degree of association statistically, with a correlation coefficient of 0.623. The research reveals that the industry relies significantly on material imports; 65% of the bitumen is imported. Despite showing that 54% of firms have adopted new technologies, the study also suggests how a greater diversification of supply chains could further mitigate these challenges and improve skill development initiatives and the faster implementation of sustainable technologies. These findings would greatly interest construction firms, policymakers, and industry associations.

Keywords: Construction duration, Cost of Materials, Human resource costs, Recommended fixtures - Asphalt construction.

Introduction

Background of the Study

Asphalt roads constitute a significant part of Kandy's infrastructure development, enabling it to discharge its historic function as one of the oldest cities in Sri Lanka. The characteristics of road networks, concerning their quality and performance, are the essential factors affecting economic growth, especially for the transport and tourism industries (Weerasinghe et al., 2018). Recent years have brought numerous difficulties for the construction industry, including the pandemic and the changes in economic rates (Gamil and Alhagar, 2020).

Problem Statement

It has been revealed that the construction industry in Kandy is encountering several crucial issues, primarily regarding material prices and hourly rate charges for labour in 2023. These unpredictable factors have caused high volatility in planning to acquire various inputs and labour costs. This implies that material procurement, cost fluctuations, and fluctuating labour rates define road construction projects' significant and challenging decision matrices (Ercan et al., 2020).

Research Objectives

This research analyses the fluctuations in the cost of construction materials, especially Asphalt used in road construction, the labour rates charged in 2023 in Kandy, and the effect on progressive construction projects. In that capacity, the research seeks to compare the differential changes in material costs, assess changes in labour costs, review the causes of such changes to project time frames, and evaluate the industry responses to these changes.

Significance and Scope

This is a valuable study for the construction sector in Kandy since it indicates the problems associated with the varying costs of materials and labour. The implications help form future project strategies to ensure project management achieves more positive outcomes for the related interest groups (K-c Julius, 2014). As the study is conducted on asphalt road construction projects in the Kandy region during 2023, this research can add to the existing knowledge in construction economics and project management in developing countries. The study primarily focuses on substantial civil construction projects of infrastructures like roads, mainly by large construction firms offering realistic recommendations to enhance project results, costs, and the quality of total road infrastructure.

Methodology

Research Design

Therefore, this study used a cross-sectional survey design and included quantitative data collection and analysis methods. These methods facilitated scrutiny of trends in material cost and labour rate, specifically in Kandy's asphalt road construction industry in 2023, as recommended by Creswell and Creswell (2018).

Population and Sampling

The target population comprised working professionals involved in asphalt road construction projects in the Kandy area, such as project managers, procurement officers, and contractors. Applying Cochran's formula for selecting a sample size, whereby the population is finite with 200 respondents, the sample size was estimated to be 132. Interestingly, the study received 95 completed questionnaires out of 163 issued questionnaires, making the overall response rate 58.3%.

Data Collection Methods

Participants' data was collected by a structured questionnaire completed through a professional self-administered online survey tool. The survey instrument, developed through literature review and expert consultation, addressed six key areas - Respondent demographics information such as age, gender, and occupation, and the cost of materials, wages cost, perceived project effects of climate change, coping mechanisms put in place and prospects of their enterprises. Subsequent reminder messages were used in weeks 1 & 2 to increase the response rate.

Data Analysis

Descriptive and inferential statistical techniques were employed to analyse data, and data analysis was done using SPSS software. The internal consistency reliability of the study was further confirmed by Cronbach's alpha coefficient (>0.7). In contrast, content validity was confirmed by subjecting the study to expert review and comparing it to the existing literature, as referenced by Nunnally and Bernstein (1994). Regression analysis, correlation studies, and ANOVA tests were used to test hypotheses about the relationships between variables and to determine the effects a change in cost had on a project.

Results

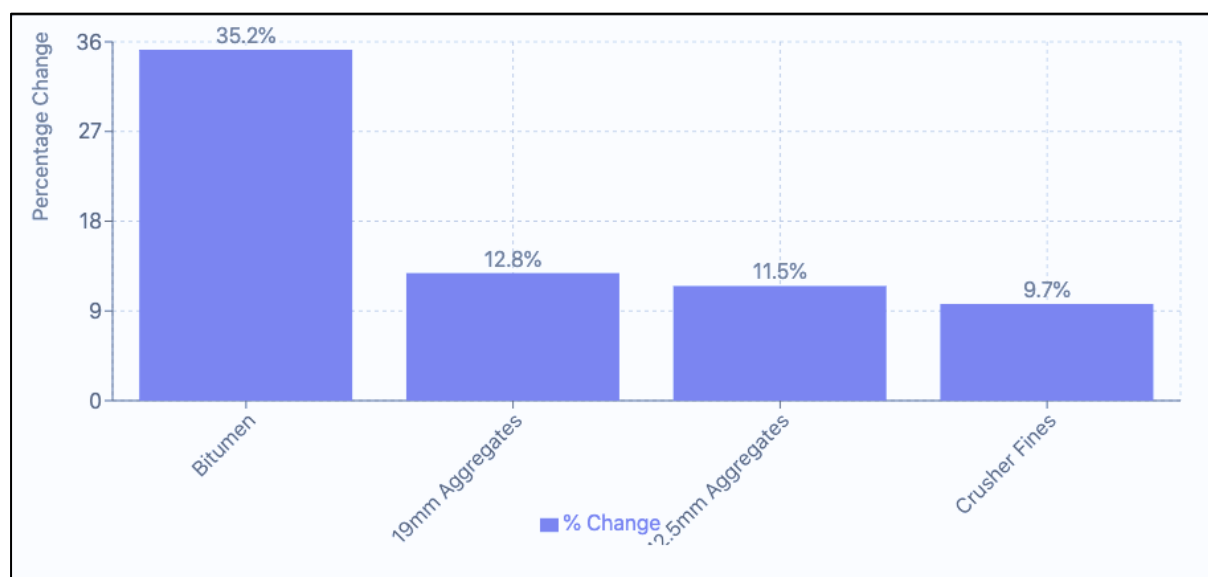
Sample Demographics

The survey sample included construction professionals, and the distribution of respondent positions was as follows - middle management (44.2%). The experience level also differed in the group - 36.8% of participants worked between 6 and 10 years, and only 26.3% worked between 11 and 15 years, indicating a well-balanced sample of experienced employees.

Material Cost Analysis

Analytical work showed that the overall cost of construction materials rise during 2023. The evidence which reflects the most significant increase was the one connected with the bitumen price – its augmentation constituted 35.2% (SD = 8.7%); this result demonstrates the tendencies in the oil price at the global level (Dunn & Mitchell, 2017). Other materials showed moderate increases. For the 19mm aggregates, the results were 12.8% (SD = 3.2%); for 12.5mm aggregates, 11.5% (SD = 2.9%); and the crusher fines, 9.7% (SD = 2.5%).

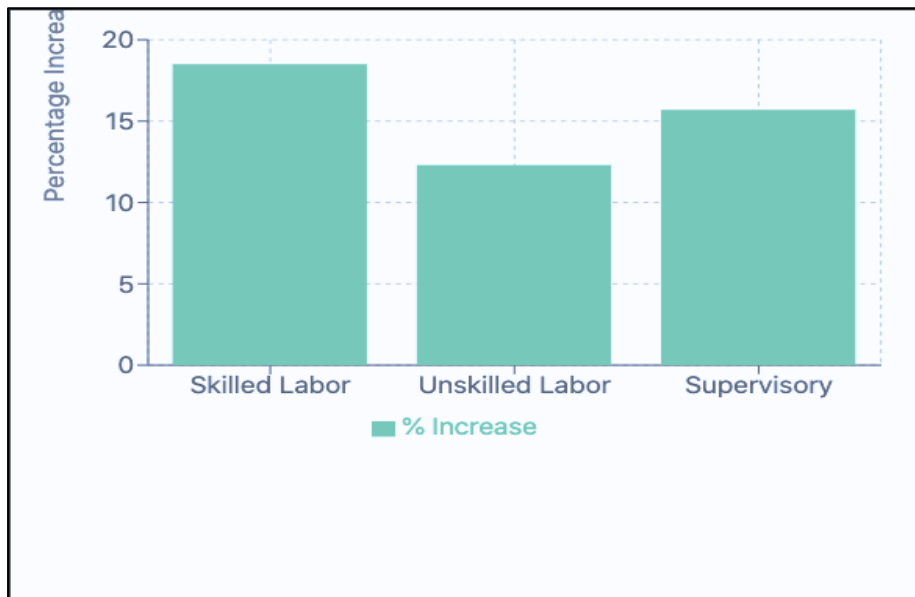
Figure 1 - Material Cost Changes



Labor Rate Changes

The paper pointed out an inconsistency in wage rises for different labour types in the sample. The results also showed that skilled labour had the highest percentage increase at 18.5 % (SD 4.2 %), supervisory roles at 15.7% (SD 3.8 %) and unskilled labour at 12.3% (SD 3.1 %). These results are comparable to other research focused on identifying skill gaps and the growing need for specialists in the construction industry (Ercan et al., 2020).

Figure 2 - Labour Rate Changes



Supply Chain Dependencies

The material sourcing analysis revealed that the industry depends heavily on imports, especially for bitumen, with 65 % imported and only 15% sourced from local suppliers. In contrast, aggregates showed more robust local supply chains - mineral aggregates were 19mm (85 % local), 12.5mm (88% local), and crusher fines were 92% local.

Project Impact Analysis

Following the regression analysis results, it can be stated that changes in material costs share 52.4% of the variations in the analysed measure – project cost overruns, $R^2 = .524$, $F(4, 90) = 29.563$, $p < 0.001$). The bitumen price was determined to exert the most significant impact ($\beta = .387$, $p < .001$). The analysis of the correlation between labour rate changes and project delays was also made for five types of labour - skilled, unskilled, administrative and clerical, managerial and other labour, and the resulting correlation was also found to be considerable ($r = .623$, $p < 0.01$).

Industry Response

Construction firms in Kandy adopted various measures - 68% of firms offered training programs for their workers. The decision to subcontract became a primary sourcing strategy for 62% of the firms, while 54% embraced new technologies to drive down costs. Also, 45%

of firms adopted new flexible work arrangement policies, and another 37% carried out automation measures to overcome labour problems and improve efficiency.

Technology Adoption

The assessment results revealed that the industry has gradually adopted sustainable technologies, with warm-mix asphalt at 37 % and Recycled Asphalt Pavement (RAP) at 32%. Researchers found that project management tools were adopted at 28% and explained that construction was slowly moving towards using technology in project delivery systems.

Results based on project size indicated that post hoc comparison had a solid relationship on the cost effects with ($F(2, 92) = 15.237, p < .001$) – the sizes of projects were more exposed to fluctuating costs.

Discussion

Material Cost Implications

Evaluating the demand in Kandy's asphalt road construction sector uncovers several issues concerning material costs, including a massive hike in bitumen prices (35.2%) that outstrips the global average (Dunn and Mitchell, 2016). This growth, coupled with the fact that 65% of bitumen is imported, increases the industry's vulnerability to international market fluctuations, calling for improved market diversification.

Labor Market Dynamics

There is a clear sign of a skills wage premium in the labour market. Thus, the cost of skilled labour increased by 18.5%, while that of unskilled labour increased by only 12.3%. This trend corresponds with prior research regarding the skill gap and its implications for the construction industry's project performance (Ercan et al., 2020). The more impressive relationship between skilled labour rates and project length ($r = .623$) supports this point, indicating that labour resource management is critical to project success.

Industry Adaptation and Innovation

Unfavorable conditions prove the industry's promising ability to develop adaptation measures. The report shows that 68% of firms have started training employees, while 54% have introduced new technologies. Overall, there is a trace of modernisation. The use of warm-mix asphalt, in addition to the increasing number of recycled materials in construction, also points to a trend in favor of sustainable solutions (D'Angelo, Gabriele, Marmo, Arcuri, de La Torre, & Vidoni, 2008).

Project Size Impact

Effects of cost changes on projects of different sizes were found to have varied effects where $F(2, 92) = 15.237, p < .001$. More significant projects mean that more effective risk management is needed. These findings hold to the current discussion by Ratnayake and Lou (2019) that the Sri Lankan construction industry is prone to external economic fluctuations in disagreement with the type 2 assertion while affirming the type 1 assertion concerning the sector's innovation in addressing the challenges.

Conclusion and Recommendations

Key Findings

This paper highlights major problems affecting Kandy's asphalt road construction industry, such as a sharp rise in bitumen prices by 35.2%* and an 18.5%* increase in the cost of skilled labour. The industry's high dependence on materials imports (65% for bitumen) clearly shows its risks in the supply chain and risks faced within it. In comparison, 54% of firms' adoption of new technologies shows a positive outlook.

Recommendations

Some suggestions include diversifying the sourcing of materials, improving local content manufacturing, and improving programs for training human capital. To this end, sustainable technologies such as instead of using current capacity of asphalt production machines

60 MT/hr.-80 MT/hr. we can deploy high-capacity machines which produce 120MT/hr.-150MT/hr. machines which will immensely boost efficiency of the road development projects, Since asphalt labour requires specialized skill therefor providing relevant special skills to the Laboure's which will greatly enhance the productivity. should be adopted mainly through construction firms, Eventhough current new technology adoption rate is around 54% which indicates a good start but need further development. Substantive policy changes must be made regarding the development of extended supply chains based on local resources and the support of vocational training activities. Further, the relationship between the construction industry's supply chain participants, policymakers, and industry associations is vital for developing long-lasting and innovatively rich solutions.

References

- Brown, S.F. and Brunton, J.M. (1993). The effect of mixture variables on the fatigue of bituminous mixtures. *Journal of the Association of Asphalt Paving Technologists*, 62, pp.506-532.
- D'Angelo, J., et al. (2008). Warm-mix asphalt: European practice. Federal Highway Administration Report FHWA-PL-08-007.
- Dunn, N.L. and Mitchell, P. (2016). Bitumen price volatility: Causes and impacts. *International Journal of Pavement Engineering*, 17(3), pp.215-224.
- Ercan, T., Onat, N.C. and Tatari, O. (2020). Investigating the labor impacts of construction industry sustainability efforts in the United States. *Journal of Cleaner Production*, 256, p.120381.
- Gamil, Y. and Alhagar, A. (2020). The impact of pandemic crisis on the survival of construction industry: A case of COVID-19. *Mediterranean Journal of Social Sciences*, 11(4), pp.122-128.
- Rathnayake, R.M. and Lou, E.C.W. (2019). Factors affecting the cost of construction in Sri Lanka. *International Journal of Construction Management*, 19(1), pp.38-52
- Weerasinghe, T.D., Gunarathna, R.P. and Perera, B.J. (2018). Evaluating road maintenance projects: A case study from Sri Lanka. *Procedia Engineering*, 212, pp.1007-1014.

CHARACTERIZATION OF PERVIOUS CONCRETE IN TERMS OF COMPRESSIVE STRENGTH, POROSITY, AND COMPACTION

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Abstract

Present study investigated pervious concrete to explore the relationships between aggregate-to-cement (A/C) ratio, compaction, and void ratio, focusing on 12-18 mm aggregate sizes, identified in prior research as optimal. The experiment used A/C ratios of 3.5, 4.0, and 4.5, compaction levels of 30, 45, and 60 blows, and a constant water-cement ratio of 0.3. Results revealed that compaction significantly affects compressive strength, with the highest strength (13.7 MPa) at 60 blows and a 3.5 A/C ratio, and the lowest strength (4.3 MPa) at a 4.5 A/C ratio. Lower A/C ratios reduced porosity, while higher A/C ratios increased it, with maximum porosity (25.9%) at a 4.5 A/C ratio and 30 blows and minimum porosity (14.1%) at a 3.5 A/C ratio and 60 blows. Void ratios decreased with increasing compaction, reaching a maximum of 36.53% and a minimum of 32.25%. These findings help optimize pervious concrete mix designs.

Keywords: Aggregate, Compressive Strength, Pervious Concrete, Porosity, Void Ratio.

Introduction

The development of pervious concrete initiated in Japan in 1980s, which offers several advantages for the environment (Sathiparan, et al., 2023). Porous or permeable concrete is another name for pervious concrete. A consistent coarse aggregate size and a low water-to-cement ratio are used to create gap-graded conventional porous concrete (Sathiparan, et al., 2023). The porosity of pervious concrete ranges from 15 to 35 percent. (Subramaniam, et al., 2023). Since it reduces water and soil pollution and controls stormwater runoff, porous concrete is becoming increasingly popular in North America, Europe, and Japan (Wijekoon, 2023). Parking lots, residential streets, walkways for pedestrians, greenhouse gases, stormwater management, tree protection, etc. are instances of such applications (Ferguson, 2007). Most researches have been conducted to investigate the interdependence between compressive strength, porosity and void ratio under varying compaction efforts and A/C ratios. Arifi, et al., (2020) points out the value of void ratio that considerably impacts the performance of pervious concrete to cope surface runoff in urban environments. Shinde & Valunjkar, (2015) were noticed that as void ratio increases, porosity also increases and compressive strength reduces and vice versa. Wijekoon, et al., (2023) revealed that the usage of aggregates with the size of (12 – 18) mm and water/cement ratio of 0.3 to 0.35 are determined for achieving the optimum compressive strength and porosity of pervious concrete. Various analytical methods, like

ImageJ and SEM, assess void ratio. Accuracy depends on factors like image quality, lighting, and angles, with ImageJ ensuring high precision. (Zhao, et al., 2024).

This research aimed to achieve three primary objectives. Firstly, a comprehensive literature review was conducted to gather insights into mix proportions and characterization techniques for pervious concrete. This analysis provided a robust foundation for the experimental phase, ensuring alignment with recent advancements. Secondly, an experimental phase involved compressive strength testing per BS1881 standards, porosity testing, and void analysis using ImageJ software. These tests evaluated the effects of compaction effort on compressive strength, porosity, and void ratio. Lastly, the study concluded with a detailed discussion and recommendations to improve pervious concrete design and application in construction projects. Notably, this research uniquely examines voids alongside compressive strength and porosity while varying aggregate-cement ratios and compaction levels. The findings establish relationships between compaction effort and concrete properties, offering valuable guidance for designing and producing pervious concrete tailored to specific performance requirements.

Materials and Methods

Pervious concrete is made from a mixture of cement, aggregates, and water. The primary binding material used was Ordinary Portland Cement (Type 1 OPC), which had a bulk density of 1280 kg/m³ and a specific gravity of 3.15. The aggregates were natural granite-gneiss, an igneous rock. The aggregate size was sieved and classified into the 12–18 mm range. To achieve a zero slump, a water-to-cement ratio of 0.3 was maintained for all mix proportions, as recommended in the literature. The aggregate-to-cement ratio varied between 3.5 and 4.5, with specific mixes at ratios of 3.5, 4.0, and 4.5.

Mix Design & Sample Preparation

The mix design of the pervious concrete is shown in Figure 1

Figure 1- Mix design of the pervious concrete

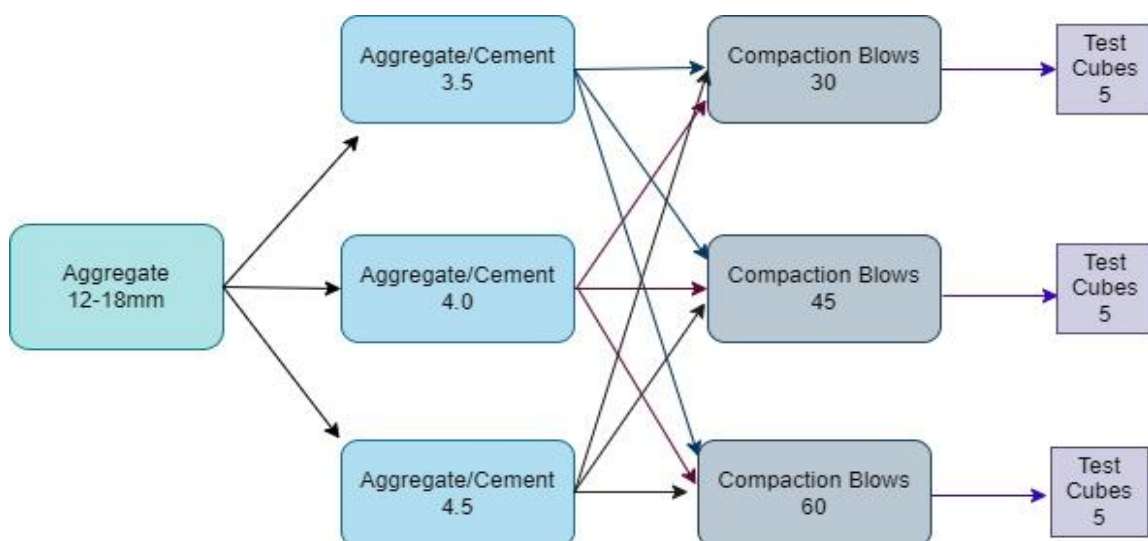


Table 1-Mix design of the pervious concrete

	A/C Ratio		
	3.5	4.0	4.5
Cement (kg)	413.30	370.80	336.20
Aggregate (12-18mm)	1446.30	1483.20	1513.00
Water (kg)	123.99	11.24	100.86

All components in the mix design were specified in kilograms, as mentioned in Table 1. To accomplish the objective of the study, there were 45 samples and ensure the same conditions for each specimen. Five test cubes for each mix proportion illustrated in Figure 1. Three, one and one test cube out of 5 will be arranged and taken through tests for compressive strength, porosity and image analysis respectively. As shown in Figure 10, the test specimens were casted using 150 mm × 150 mm × 150 mm molds. Each component was weighed using a digital balance. The dry aggregates were combined to ensure uniform composition in the mixture. This investigation used manual mixing. Water was gradually combined into the dry mixture. The compaction was done with 3 different levels of blows (30, 45, 60) using standard proctor compaction rammer. Finally, cubes were labeled and kept for dry for 24hrs. After 24hrs, all the cubes were demolded and kept curing for 28 days.

Testing

Compressive Strength Testing

Tests of compressive strength were performed according to BS1881 (BS-, 1881–124 2015). After 28 days, the specimens were removed from the curing tank and dried beforehand for testing. The UTM (Universal Compressive Strength Testing Machine) was used. Under displacement control, the specimens were loaded at a rate of 1 mm/min. The compressive strengths of porous concrete were obtained after 28 days.

Porosity Testing

To measure the porosity, one cube specimen of each mix proportion was dried in an oven. Subsequently, the sample was carefully soaked 48 hours in a filled water bucket as illustrate in Figure 2. Then discharged water was used to calculate the volume of water that filled the pores in the pervious concrete cube.

Figure 2- Porosity testing after 28 days



$$Porosity (\%) = \frac{V_{water}}{V_{specimen}} * 100 \quad \text{Eq -1}$$

V_{water} = Volume of water displaced by the sample (the volume of water absorbed by the pores of the specimen). $V_{specimen}$ = Volume of the concrete specimen (the total volume of the cube before soaking).

Image Analysis

The porous concrete cubes were sliced equally through cross cross-sections. Afterwards, paint was applied to both interior surfaces, and photos (of both sides of the surface) were taken onto papers as indicate in Figure 3.

Figure 3 - Internal cross-section of a specimen

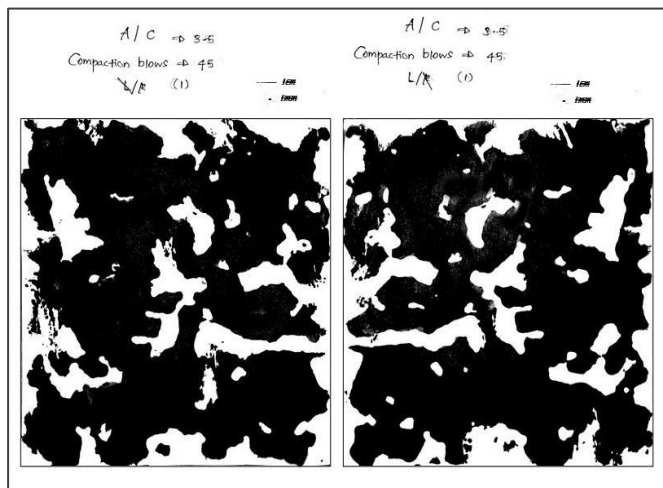
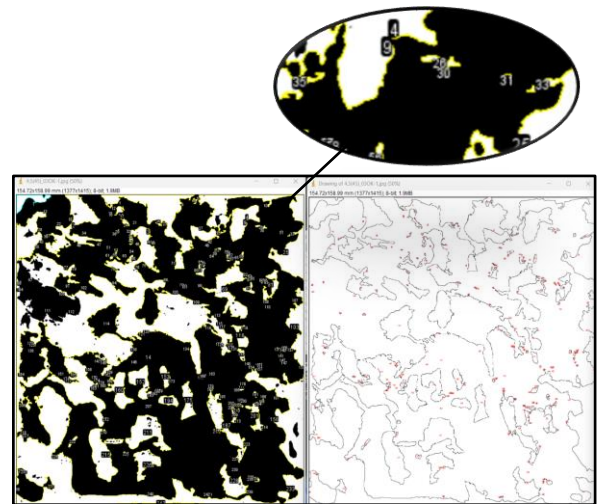


Figure 4 -Void analyzing using ImageJ software



$$Voide Ratio = \frac{Average\ void\ area\ of\ cube}{Solid\ area\ of\ a\ cube} * 100 - \text{Eq 2}$$

The void ratio study has been carried out by averaging the void area for each cube using ImageJ software. As indicated by Figure 4, the application of this software was clearly capable of obtaining improved accuracy. This capacity derived from its ability to permit the accurate

identification of each and every tiny empty region inside the sample. The following Table 2 & Table 3 showed the results of average void area and void ratio respectively.

Table 2- The average Void Area ($\times 10^{12}$ nm)

Compaction Blows	Aggregate-to-Cement Ratio		
	3.5	4.0	4.5
30	33.00207	33.94687	36.52984
45	32.79811	33.79811	36.16096
60	32.25048	32.25048	33.35378

Table 3-Void Ratio (%) of specimens

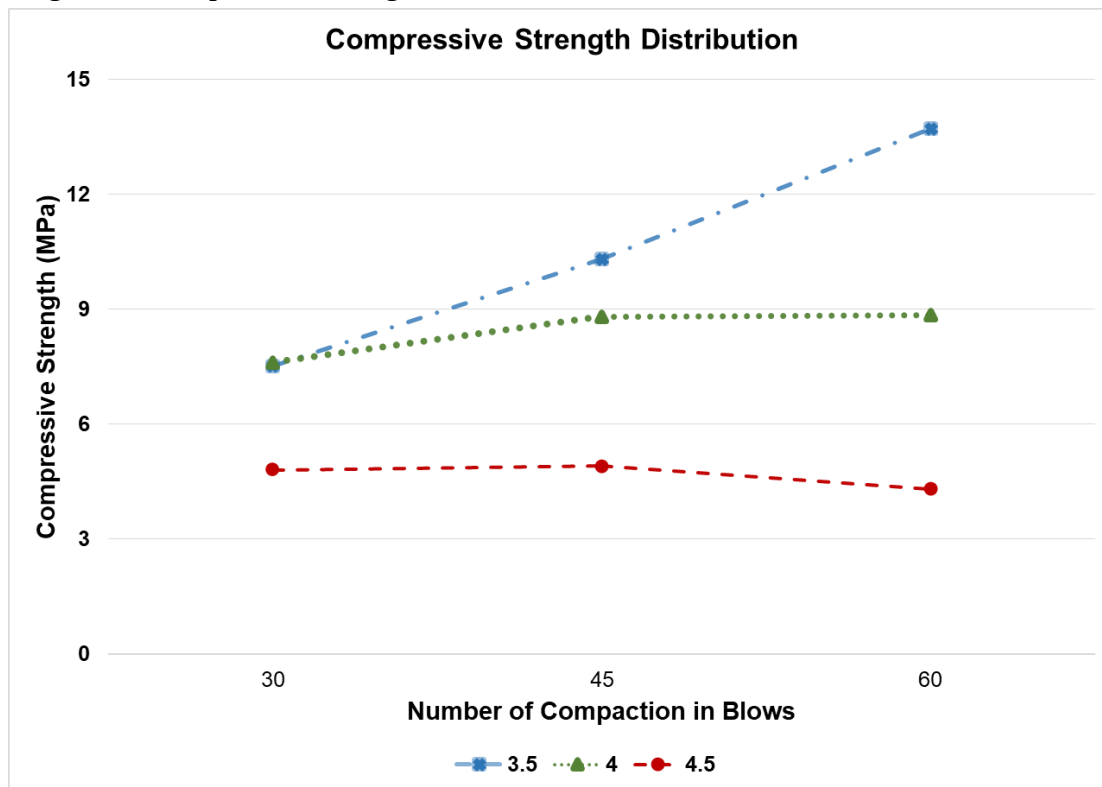
Compaction Blows	Aggregate-to-Cement Ratio		
	3.5	4.0	4.5
30	7425.446	7638.046	8219.215
45	7379.575	7578.833	8136.217
60	8256.358	7300.474	7504.593

Data Analysis & Discussion

Impact of Aggregate to Cement Ratio & Compaction on Compressive Strength.

Figure 5 illustrates compressive strength across compaction levels (30, 45, 60 blows) and A/C ratios (3.5, 4.0, 4.5). At 60 blows and a 4.5 A/C ratio, compressive strength peaked between 10-15 MPa. Strength increased with compaction, but higher A/C ratios introduced voids, creating weak spots and reducing overall compressive strength.

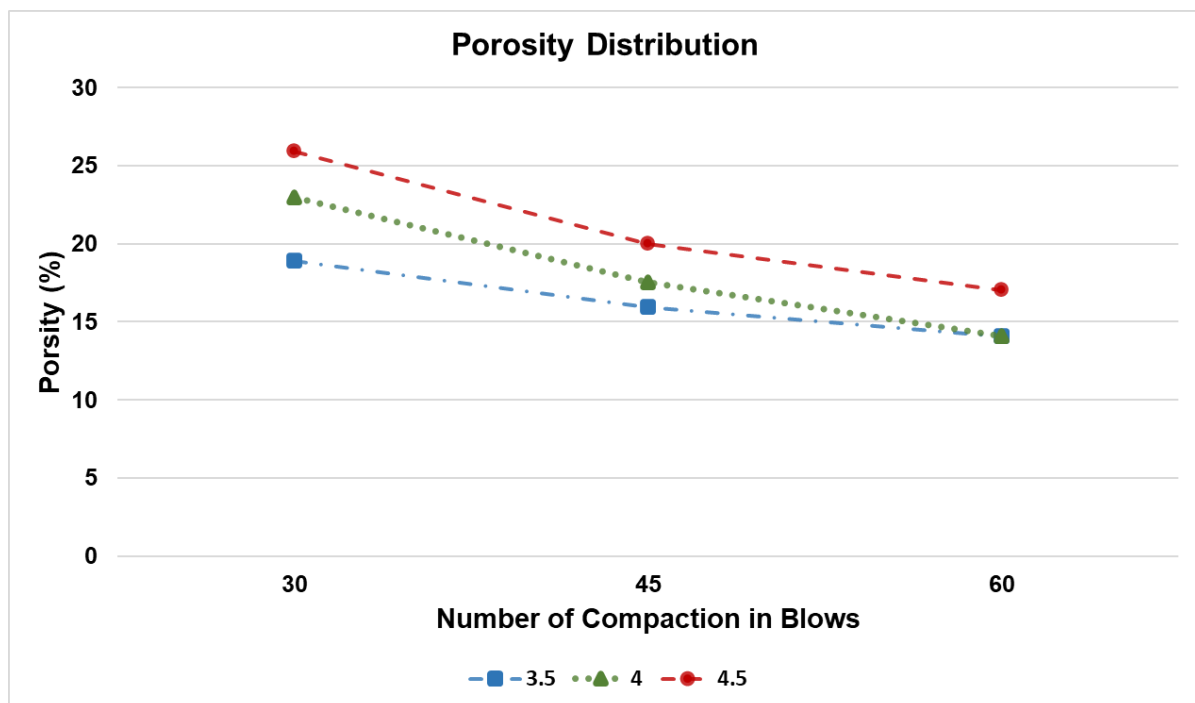
Figure 5- Compressive strength distribution



Impact of Aggregate to Cement Ratio & Compaction on Porosity.

Results illustrated in Figure 6 a decreasing trend in porosity when the compaction blow level rose from 30 to 60 for all aggregate/cement ratios (3.5, 4.0, and 4.5) can be observed. This indicates increased compaction blow levels resulted in denser concrete with lower porosity. In the present study the maximum porosity value was recorded at an aggregate/cement ratio of 4.5 and a compaction blow level of 30. The lowest porosity values were recorded in the two experiments at a compaction blow level of 60 and an aggregate/cement ratio of 4.5. Further, found that the porosity showed similar trends as those discovered in the current study. The results demonstrated that both compaction and aggregate/cement ratio had an influence on the porosity of the concrete, which means increased porosity was led to by the higher A/C ratio.

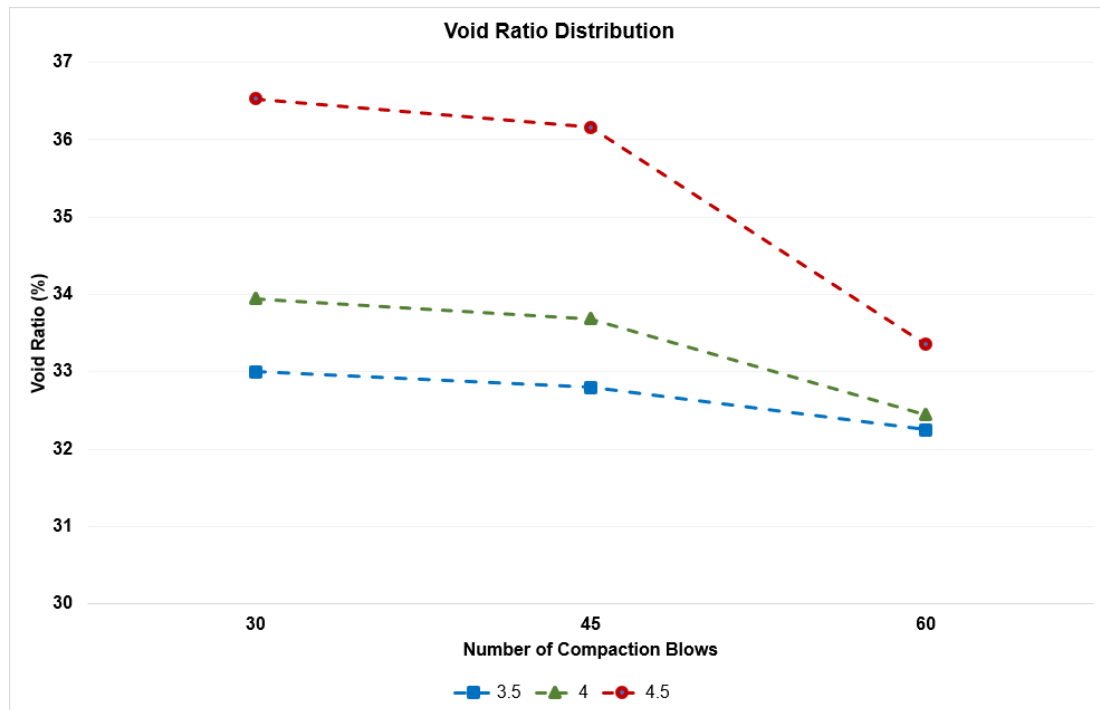
Figure 6 - Porosity distribution



Impact of Aggregate to Cement Ratio & Compaction on Void Ratio.

Figure 7 shows the void ratio decreasing with increased compaction. For the 3.5 mix, it dropped from 33% at 30 blows to 32.25% at 60 blows. Similarly, the 4.0 mix decreased from 33.68% to 32.45%, and the 4.5 mix from 36.53% to 33.35% with increasing compaction intensity. Pervious concrete is intended to have a high void percentage, often between 15% and 35% (Torres, et al., 2018).

Figure 7- Aggregate/Cement & compaction blows vs Void ratio



Overall, the graph revealed that all three mix designs witnessed a reduction in void ratio as the number of compaction blows rose, which indicates the effective performance of the compaction process in densifying the material and lowering the amount of void volume between the particles (Sahdeo, Chandrappa, & Biligiri, 2021). Mixes with greater A/C ratios exhibit larger void ratios (Najah, et al., 2021), which may be attributed to the increased interstitial space between the aggregate particles. As predicted for pervious concrete, the data shown in the figures verifies the inverse relationship between void ratio, porosity and compressive strength. (Shinde & Valunjkar, 2015). The figures reveal that greater aggregate to cement ratios (3.5 to 4.5) and a larger number of compactions blows (30 to 60) result in lower void ratios and porosities but conversely higher compressive strengths. Furthermore, Void ratio and porosity increased concurrently. This is because void ratio is a direct measure of the number of voids in a material relative to the volume of solid material. Porosity is the proportion of the total volume of the material that is filled by voids. As the number of voids rises, both the void ratio and porosity increase (Chandrappa & Biligiri, 2016). The Compressive strength reduced as void ratio and porosity rose. This is because voids operate as weak points in the concrete matrix, limiting its capacity to withstand compressive forces (Najah, et al., 2021). In summary, the result validates the predicted connections between void ratio, porosity and compressive strength in pervious concrete.

Conclusion & Recommendations

Conclusions

Pervious concrete, also known as porous or no-fines concrete, is engineered for water drainage, making it a valuable material for sustainable construction and rainwater management. This study examined the effects of aggregate size (12-18 mm), three A/C ratios (3.5, 4.0, 4.5), and compaction levels (30, 45, 60 blows) on its properties. A constant water-cement ratio of 0.3 was maintained. Void ratio analysis, conducted using ImageJ software, revealed similar trends to porosity across variables. Higher compaction and lower A/C ratios improved compressive strength, reduced porosity, and decreased void ratios. The highest strength (13.7 MPa) was achieved at a 3.5 A/C ratio and 60 blows, while the lowest porosity (14.1%) and void ratio (32.25%) were observed under the same conditions. Findings suggest that a 3.5 A/C ratio with moderate compaction provides a balanced mix, combining strength with sufficient permeability for water passage.

Recommendations

Incorporating SEM analysis to assess void structure and morphology, along with studying aggregate size variations, cement types, curing conditions, and admixtures, is crucial for optimizing pervious concrete performance, particularly in sustainable urban drainage systems, where enhanced water infiltration and durability are essential for mitigating flooding and improving groundwater recharge.

References

- Arifi, E., Nur Cahya, E. & Setyowulan, D., 2020. The influence of various materials to the void ratio of Pervious Concrete. *IOP Conference Series: Earth and Environmental Science*, 437(1), p. 012016.
- BS, 1988. BS 1881-124:1988. Testing concrete. Part 124: Methods for analysis of hardened concrete. In: *BS 1881-124:1988. Testing concrete..* s.l.:BSI Standards Limited..
- Chandrappa, A. K. & Biligiri, K. P., 2016. Pervious concrete as a sustainable pavement material – research findings and future prospects: A state-of-the-art review. *Construction and Building Materials*, Volume 111, pp. 262-274.
- Ferguson, B. K., 2007. Porous pavements. In: *Encyclopedia of water Science*. Boca Raton, FL: CRC, p. 3.
- Gallagher, S. R., 2014. Digital Image Processing and analysis with imagej. *Current Protocols Essential Laboratory Techniques*, 9(1), pp. 9:A.3C.1-A.3C.29.
- Najah, N. S. et al., 2021. Compressive strength, permeability, and porosity analysis of pervious concrete by variation of a/c without fine aggregate. *AIP Conference Proceedings*, Volume 1, p. 2339.
- Sahdeo, S. K., Chandrappa, A. & Biligiri, K. P., 2021. Effect of compaction type and compaction efforts on structural and functional properties of Pervious Concrete. *Transportation in Developing Economies*, 7(2), p. 19.

Schneider, C., Rasband, W. & Eliceiri, K., 2012. NIH Image to ImageJ: 25 years of image analysis. *Nature Methods*, Volume 9, p. 671–675.

Shinde, G. U. & Valunekar, S. S., 2015. An experimental study on compressive strength, Void Ratio and infiltration rate of pervious concrete. *International Journal of Engineering Research and*, 4(4).

Torres, A. et al., 2018. Comparing design void content with actual void content of laboratory prepared pervious concrete. *Materials Sciences and Applications*, 9(7), pp. 596-613.

Wijekoon, S., 2023. Comparison Of Compressive Strength Between Two Porous Concretes Based On The Size Of Aggregates Used. *5th Annual International Research Symposium – 2022*.

Wijekoon, S. H., Shajeeferanath, T., Subramaniam, D. N. & Sathiparan, N., 2023. A mathematical model to predict the porosity and compressive strength of pervious concrete based on the aggregate size, aggregate-to-cement ratio and compaction effort. *Asian Journal of Civil Engineering*.

Zhao, N. et al., 2024. Application of a diabetic foot smart app in the measurement of diabetic foot ulcers. *International Journal of Orthopaedic and Trauma Nursing*, Volume 54, p. 101095.

THE IMPACT OF THE ECONOMIC CRISIS ON THE MEDIUM SCALE HOUSING INDUSTRY IN SRI LANKA

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Abstract

The 2022 economic crisis in Sri Lanka had a profound impact on the medium-scale housing sector in the Western Province, disrupting project budgets, timelines, and quality. This study explores these challenges from a project management perspective, focusing on five key variables: material and labour cost fluctuations, financial risk management, procurement delays, stakeholder dynamics, and scope adjustments. Analysing data from 125 construction professionals using correlation and regression methods revealed that material cost fluctuations and stakeholder dynamics were the most significant drivers of budget increases. The findings emphasize the importance of robust financial planning, proactive procurement strategies, and effective stakeholder collaboration in mitigating the crisis' impact. Policy measures such as tax incentives and enhanced credit access are identified as crucial to stabilizing and strengthening the sector.

Keywords: Budget Increase, Economic Crisis, Medium-Scale Housing, Material Cost Fluctuations, Policy Measures

Introduction

Sri Lanka's 2022 economic crisis brought unprecedented socio-economic and political challenges, with the country declared bankrupt (Athas et al., 2022). GDP fell by 7.8% compared to 3.5% growth in 2021 (Daily FT, 2023), affecting all sectors, including construction, a key employer of over 1.2 million people (Nilar, 2022). The medium-scale housing sector, vital for urban housing needs, was severely impacted by inflation, import restrictions, fuel shortages, and high borrowing costs, raising concerns about housing feasibility (Fernando, 2024).

The housing market saw the Housing Index rise by 57% between the first and third quarters of 2022, highlighting affordability challenges (Trading Economics, 2024). Construction professionals faced rising material costs, delays, and budget overruns, often compromising quality as clients opted for cheaper materials (Thilakshan, Arsecularatne, and Sandanayake, 2023). Additionally, the material industry faced price surges, import restrictions, and cash flow issues, leading to layoffs and unemployment (De Silva, Wijekoon, and Kalugala, 2023).

This research examines the economic crisis's impact on Sri Lanka's medium-scale housing sector, focusing on challenges faced by project managers due to cost increases. It explores the effects of inflation, material and labour cost escalations, financial constraints, and contractual adjustments on project budgets, procurement strategies, workforce management, and stakeholder relationships.

Objectives

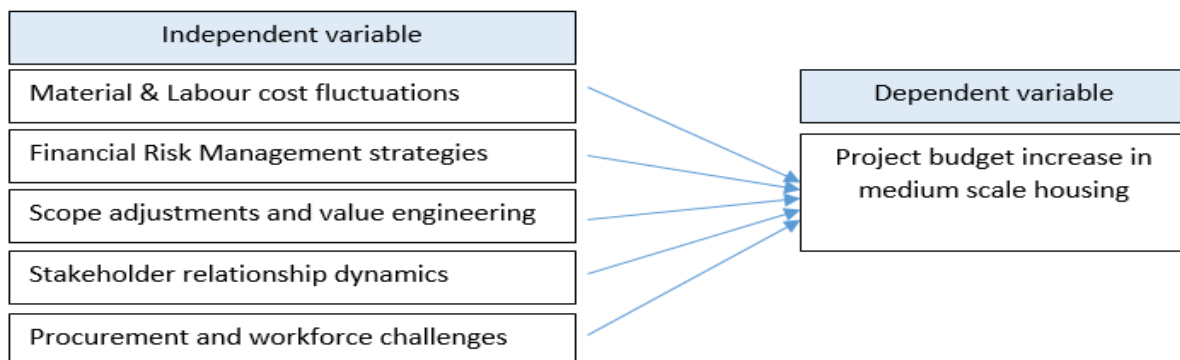
1. Examine the impact of material cost fluctuations on project budgets, including inflation, supply chain disruptions, and currency depreciation.
2. Analyze workforce challenges, such as labour shortages, wage inflation, and productivity issues.
3. Evaluate procurement delays caused by supplier uncertainties and import restrictions.
4. Investigate stakeholder interactions and their influence on project budgets during economic uncertainty.
5. Assess the effectiveness of crisis management strategies, including risk mitigation, cost optimization, and adaptive planning.

By addressing these objectives, the study aims to offer actionable recommendations to mitigate challenges and strengthen the resilience of the medium-scale housing sector during economic uncertainties. Its findings will provide valuable insights for policymakers, industry stakeholders, and researchers navigating future crises.

Methodology

This study adopted a mixed-methods approach to investigate the impact of the 2022 economic crisis on medium-scale housing projects in Sri Lanka. A structured questionnaire was distributed to 150 construction professionals, with 125 valid responses. The questionnaire incorporated both Likert-scale items and open-ended questions to capture quantitative and qualitative data. The key independent variables explored included material and labour cost fluctuations, financial risk management, procurement and workforce challenges, stakeholder dynamics, and scope adjustments. Data analysis was conducted using SPSS, with descriptive statistics, correlation, and regression analysis to identify relationships between variables and offer deeper insights into the effects of the crisis. The qualitative data were analyzed through thematic analysis to provide additional context. A purposive sampling method was employed to select construction professionals directly involved in medium-scale housing projects, ensuring relevance to the research objectives. Reliability and validity were confirmed through a pilot study, Cronbach's Alpha, and expert reviews. The study adhered to ethical standards, ensuring participant confidentiality, voluntary participation, and data protection.

Figure 1: Conceptual Framework (Developed by the Author)



Hypotheses Development

This research analyses challenges faced by medium-scale housing projects during Sri Lanka's 2022 economic crisis, focusing on factors driving budget increases. The following hypotheses were developed based on the study's objectives and key variables.

Figure 2: Hypotheses Development

H1	Material and labour cost fluctuations significantly increase project budgets
H2	Financial constraints strongly contribute to budget overruns
H3	Procurement delays negatively impact budgets and timelines
H4	Stakeholder dynamics significantly affect budget adjustments and delays
H5	Scope adjustments reduce costs but compromise quality and extend timelines

Quantitative Data Analysis

The results of this study highlight the significant impact of the 2022 economic crisis on medium-scale housing projects in Sri Lanka's Western Province. Key findings from the descriptive, correlation, and regression analyses are summarized below, with supporting tables for clarity.

Descriptive Statistics

Descriptive analysis revealed that the economic crisis had a profound effect on project budgets. Participants agreed strongly that material cost fluctuations, procurement delays, and financial constraints were critical challenges.

Table 1: Mean and Standard Deviation of Dependent & Independent Variables

Variable	Mean	Standard Deviation	Interpretation
Dependent Variable			
Project Budget Increases	4.45	0.70	Significant agreement on budget increases due to the economic crisis
Independent Variables			
Material and Labour Cost Fluctuations	4.44	0.67	Major contributor to budget instability due to inflation and supply disruptions.
Financial Risk Management Strategies	4.35	0.68	High-interest rates and limited credit caused severe financial stress.

Procurement and Workforce Challenges	4.28	0.63	Procurement delays and workforce shortages created operational bottlenecks.
Stakeholder Relationship Dynamics	4.30	0.76	Strained relationships led to frequent budget revisions and project delays.
Scope Adjustments and Value Engineering	4.10	0.85	Helped control costs but caused quality trade-offs and delays.

Correlation Analysis

Correlation analysis showed significant positive relationships between the independent variables and the dependent variable, project budget increases. Stakeholder dynamics and material cost fluctuations emerged as the strongest predictors.

Table 2: Correlation Analysis

Independent Variable	Correlation Coefficient (r)	Significance (p-value)	Strength of Correlation
Stakeholder Relationship Dynamics	0.672	< 0.001	Strong
Material & Labour Cost Fluctuations	0.648	< 0.001	Strong
Financial Risk Management Strategies	0.638	< 0.001	Strong

Regression Analysis

The regression analysis quantified the impact of each independent variable on budget increases. Material cost fluctuations and financial constraints were the most significant contributors.

Table 3: Regression Analysis

Variable	Unstandardized Coefficient (B)	Significance (p-value)	Interpretation
Material & Labour Cost Fluctuations	0.336	< 0.001	Strong positive influence on budget increases.
Financial Risk Management Strategies	0.281	< 0.005	Significant contributor to budget overruns.
Stakeholder Relationship Dynamics	0.292	< 0.002	Notable impact on budget adjustments.

The ANOVA test validated the regression model as highly significant ($p < 0.001$), with the model summary demonstrating a strong fit and a high R-squared value, confirming that the independent variables accounted for a substantial portion of the variance in project budget increases. The normality test, assessed through skewness and kurtosis, confirmed the dataset's appropriateness for analysis, as all values were within the acceptable range of -3 to +3. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy scored 0.874, indicating strong suitability for factor analysis, while Bartlett's Test of Sphericity (Chi-Square = 415.271, $p <$

0.001) verified significant correlations among variables, ensuring the dataset's validity for further statistical evaluation.

Qualitative Data Analysis

The thematic analysis of open-ended responses provided contextual insights into the quantitative findings, highlighting recurring themes related to challenges and strategies in medium-scale housing projects during the 2022 economic crisis.

Table 4: Qualitative Data Analysis

Theme	Key Issues Identified	Strategies Employed
Material Cost Escalation	Inflation, currency depreciation, and import restrictions caused price surges.	Substituting high-cost materials with local alternatives; early procurement to avoid future price hikes.
Financial Constraints	High-interest rates and restricted access to credit strained project finances.	Downsizing project scope, renegotiating payment terms, and employing contingency funds where available.
Procurement Delays	Supply chain disruptions and import restrictions led to project delays.	Bulk purchasing and material storage during stable economic periods to ensure supply continuity.
Stakeholder Collaboration	Disputes and communication breakdowns delayed critical decisions.	Proactive stakeholder engagement, regular budget revisions, and transparent communication.
Scope Adjustments	Scope reductions to manage escalating costs often compromised project quality.	Value engineering to optimize costs without sacrificing critical aspects of quality.

Trend Series Analysis

The trend series analysis reveals that material prices saw a dramatic 141% increase in 2022, reflecting the peak impact of the economic crisis. Following the crisis, material prices began to decline, yet in 2024, they still remained elevated, showing a 98% increase, marking one of the highest values recorded.

Figure 3: Percentage Increase of Materials in Relation to the year 2020 (Developed by author)

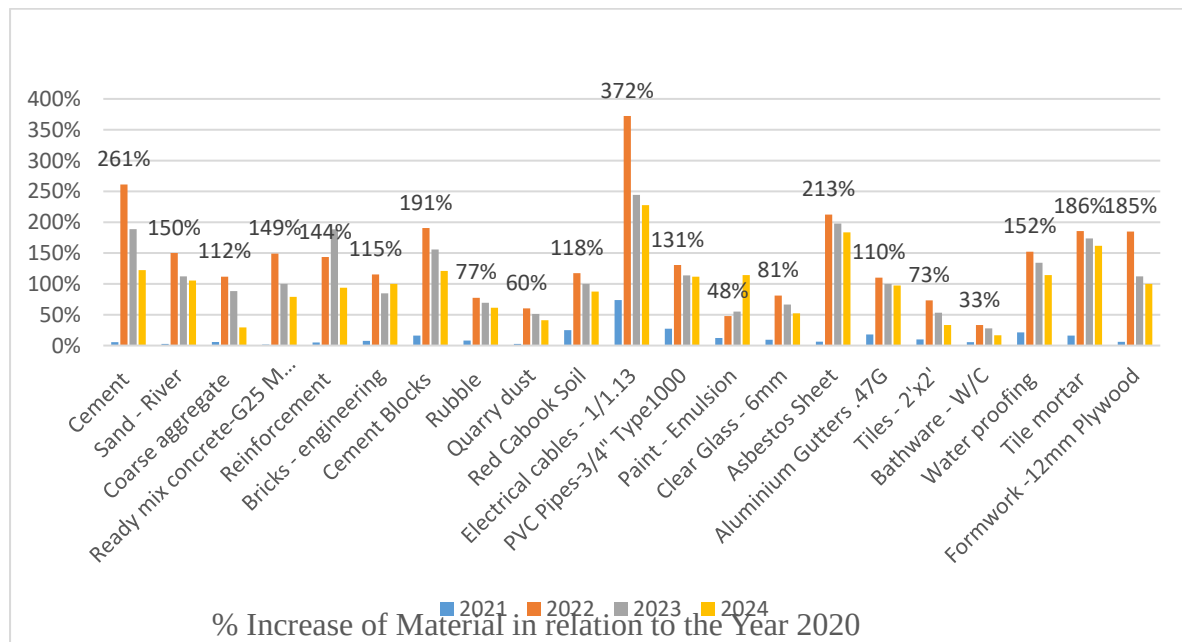
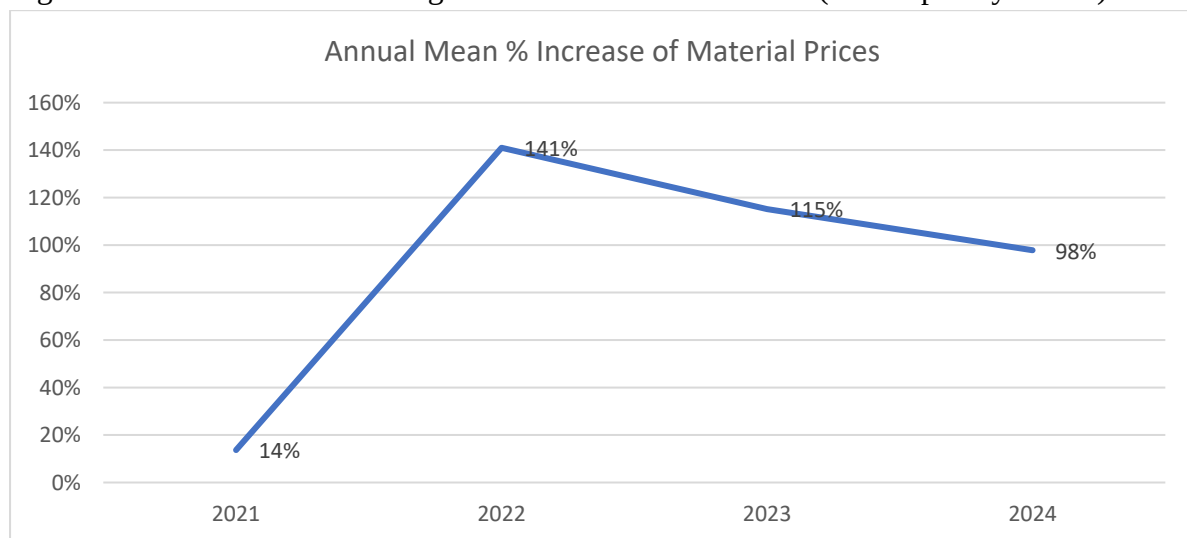


Figure 4: Annual Mean Percentage Increase of Material Prices (Developed by author)



The bar chart is a depiction of a series of material-wise values ranging from the years 2021-2024. The base point values have been derived from the year 2020.

Discussions & Key Findings

The findings of this research align with and extend previous studies in key areas. Similar to (Thilakshan, Arsecularatne and Sandanayake, 2023) who identified material and labour cost fluctuations as significant contributors to budget overruns, this study found that inflation, currency depreciation, and procurement delays greatly impacted project costs (Langappuli et al., 2023) highlighted the financial strain caused by high-interest rates and limited credit, which this study corroborates, while also emphasizing the underutilization of contingency planning, a less explored area in prior research. (Vivekanantharasa and Somarathna, 2023) suggested local material production as a solution, but this study revealed practical challenges, such as

limited supply chain capacity and material availability during crises. Effective stakeholder communication, as noted by (Langappuli et al., 2023), mitigated financial issues; however, this research shows that communication breakdowns and delayed negotiations often caused project delays and additional costs. While previous studies acknowledged procurement issues, this study highlights the interconnection between procurement delays and labour shortages as significant contributors to cost escalations. Additionally, unlike (Jayamal, Gunaratne, and Perera, 2023) who focused on macroeconomic policies and (Nilar, 2022) who emphasized technological solutions, this study fills a critical gap by addressing the unique challenges of medium-scale housing projects.

Conclusions & Recommendations

The study proposes strategies to strengthen the resilience of the medium-scale housing sector during economic crises. Construction professionals should prioritize comprehensive financial planning by establishing contingency funds and adopting flexible financing approaches to address cost escalations and credit challenges. Proactive procurement measures, such as early material sourcing and storage, are essential to reduce supply chain vulnerabilities. Implementing value engineering can optimize costs while maintaining quality, with careful scope management to prevent delays and compromises. Enhancing stakeholder communication and collaboration is key to resolving conflicts and ensuring timely decisions. Policymakers should stabilize material costs, incentivize local production, reinforce supply chains, and offer subsidized loans to ease financial burdens and sustain projects.

References

- Athas, I., Liakos, C., Mogul, R., and Gonzalez-Roman, D. (2022) *Sri Lanka is 'bankrupt,' Prime Minister says*. CNN News [online], 6th July 2022
Available at:
<https://edition.cnn.com/2022/07/05/asia/sri-lanka-bankrupt-fuel-crisis-intl-hnk/index.html>
[Accessed: 6th October 2023]
- Daily FT, (2023) *2022 suffers worst ever economic contraction of 7.8%* [online], 16th March 2023
Available at:
https://www.ft.lk/top-story/2022-suffers-worst-ever-economic-contraction-of-7-8/26-746398?fbclid=IwAR3vtqEkp-v3ZZIDSvGohDGrC215MWwquEaluua_9eRqU1_Dh1z83zEDa2w
[Accessed: 7th October 2023]
- 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: Proceedings of the 11th World Construction Symposium*, 21-22 July 2023, Sri Lanka. [online]. pp. 557-568
Available at:
<http://dl.lib.uom.lk/bitstream/handle/123/21302/46-S15091.pdf?sequence=1#:~:text=According%20to%20the%20questionnaire%20survey,employees%20of%20the%20construction%20industry>

[Accessed: 12th October 2023]

Fernando, D. (2024) *Middle class caught in housing dilemma*: Advocata Institute, 10th February 2024 [online]

Available at:

<https://www.advocata.org/commentary-archives/2024/02/10Middle%20class%20caught%20in%20housing%20dilemma>

[Accessed: 14th October 2024]

Langappuli, B.L., Ilangakoon, I.W.M.A.D., Disaratna, P.P.V.D.S. and Perera, B.A.K.S. (2023) *Framework to Manage the Impacts on the Contractor's Budget for Construction Projects Due to the Economic Crisis in Sri Lanka*: Journal of Design and Built Environment, Vol.23(3), 2023, 98–117, September 2023 [online]

Available at:

<https://adab.um.edu.my/index.php/jdbe/article/view/46792/16416>

[Accessed: 14th October 2024]

Nilar, A. (2022) *1.2Mn in construction industry face unemployment within a month*. News1st [online], 28th May 2022

Available at:

<https://www.newsfirst.lk/2022/05/28/1-2mn-in-construction-industry-face-unemployment-within-a-month/>

[Accessed: 10th October 2023]

Thilakshan, K., Arsecularatne, B., and Sandanayake, Y.G. (2023) *Impact of economic decisions on building construction material prices in Sri Lanka: Proceedings of the 11th World Construction Symposium*, 21-22 July 2023, Sri Lanka. [online]. pp. 569-581

Available at:

<https://acrobat.adobe.com/link/review?uri=urn%3Aaid%3A%3AUS%3A76db2d6e-95ae-376c-bcc9-ef3293d75d18>

[Accessed: 14th October 2023]

Trading Economics. (2024) *Sri Lanka Housing Construction Costs Index, 2024* [online]

Available at: <https://tradingeconomics.com/sri-lanka/housing-index>

[Accessed: 14th October 2024]

INVESTIGATION OF FACTORS LEADING TO DELAYS IN LARGE SCALE WATER SUPPLY PROJECTS IN SRI LANKA

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Abstract

Most of the infrastructure developments are carried out on project basis. Construction projects frequently suffer from delay, though there are many sophisticated tools and techniques available for construction project management. This research investigates the factors contributing to delays in Large Scale Water Supply Projects (LSWSP) in Sri Lanka and proposes effective mitigation strategies. The study aims to identify key delay factors, categorize them into client/consultant-related, contractor/subcontractor-related and external factors and their impact on project timelines. A quantitative approach was employed, using a structured questionnaire survey distributed to different stakeholders. The findings revealed that client payment delays, material import delays, and the COVID-19 pandemic were the most significant contributors to project delays. Effective project scheduling, minimizing change orders, and effective strategic planning were identified as key strategies to mitigate delays. The study provided actionable insights for project stakeholders to improve project delivery, reduce costs, and ensure timely access to clean water.

Keywords: Delay Factors, Large Scale Water Supply Projects, Project Delay Mitigation

Introduction

Access to clean and safe drinking water is a fundamental human right, yet in Sri Lanka, only 57.7% of the population has access to piped water. The Government of Sri Lanka aims to achieve 100% access to safe drinking water by 2025, as part of the “Water for All” initiative, aligned with the United Nations Sustainable Development Goal 6 (National Water Supply & Drainage Board, 2020). To achieve this, several large-scale water supply projects (LSWSP) have been launched. The projects face significant delays, leading to increased project costs, interest payments on foreign loans, and delays in public access to clean water. Addressing these delays is crucial for achieving national development goals and improving the well-being of Sri Lanka's citizens (Ministry of Water Supply Sri Lanka, 2022).

Previous studies, such as Halwatura and Perera (2012), highlight that construction project delays often result from client, contractor, and consultant-related issues, as well as external factors like inflation, funding delays, and global crises. In Sri Lanka, inadequate project planning, and mismanagement have been identified as primary internal factors (Ranasinghe, Jayathilake, & Silva, 2019). Similarly, poor project planning, including inaccurate cost

estimation and unrealistic timelines, exacerbates delays (Wickramasinghe & Gunasekara, 2020).

The most significant ranking factors identified by Sivarajah (2021) and (Abdel-Wahab, et al. (2019), include lack of communication with parties, shortage of materials, improper planning, site management, and mistakes during construction. The contractor's role in causing delays could be attributed to several factors. In Sri Lanka, environmental concerns, land acquisition issues, and community opposition are prominent external causes of delays (Fernando & Abeygunawardene, 2021). Environmental impact assessments often prolong project timelines due to rigorous regulatory requirements (Perera & Gunaratne, 2018).

This study identifies and ranks critical delay factors affecting LSWSP in Sri Lanka, focusing on client, contractor, and external causes. Delays in LSWSP, often linked to cost overruns and financial strains, are analyzed through stakeholder surveys to propose effective mitigation strategies. Emphasis is placed on minimizing delays caused by systematic inefficiencies, contractual shortcomings, and unforeseen circumstances. Findings aim to assist stakeholders in reducing delays, fostering better project management, and enhancing the timely delivery of LSWSP.

Methodology

Data Collection

The data collection process was carried out using both primary and secondary methods. Secondary data was obtained from literatures sources. Primary data was gathered through a structured questionnaire survey, in which Likert scale questions were utilized to rank delay factors and mitigation strategies. The questionnaire was developed based on a comprehensive review of existing literature and extension of time (EOT) documents from large-scale water supply projects. Respondents were requested to rank delay factors using a 5-point Likert scale, allowing for the quantification of responses.

Sampling Strategy

The population, consisting of professionals with LSWSP experience in Sri Lanka such as construction managers, engineers, quantity surveyors, surveyors, and technical officers, was sampled using convenience and snowball sampling to ensure diverse stakeholder representation. Sampling, the method to gather data from a specific set of individuals, employed convenience and snowball techniques (McCombes, 2023). A sample size of 131 individuals, representative of the population, was collected for analysis in this study.

Data Analysis

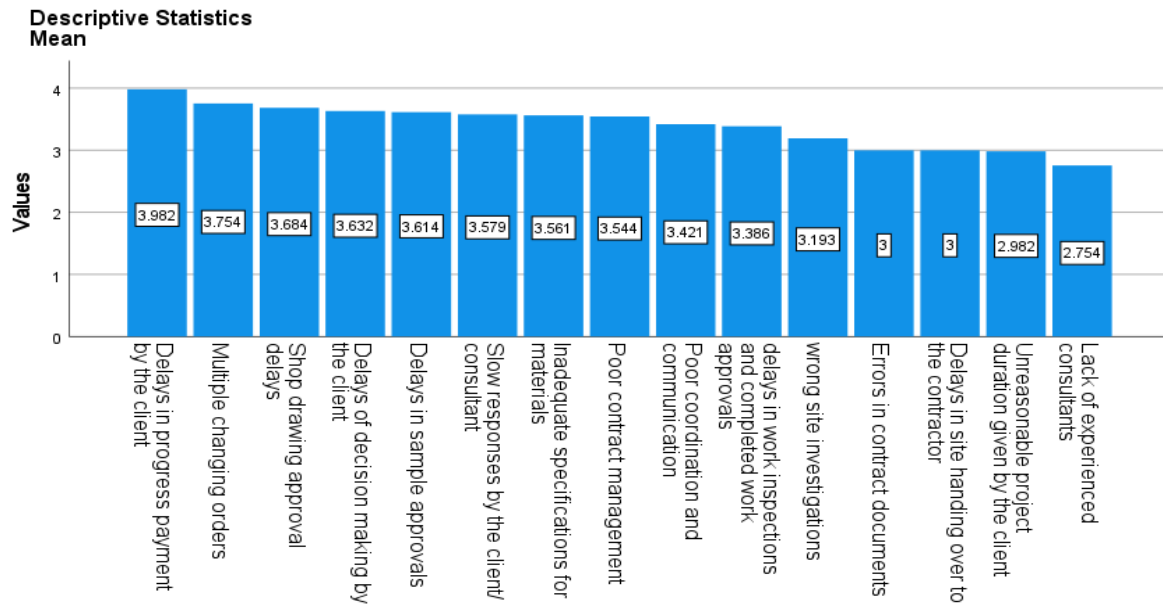
The collected data from the questionnaire survey was analyzed quantitatively. The Likert scale responses, ranging from 1 to 5, were utilized to gauge the relevance of delay factors and mitigation strategies based on respondents' experiences. The analysis involved ranking the most crucial delay factors separately for contractors and clients using the mean method. Mitigation factors were ranked according to the frequency method (Dudovskiy, 2022).

Results and Discussion

Client/Consultant-Related Delay Factors

The questionnaire encompassed 15 factors and mean values of the factors were calculated, enabling the arrangement of factors in descending order based on their impact on project delays.

Figure 1: Delay factors related to client/Consultant

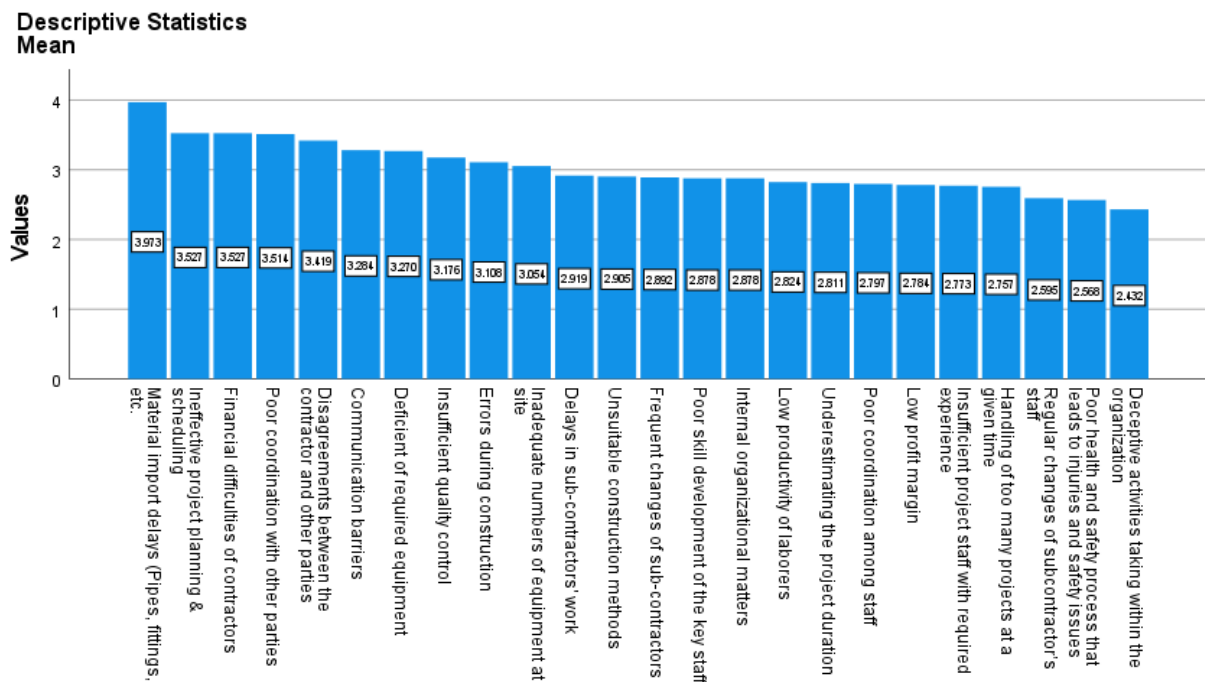


In the analysis of client/consultant related delay factors (Figure 1), the mean values were utilized to rank the factors in order of significance. The findings indicate that "Delays in progress payment by the client" emerged as the most significant factor. This suggests that delays in receiving payments from the client have a substantial impact on project timelines. Following closely behind is "Multiple changing orders" and ranked second. This highlights the detrimental effect of frequent changes in project scope on project progress and completion.

Contractor/Subcontractor - Related Delay Factors

By presenting the factors in descending order of mean values, it identifies the most significant contributors to delays in LSWSP.

Figure 2: Delay factors related to contractors/ sub-contractors



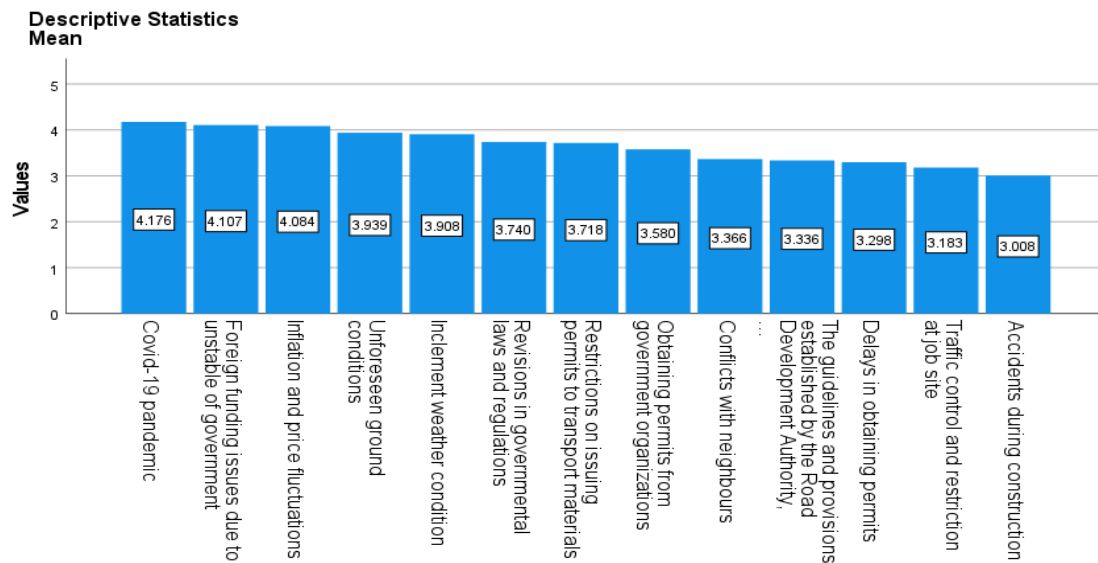
As per Figure 2, material import delays emerged as the most significant factor. Following closely behind, two factors, namely ineffective project planning & scheduling and financial difficulties of contractors.

External Delay Factors

The analysis highlighted specific external factors that significantly impacted project delays, shedding light on critical areas requiring attention and mitigation strategies. By presenting the factors in descending order of mean values, the chapter identifies the most influential external contributors to delays, providing stakeholders with valuable insights to address external challenges effectively in project management.

As per figure 3, the analysis reveals that project delays are most significantly affected by the COVID-19 pandemic. This unprecedented global health crisis has led to disrupted supply chains, restricted mobility, and stringent health and safety measures, significantly impacting construction activities worldwide. Following closely behind, foreign funding issues due to government instability were identified as the second most influential factor.

Figure 3: External delay factors



Project Delay Mitigation Strategies

The survey comprised multiple-choice questions designed to gauge respondents' perspectives and experiences in identifying effective mitigation strategies. The analysis revealed certain mitigation strategies that resonated more strongly with respondents compared to others.

Figure 4: Mitigation method frequencies

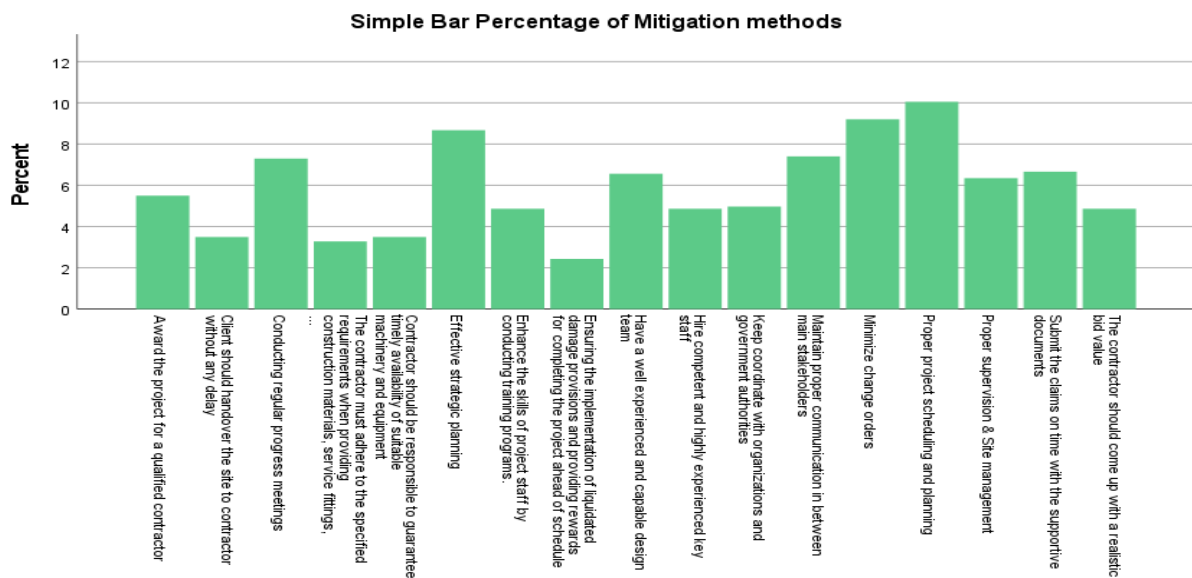


Table 1: Ranking delay mitigation strategy

Delay mitigation strategy	Responses (Percentage)	Rank
Proper project scheduling and planning.	10.10%	1
Minimize change orders.	9.20%	2
Effective strategic planning.	8.70%	3
Maintain proper communication in between main stakeholders.	7.40%	4
Conducting regular progress meetings.	7.30%	5
Submit the claims on time with the supportive documents.	6.70%	6
Have a well experienced and capable design team.	6.60%	7
Proper supervision & Site management.	6.30%	8
Award the project for a qualified contractor.	5.50%	9
Keep coordinate with organizations and government authorities.	5.00%	10
Hire competent and highly experienced key staff.	4.90%	11
Enhance the skills of project staff by conducting training programs.	4.90%	11
The contractor should come up with a realistic bid value.	4.90%	11
Client should handover the site to contractor without any delay.	3.50%	14
Contractor should be responsible to guarantee timely availability of suitable machinery and equipment.	3.50%	14
The contractor must adhere to the specified requirements when providing construction materials.	3.30%	16
Ensuring the implementation of liquidated damage provisions and providing rewards for completing the project ahead of schedule.	2.40%	17

In the analysis conducted in Figure 4 and Table 1, delay mitigation strategies were ranked based on their frequencies, with percentages indicating their effectiveness. Proper project scheduling and planning emerged as the most significant strategy, attributing high effectiveness to it, positioning it as the top-ranked strategy. Following closely, minimizing change orders garnered. These findings provide valuable insights into the prioritization of delay mitigation strategies, guiding stakeholders in implementing targeted measures to optimize project outcomes.

Overall Discussion

Table 2: Case summary of delay factors

Delay factor	Mean	Percentage
External delay factors	3.649	36.19%
Client/Consultant related delay factors	3.406	33.78%
Contractor/sub-contractor related delay factors	3.028	30.03%

As per Table 2, the overall analysis of the delay factors reveals that external factors have the highest mean value of the total influence on project delays. This suggests that external challenges, such as the COVID-19 pandemic, foreign funding issues, and inflation, play a significant role in impeding project timelines. Client/consultant related delay factors follow closely behind because delays in progress payment by the client, multiple changing orders, and shop drawing approval delays are among the key contributors in this category. Contractor/ sub-contractor related delay factors exhibit material import delays, ineffective project planning & scheduling, and financial difficulties of contractors are identified as primary factors influencing project delays within this category.

Both internal and external factors significantly impact project delays, with external factors exerting a greater influence in recent times. The COVID-19 pandemic, for instance, has caused widespread disruptions, including country shutdowns, travel restrictions, and health and safety concerns, leading to project delays. Moreover, the economic crisis has exacerbated the situation, resulting in funding issues and the suspension of several projects pending International Monetary Fund (IMF) support. Furthermore, steep price fluctuations and material import issues have further complicated project execution. The fluctuating prices have rendered contractors unable to provide accurate quotations, while the importation of critical materials such as HDPE and DI pipes and fittings has faced significant hurdles. These challenges have been pervasive across many projects, severely hampering progress.

In addition to external factors, internal issues related to clients and consultants play a pivotal role in project delays. Delays in progress payments, frequent change orders, and delays in decision-making processes directly impact project timelines. Therefore, it is imperative for stakeholders to address both internal and external challenges effectively to mitigate project delays and ensure successful project delivery.

From these factors, both internal and external, effective mitigation strategies were derived to address the most significant challenges encountered in large scale water supply projects. For the external factors, the most impactful mitigation strategies were devised to tackle the prominent challenges faced by the construction industry. Strategies such as proactive risk management plans to navigate through crises like the COVID-19 pandemic and establishing robust financial management practices to mitigate funding issues due to economic instability were emphasized. Regarding internal factors, strategies focused on enhancing project planning and coordination mechanisms were proposed. These include refining project scheduling

techniques to minimize change orders and ensuring effective communication channels among stakeholders to streamline decision-making processes and minimize conflicts.

The findings of this study emphasize the complexity of managing LSWSP, with client, contractor, and external factors all playing a significant role in causing delays. According to the Silva (2023) and Wickramasinghe & Gunasekara (2020), Bureaucratic hurdles and poor planning, including inaccurate cost estimates and unrealistic timelines, are attributed to clients. As per the Dolage & Pathmarajah (2015), delays are also linked to contractors due to financial pressures, limited project management experience, and resource challenges. According to the Gammange & Gunarathna (2022) and (Bandaranayake & Rathnayaka, 2022), external factors, such as the Covid-19 pandemic, have resulted in supply chain disruptions, labor shortages, and schedule interruptions which correspond with findings from this research on pandemic-related project delays. The mitigation strategies suggested, including improved financial management, better stakeholder coordination and use of advanced project planning tools are crucial for improving the efficiency of LSWSP in Sri Lanka.

Conclusion

The research embarked on a thorough exploration of factors contributing to delays in LSWSP within Sri Lanka. It began with a comprehensive literature review of delays in water supply projects worldwide, using various sources such as journal articles, reports, and online platforms like Google Scholar and Science Direct to gain a thorough understanding of the issue. Relevant ongoing and completed LSWSPs in Sri Lanka were identified through the analysis of statistics, industry consultations, and reports from the National Water Supply and Drainage Board (NWSDB). A structured questionnaire survey was then conducted among stakeholders, including construction managers, engineers, and surveyors, to gather insights on delay factors and potential mitigation strategies. The collected data was analyzed using SPSS and Microsoft Excel to identify and rank the key factors causing delays.

Based on the analysis, the most effective delay mitigation strategies were identified. These strategies were ranked based on their frequency of selection by respondents, providing insights into the most favored approaches to mitigating project delays. Recommendations for stakeholders were formulated based on the analysis of delay factors and mitigation strategies. These recommendations aimed to offer practical solutions for minimizing delays.

By systematically addressing the research aim, analyzing data, and interpreting findings, this study has provided valuable insights into the challenges faced in project management within the construction industry. The study's recommendations aim to improve project performance by encouraging timely client payments, effective strategic planning, minimize change orders and supply chain diversification.

Recommendations

Future studies can advance construction project management by exploring key areas. Comparative analyses of small and medium-scale water supply projects can identify unique delay factors, while investigating emerging technologies like BIM and artificial intelligence

may improve delay mitigation. Research into sustainable construction practices and green building principles could offer strategies to address environmental challenges and enhance project resilience.

Further, analyzing legal and regulatory frameworks, including contract management and dispute resolution, can uncover ways to minimize delays. Exploring innovative risk management strategies tailored to LSWSP and examining effective stakeholder engagement approaches can foster collaboration, reduce conflicts, and improve overall project efficiency. By implementing these strategies, stakeholders can reduce delays, improve project delivery, and support Sri Lanka's goal of achieving 100% access to clean water by 2025.

References

- Abdel-Wahab, A., El-Kady, M. & El-Masry, A., (2019). Causes of delay in water and wastewater projects: A case study. *Alexandria Engineering Journal*, V(8), pp. 1277-1286.
- Bandaranayake, B. & Rathnayaka, M., (2022). *The Effect Of Labour Productivity On Successful Completion Of Major Contracts During The Covid Pandemic In Sri Lanka*. s.l., Proceedings of the 10th World Construction Symposium.
- Dolage, D. & Pathmarajah, T., (2015). Mitigation of Delays Attributable to the Contractors in the Construction Industry of Sri Lanka -Consultants' Perspective. *The Institution of Engineers, Sri Lanka*, XLVIII(1), pp. 21-30.
- Dudovskiy, J., (2022). *The Ultimate Guide to Writing a Dissertation in Business Studies*. 6th ed. s.l.:s.n.
- Fernando, S. & Abeygunawardene, P., (2021). *Assessing Delays in Water Supply Projects in Sri Lanka: The Case of Water Supply Project for Hambantota District*. In *Proceedings of the International Conference on Industrial Engineering and Operations Management*. Colombo, s.n.
- Gammage, S. & Gunarathna, N., (2022). *Delays And Disruptions In The Construction Industry During The Global Pandemic*. s.l., Proceedings of the 10th World Construction Symposium.
- Halwatura R, U. & Perera W, D., (2012). Causes and Effects of Delays in Construction of Medium Scale Drinking Water Supply Projects in Sri Lanka. *Annual Transactions of IESL*, pp. 151-159.
- McCombes, S., (2023). *Sampling Methods | Types, Techniques & Examples*. [Online] Available at: <https://www.scribbr.com/methodology/sampling-methods/> [Accessed 2 August 2023].
- Ministry of Water Supply Sri Lanka, (2022). *National Water Supply & Drainage Board, Corporate Plan 2020-2025*, Colombo: Government of democratic socialist republic of Sri Lanka.

National Water Supply & Drainage Board, (2020). *Annual Report 2020*, s.l.: Ministry of Water Supply.

Perera, H. & Gunaratne, L., (2018). Environmental Impact Assessment in Developing Countries: A Case Study of a Water Supply Project in Sri Lanka.. *International Journal of Environmental Science and Development*, IX(11), pp. 311-316.

Ranasinghe, M., Jayathilake, S. & Silva, R., (2019). Impact of Bureaucratic Decision Making on Project Success. *Journal of Economic and Sustainable Development*, X(15), pp. 136-145.

Silva, P., (2023). *Daily FT.* [Online] Available at: <https://www.ft.lk/columns/Global-economic-crisis-and-implications-for-Sri-Lanka-s-construction-industry/4-750925#:~:text=In%20fact%2C%20it%20has%20been,over%206%2C000%20insolvencies%20in%202023.>

[Accessed 28 July 2023].

Sivarajah, T., (2021). Construction Projects delays in Sri Lanka. *Journal of Research Technology & Engineering*, II(4), pp. 25-29.

Wickramasinghe, K. & Gunasekara, H., (2020). *Challenges Faced by Sri Lankan Government Megaprojects. In Proceedings of the International Conference on Sustainability and Resilience of Mega Projects*. Colombo, s.n.

FEASIBILITY OF INCREASING SOIL STRENGTH CHARACTERISTICS BY ADDING WASTE PAPER PULP WITH CEMENT AND LIME

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Abstract

Soil stabilization plays a vital role in construction, particularly in addressing the limitations of native soils that lack adequate strength to bear structural loads. Conventional stabilizers, such as cement and lime, improve soil strength but come with significant environmental and economic costs. This research explores the feasibility of incorporating waste paper pulp (WPP) as a partial replacement for cement and lime to enhance soil stabilization, thereby reducing environmental impacts and resource dependency. Laboratory tests, including sieve analysis, Proctor compaction, and California Bearing Ratio (CBR) tests, were conducted on various soil compositions. The results indicated that adding WPP improves soil strength characteristics while reducing reliance on traditional stabilizers. The findings advocate for sustainable soil stabilization practices by integrating waste materials, conserving resources, and mitigating ecological impacts.

Keywords: Soil Stabilization, Sustainable Construction, Soil Strength, Cement and lime, Waste Paper Pulp.

Introduction

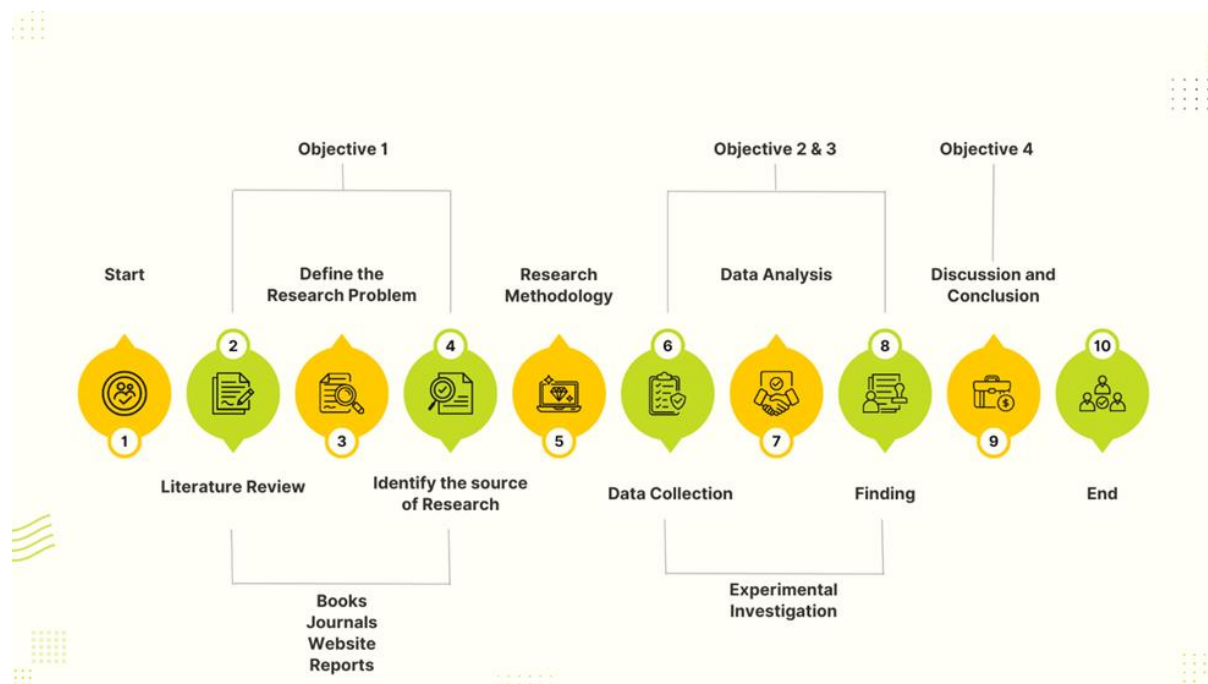
Soil stabilization is a crucial process in civil engineering, aimed at enhancing the physical and mechanical properties of soil to meet specific construction requirements. In regions where native soils lack sufficient load-bearing capacity, stabilization techniques become essential for ensuring the durability and safety of structures. Traditionally, cement and lime have been widely utilized as stabilizing agents due to their proven effectiveness in improving soil strength and shear capacity. However, these materials have significant drawbacks, including high environmental costs, such as the release of CO₂ during cement manufacturing and the ecological damage caused by limestone extraction. These challenges highlight the urgent need for more sustainable and eco-friendly alternatives in construction practices.

Waste paper pulp (WPP), an abundant byproduct of the paper industry, offers an innovative solution to these issues. With over 414 million metric tons of paper produced globally each year, approximately 26% ends up in landfills, contributing to waste accumulation and environmental degradation. Utilizing WPP in soil stabilization not only addresses waste management concerns but also reduces dependency on traditional stabilizers. This approach aligns with global efforts to promote sustainable practices and minimize the carbon footprint of construction activities.

This study investigates the feasibility of integrating WPP with cement and lime to enhance soil strength while mitigating environmental impacts. Through laboratory experiments, the research evaluates the mechanical performance of soil stabilized with varying proportions of WPP, cement, and lime. The findings aim to provide practical insights into adopting waste materials for sustainable soil stabilization, paving the way for innovative and environmentally responsible construction solutions.

Methodology

Figure 1: Methodology Chart



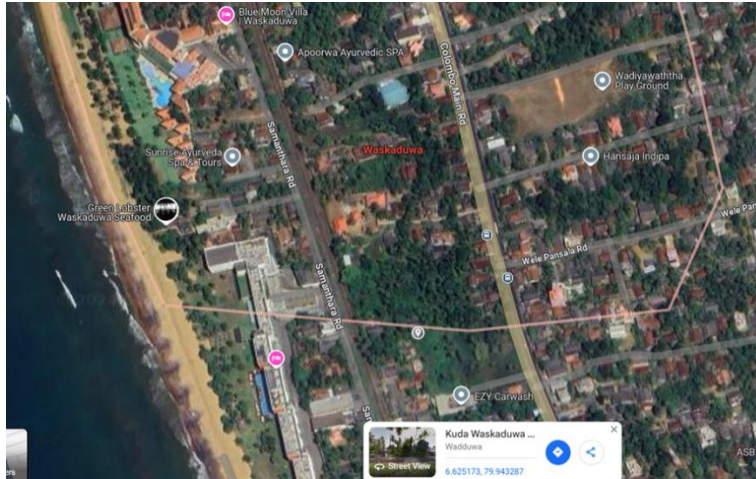
This research adopted a quantitative approach to investigate the feasibility of incorporating waste paper pulp (WPP) as a partial stabilizer in soil stabilization, alongside cement and lime. The methodology was carefully designed to ensure the reliability and validity of results, adhering to standard protocols for soil stabilization studies. The steps involved in the research process are outlined below:

Sample Collection and Preparation

Soil samples were sourced from Waskaduwa, Sri Lanka, a coastal area characterized by sandy soil with low compressibility. This location was selected due to its relevance to construction projects requiring enhanced soil stability. The collected samples underwent an initial cleaning process to remove organic matter and debris. Subsequently, the soil was dried, sieved, and classified according to its particle size distribution using ASTM D422 standards. The sieve analysis provided crucial insights into the soil's gradation and suitability for stabilization.

Figure 2: Location of collected soil sample

(source: <https://www.google.com/maps/place/Waskaduwa>)



Stabilization Mix Design

A total of four different stabilization mix ratios were prepared to evaluate the effects of varying proportions of cement, lime, and WPP on soil strength. The base mix comprised 90% soil, with the remaining 10% allocated among the stabilizing agents. The ratios tested included:

90% soil + 5% cement + 5% lime (no WPP).

90% soil + 4% cement + 4% lime + 2% WPP.

90% soil + 3% cement + 3% lime + 4% WPP.

100% soil (control sample with no stabilizers).

The WPP was prepared by soaking waste paper in water at a 4:1 water-to-paper ratio to produce a consistent pulp.

Figure 3: Mix proposition that use to test



Testing Protocol and Standards

The laboratory procedures adhered to ASTM standards, ensuring consistency and comparability with prior studies. The Proctor Compaction Test followed ASTM D698, while the CBR test conformed to ASTM D1883. These standardized protocols ensured that the results were accurate, reproducible, and aligned with industry practices.

Figure 4: Sieve Analysis Test done for soil sample



Figure 5: California bearing test



Data Analysis

The experimental results were analyzed using statistical tools to identify trends and relationships between the mix compositions and the observed soil properties. The unsoaked and soaked CBR values were compared across all samples to evaluate the influence of WPP on soil strength. Additionally, regression analysis was employed to assess the correlation between WPP content and the mechanical properties of the stabilized soil. The findings were further validated by comparing them with existing literature on soil stabilization techniques.

This comprehensive methodology ensured a robust evaluation of WPP's potential as a sustainable alternative in soil stabilization, providing valuable insights into its applicability and effectiveness.

Results

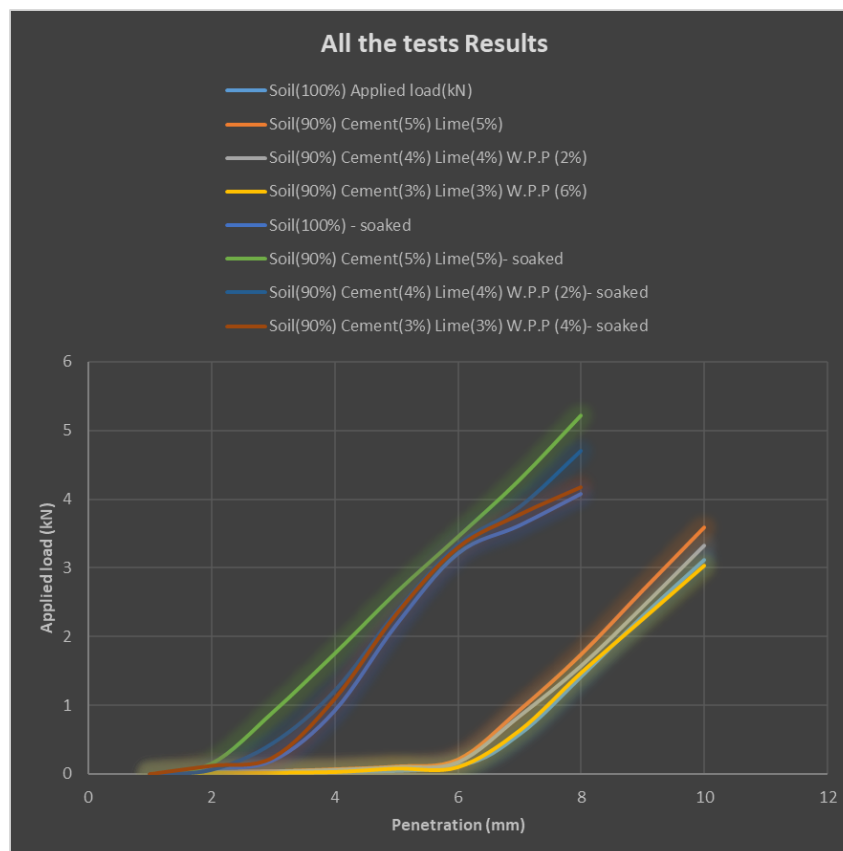
The study investigated the feasibility of improving soil strength by incorporating waste paper pulp (WPP) with cement and lime as stabilizers. For unsoaked samples, the optimal mix of 90% soil, 5% cement, and 5% lime yielded the highest California Bearing Ratio (CBR) value of 0.551%, while the addition of WPP slightly reduced unsoaked strength. Specifically, 2% WPP achieved a CBR value of 0.501%, and 4% WPP further decreased it to 0.401%. In soaked conditions, which typically simulate water exposure, the CBR values were higher across all samples. The combination of 90% soil, 5% cement, and 5% lime again exhibited the highest soaked CBR value of 18.797%. The inclusion of 2% and 4% WPP resulted in slightly lower

soaked CBR values of 16.742% and 16.491%, respectively, indicating that WPP moderately reduced soil strength compared to the lime-cement mix but remained effective. Overall, the 90% soil, 5% cement, and 5% lime mixture demonstrated the best performance in both unsoaked and soaked conditions, making it the most effective combination for soil stabilization. The study also highlights the environmental benefits of using WPP as a sustainable alternative to reduce reliance on cement and lime, thereby addressing concerns like CO₂ emissions and resource depletion. However, limitations include the focus on a single soil type, restricting the generalizability of findings, and the lack of long-term durability assessments for WPP-stabilized soil under varying environmental conditions.

Table 1: CBR test values

Sample				Applied load (kN)				CBR value (%)			
Mix ratio (%)				Unsoaked		Soaked		Unsoaked		Soaked	
Soil	Cement	Lime	WPP	2.5mm	5mm	2.5mm	5mm	2.5 mm	5 mm	2.5 mm	5 mm
100	0	0	0	0.02	0.04	0.08	3.21	0.152	0.201	0.606	16.090
90	5	5	0	0.03	0.11	1.5	3.75	0.227	0.551	11.364	18.797
90	4	4	2	0.032	0.1	0.75	3.34	0.242	0.501	5.682	16.742
90	3	3	4	0.02	0.08	0.56	3.29	0.152	0.401	4.242	16.491

Graph 1: All the CBR tests results



Discussion

The study shows that incorporating waste paper pulp (WPP) with cement and lime effectively enhances soil strength, with the mix of 90% soil, 5% cement, and 5% lime achieving the highest CBR values in both unsoaked and soaked conditions. While adding WPP slightly reduced strength compared to the lime-cement mix, its performance remained sufficient, especially in soaked conditions. This highlights WPP's potential as a sustainable partial substitute for cement and lime, reducing environmental impacts like CO₂ emissions.

However, the study's focus on a single soil type limits its generalizability, and the long-term durability of WPP-stabilized soil remains unexplored. Future research should assess this method across diverse soil types and environmental conditions. Despite these limitations, the findings support using waste materials in sustainable construction, promoting resource conservation and environmental protection.

Conclusions and Recommendation

Conclusions

This research explored the feasibility of incorporating waste paper pulp (WPP) with cement and lime as a sustainable soil stabilization solution. The findings demonstrate that WPP can significantly enhance soil strength characteristics while addressing key environmental challenges posed by traditional stabilizers. Specifically:

1. **Mechanical Improvements:** The integration of WPP with cement and lime improved soil compressive strength and load-bearing capacity, as evidenced by increased California Bearing Ratio (CBR) values, particularly in soaked conditions.
2. **Environmental Benefits:** Incorporating WPP reduced reliance on cement and lime, mitigating the environmental impact of limestone extraction and CO₂ emissions from cement production. The study also diverted paper waste from landfills, contributing to waste management and resource conservation.
3. **Optimal Mix Ratio:** Among the tested compositions, the mix of 90% soil, 5% cement, and 5% lime consistently yielded the highest CBR values in both soaked and unsoaked conditions, making it the most effective combination for stabilizing soils. While higher WPP content reduced strength in unsoaked conditions, its performance under soaked conditions remained comparable, indicating its potential for wet or water-saturated environments.

Despite these promising results, the study highlighted certain limitations, including the focus on a single soil type and the lack of long-term durability testing for WPP-stabilized soils. These findings underscore the need for further research to optimize WPP utilization and explore its broader applicability in civil engineering projects.

Recommendation

To advance the use of WPP in soil stabilization, the following steps are suggested:

- Expand Research Scope: Test WPP stabilization on various soil types and under diverse environmental conditions to ensure broader applicability.
- Optimize Mix Ratios: Investigate alternative proportions of WPP, cement, and lime to maximize performance while enhancing sustainability.
- Study Long-Term Durability: Conduct field trials and accelerated aging tests to evaluate the long-term stability and biodegradation of WPP-stabilized soils.
- Encourage Policy Support: Advocate for WPP inclusion in construction guidelines and incentivize its adoption in infrastructure projects.
- Promote Awareness: Educate engineers and policymakers on WPP's benefits through workshops and training programs.

These actions will foster sustainable construction practices while addressing environmental challenges.

References

ASTM International - Standards Worldwide. Available at: <https://www.astm.org/> (Accessed: 28 April 2024).

Afrin, H. (2017) 'A review on different types soil stabilization techniques', *International Journal of Transportation Engineering and Technology*, 3(2), p. 19. doi: 10.11648/j.ijtet.20170302.12.

Aven, T. (2016) 'Risk assessment and risk management: Review of recent advances on their foundation', *European Journal of Operational Research*, 253(1), pp. 1–13. doi:10.1016/j.ejor.2015.12.023.

Aytekin, M., (1998) *Soil stabilization with lime and cement*. [online] Available at: https://www.researchgate.net/publication/258369486_Soil_stabilization_with_lime_and_cement.

Esdac (2024) *Soil map of Sri-Lanka*. [online] Europa.eu. Available at: <https://esdac.jrc.ec.europa.eu/content/soil-map-sri-lanka> [Accessed 27 Sep. 2024].

EXPERIMENTAL STUDY ON IMPROVING GEO-TECHNICAL PROPERTIES OF PROBLEMATIC SANDY SOIL USING RECYCLED AGGREGATES

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Abstract

Sandy soils are widely recognized for their poor geotechnical properties, including low compressive strength, high permeability, and limited load-bearing capacity. These characteristics create significant challenges for the construction industry. Traditional stabilization methods, such as cement, improve soil properties but result in environmental concerns due to high carbon emissions. This study investigates the use of recycled concrete aggregates (RCA) as a sustainable alternative for stabilizing sandy soils in Sri Lanka. Laboratory tests were conducted to evaluate baseline properties of untreated sandy soils and improvements observed with RCA proportions of 5%, 10%, and 15%. Finite Element Modeling (FEM) was employed to analyze displacement and load-bearing capacity under different loading conditions. The results demonstrated that a 15% RCA mix provided the optimal improvement, significantly enhancing bearing capacity and reducing permeability. These findings highlight the potential of RCA as a sustainable solution to problematic sandy soils in infrastructure development.

Key Words: Bearing Capacity, Recycled Concrete Aggregates, Sandy Soil Stabilization, FEM Analysis, Sustainability

Introduction

Rapid urbanization and growing infrastructure demands have intensified geotechnical challenges associated with problematic soils. Sandy soils, in particular, pose significant issues due to their low compressive strength, poor cohesion, and high permeability, making them unsuitable for load-bearing structures (Bilgen, 2020). Traditional stabilizers, such as cement and lime, are commonly used to improve these properties but have significant environmental drawbacks, including high carbon emissions, which contribute approximately 7% of global emissions (Park et al., 2014). These environmental concerns necessitate the exploration of sustainable alternatives.

Recycled Concrete Aggregates (RCA), derived from crushed concrete waste, offer an eco-friendly solution by addressing both geotechnical challenges and waste reduction needs. RCA has been shown to improve soil properties by enhancing compaction, reducing permeability, and increasing load capacity through void filling and improved interparticle friction (Pauzi et al., 2024). However, its application in sandy soils remains underexplored, particularly in Sri Lanka (Gupta et al., 2018). This research aims to fill this gap by assessing RCA's potential to stabilize sandy soil under local conditions.

Finite Element Modeling (FEM) has proven effective in simulating soil behavior under various loading conditions, predicting settlement, and analyzing stress-strain responses (Espinosa et al., 2023). Despite its effectiveness, there is a lack of region-specific research into RCA-treated

sandy soils in Sri Lanka, highlighting the need for studies tailored to local geotechnical conditions.

This study investigates the geotechnical properties of untreated sandy soils and evaluates the effects of varying RCA proportions (5%, 10%, and 15%) on soil properties. By using FEM to simulate RCA-treated soils under diverse loading conditions, the research aims to identify the optimal RCA mix to enhance soil performance, reduce permeability, and promote sustainable infrastructure development in Sri Lanka.

Methodology

Research Design

The study uses a mixed-method approach, combining laboratory tests to assess baseline and RCA-treated soil properties with Finite Element Modeling (FEM) to simulate the performance of RCA-treated soils under different loading conditions.

Materials

Sandy Soil

Sandy soil samples from Elakanda Beach, Sri Lanka, were excavated at a 3-foot depth to avoid contamination, sun-dried for two days, sieved to remove impurities, and stored in airtight containers for consistency.

Figure 1 - Sun-drying process



Recycled Concrete Aggregates (RCA)

RCA was sourced from construction waste in Colombo, crushed manually, and sieved to particles under 2 mm for uniformity. It was stored in dry conditions to prevent moisture absorption.

Figure 2 - Pulverized RCA



Sample Preparation

To evaluate the impact of RCA proportions, sandy soil samples were mixed with RCA in three different percentages: 5%, 10%, and 15% by weight.

Table.1- Mixture Proportions of Samples

Specimen No.	Sand (%)	RCA (%)
1	100	0
2	95	5
3	90	10
4	85	15

Laboratory Testing

A series of laboratory tests, conducted according to ASTM standards, evaluated the geotechnical properties of untreated and RCA-treated sandy soils:

Particle Size Distribution (ASTM D6913-04)

This test analyzed the gradation of soil particles to classify the soil and determine its suitability for stabilization. The results confirmed a predominantly sandy texture with minimal silt and clay content.

Proctor Compaction Test (ASTM D698)

This test determined the OMC and Maximum Dry Density (MDD) of untreated and RCA-treated soils. These parameters were critical for assessing the compaction characteristics.

Figure 3 - Proctor compaction test



California Bearing Ratio (CBR) Test (ASTM D1883)

The CBR test evaluated the load-bearing capacity of the soil. Samples were compacted at OMC and tested under simulated loading conditions to determine their resistance to penetration.

Figure 4 - CBR test



Permeability Test (ASTM D2434)

Permeability was measured to assess the ability of the soil to resist water flow. RCA-treated samples were compared to untreated soil to evaluate reductions in permeability with increasing RCA content.

Figure 5 - Permeability Test



Direct Shear Test (ASTM D3080)

This test measured shear strength parameters, including cohesion and internal friction angle, with RCA-treated samples showing improved shear stress resistance.

Figure 6 - Direct shear test



Finite Element Modeling (FEM)

Numerical Modeling

Finite Element Modeling (FEM) was employed using Plaxis 2D software to simulate the performance of RCA-treated soils under structural loads. The numerical modeling process is outlined below:

Input Parameters

Laboratory test results, including MDD, CBR, permeability, and shear strength, were used as input parameters for the FEM simulations. Poisson's ratio is often assumed constant in numerical models for coarse-grained soils, as wetting and drying cycles minimally impact stress and volume changes (Oh and Vanapalli, 2016). These parameters define the soil's stress-strain behavior and displacement characteristics under load.

Table 2 - Input parameters for Plaxis 2D

Index Property	RCA 0%	RCA 5%	RCA 10%	RCA 15%
Modulus of Elasticity E_s (kPa)	11,640.44	31,514.09	36,380.66	63,596.96
Poisson's Ratio (ν)	0.30	0.30	0.30	0.30
Angle of Internal Friction (ϕ)	31.38	33.75	34.33	37.56
Cohesion C' (kPa)	0.69	1.88	2.16	3.78
Unit Weight (Unsaturated) (kN/m ³)	15.14	15.33	15.41	15.51
Unit Weight (Saturated) (kN/m ³)	16.82	17.03	17.12	17.23

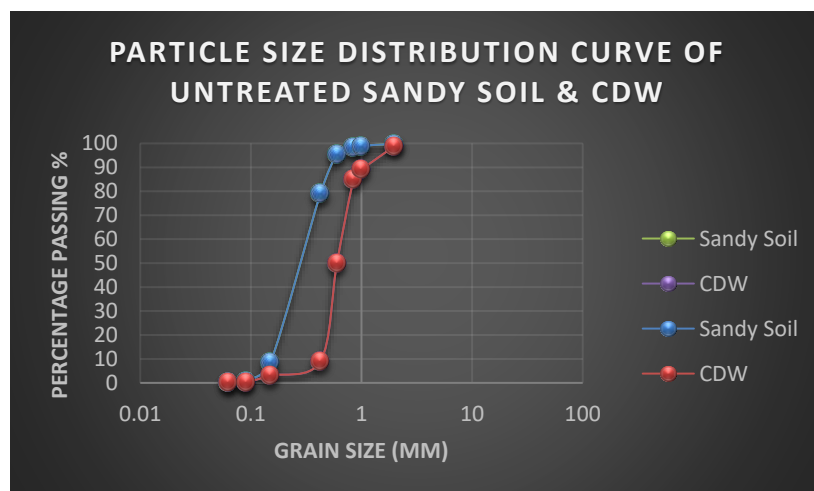
The FEM analysis simulated incremental loading conditions of 100 kN, 200 kN, 300 kN, and 400 kN to replicate real-world structural loads on RCA-treated soils.

Results & Discussion

Particle Size Distribution of Soil & RCA

The sieve analysis test results classify the grain size distribution of both materials.

Figure 7 - Particle Size Distribution of Soil & RCA

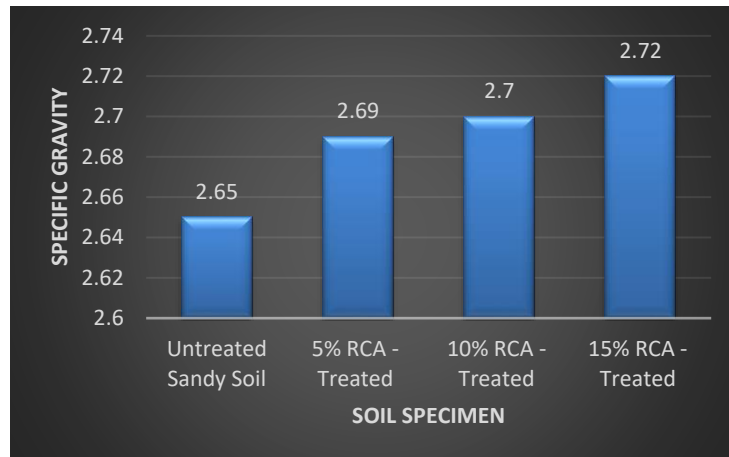


The sandy soil had a coefficient of uniformity (C_u) of 6.46 and curvature (C_c) of 0.88, indicating poor grading with limited particle size variation, affecting compaction and load-bearing capacity. RCA's uniform particle distribution improved soil stability when mixed.

Specific Gravity

This increase in specific gravity is due to the denser composition of RCA particles compared to untreated soil, which enhances the overall weight of the soil mixture. The results suggest that RCA improves soil density.

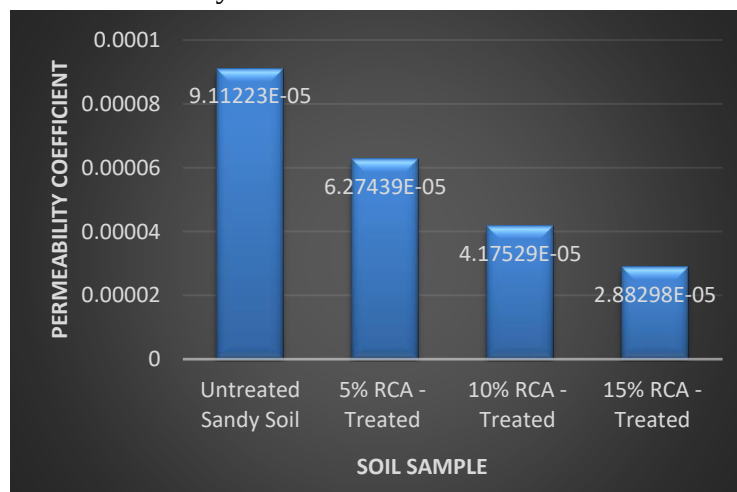
Figure 8 -Variations of Specific gravity



Permeability

For untreated sandy soil, the permeability was measured at $9.11223 \times 10^{-5} \text{ ms}^{-1}$, indicating a relatively high permeability typical of sandy soils. As RCA was added, the permeability values significantly decreased. For the 5% RCA-treated sample, permeability dropped to $6.27439 \times 10^{-5} \text{ ms}^{-1}$, while the 10% RCA sample showed a further reduction to $4.17529 \times 10^{-5} \text{ ms}^{-1}$. The lowest permeability was recorded for the 15% RCA sample, with a value of $2.88298 \times 10^{-5} \text{ ms}^{-1}$.

Figure 9 -Variations of Permeability coefficients

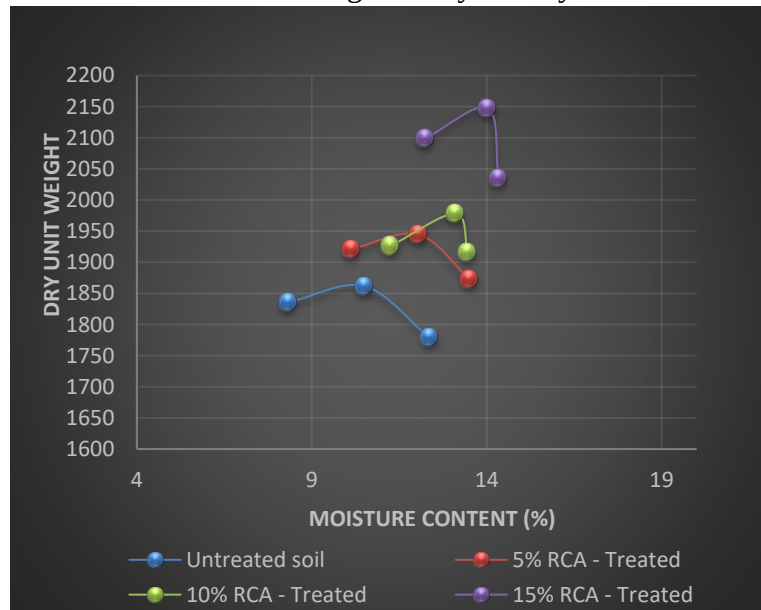


Proctor Compaction

The Proctor Compaction Test determined OMC and MDD for untreated and RCA-treated soils. Untreated soil had an OMC of 10.499% and MDD of 1861.74 kgm^{-3} . As RCA increased, OMC

and MDD rose, peaking at 14.03% and 2147.88 kgm⁻³ for 15% RCA-treated soil, demonstrating improved compaction.

Figure 10 - Summarized moisture content against dry density

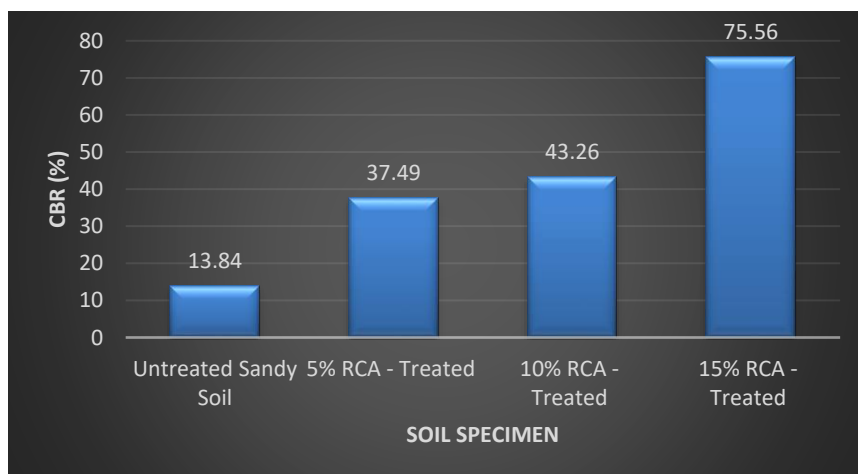


The increase in MDD with RCA aligns with Bilgen's (2020) findings, which noted improved compaction from RCA stabilization. The rise in OMC stems from RCA's higher water absorption compared to untreated soils, enhancing moisture-holding capacity.

California Bearing Ratio Test

The CBR test shows significant load-bearing improvement with RCA treatment. Untreated soil had a low CBR of 13.84%, reflecting poor strength, but incorporating RCA led to marked enhancements in mechanical strength and load capacity.

Figure 11 - CBR variations of four specimens

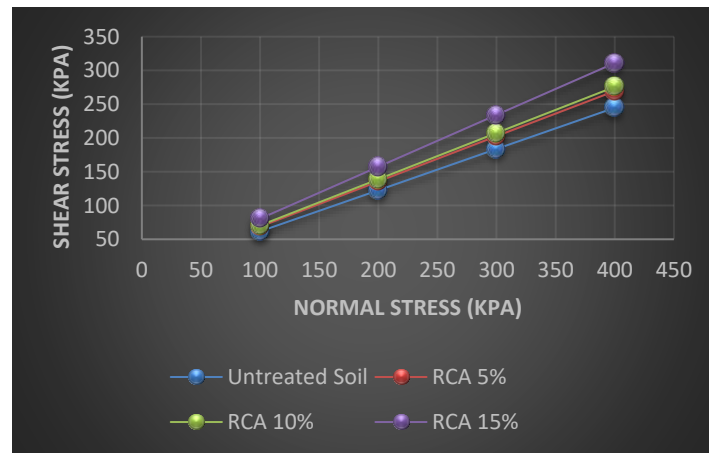


The 15% RCA-treated sample, with the highest CBR value, confirms a direct link between RCA content and load-bearing capacity, essential for road construction and foundation subgrades. These findings align with Bilgen (2020) and Fernandes et al. (2023), who reported RCA's effectiveness in enhancing soil bearing capacity and compaction.

Direct Shear Test

The Direct Shear Test revealed that RCA incorporation significantly improves sandy soil's shear strength. Under 100 kN/m² normal stress, shear stress increased from 61.69 kPa (untreated) to 68.78 kPa, 70.56 kPa, and 80.58 kPa for 5%, 10%, and 15% RCA, respectively.

Figure 12 - Shear stress against normal stress of soil specimens



Increased shear strength from RCA's angularity raised the internal friction angle from 31.38° to 37.56° and cohesion from 0.69 kPa to 3.78 kPa (15% RCA). These findings, aligning with Bilgen (2020), confirm RCA's role in sustainable stabilization. Direct Shear Test parameters, vital for FEM analysis, showed improved particle bonding in treated soils.

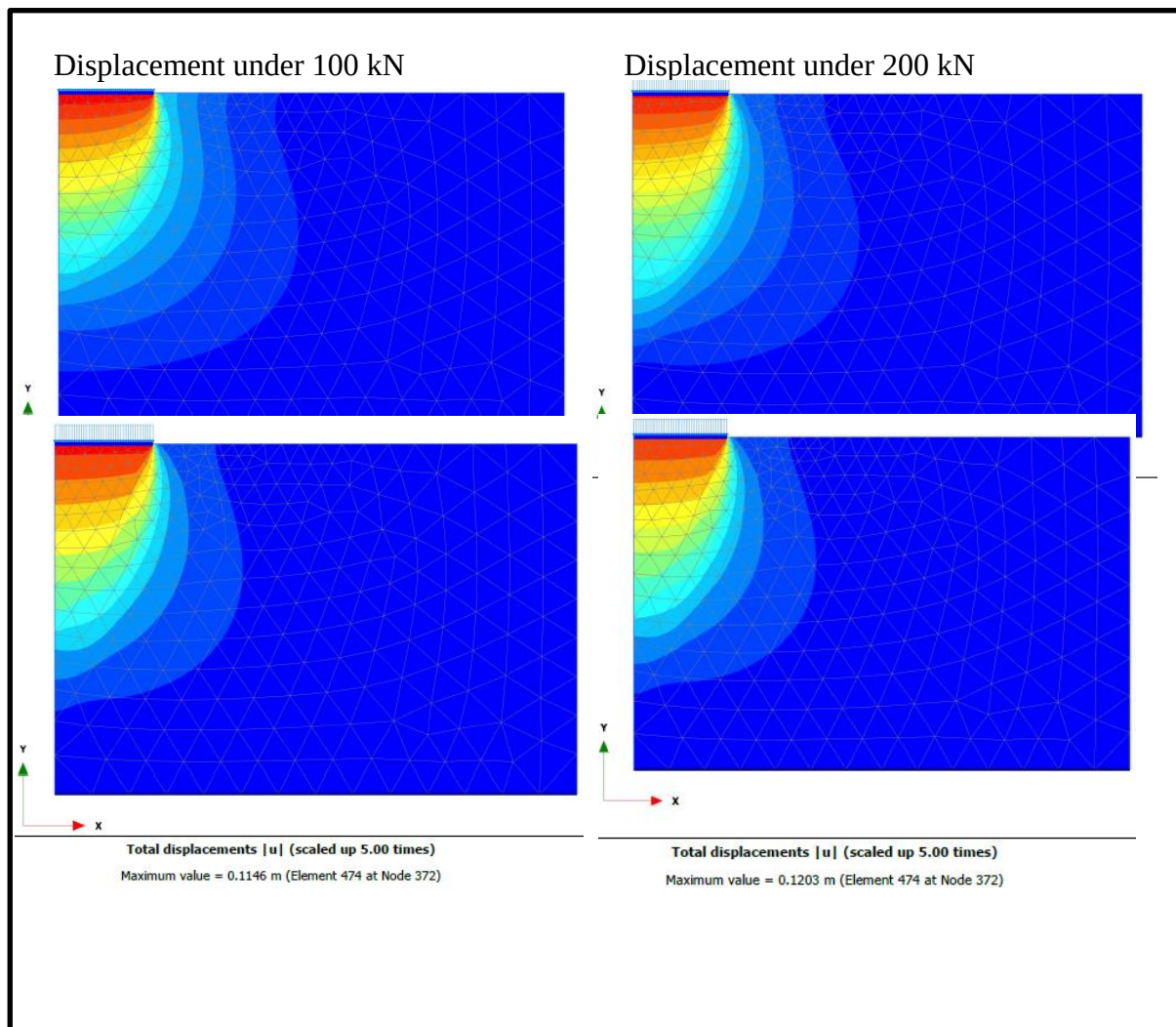
FEM data analysis for RCA-treated and untreated sandy soils

The FEM analysis has been carried out using Plaxis 2D software to investigate the total displacement behaviour of four soil samples; untreated sandy soil and three RCA-treated soils with contents of RCA being 5%, 10%, and 15%. The main focus was on analysing how variations in displacement take place under increased load from 100 kN to 400 kN. This analysis was essential in providing the relationship between the addition of RCA and its resultant performance in sandy soils, mainly concerning load-carrying capacity and settlement.

Untreated sandy soil behavior

The untreated sandy soil displayed significant displacement under the applied loads, indicating its weak mechanical properties and low load-bearing capacity.

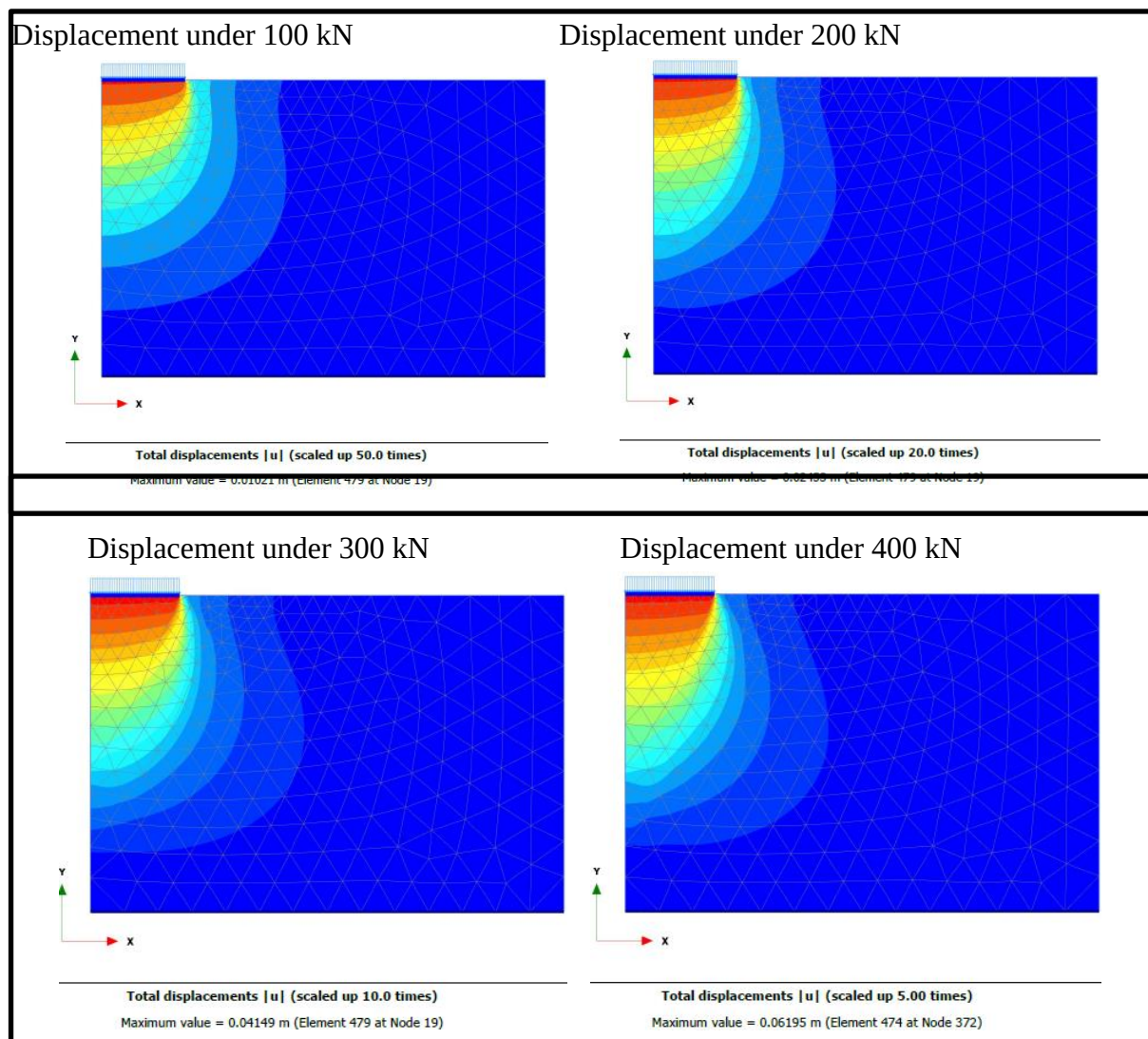
Figure 13 - Total displacement of untreated soil under varying loads



5% RCA-treated sandy soil

With inclusion of **5% RCA**, the displacement decreased compared to untreated sandy soil, signifying RCA's immediate benefits in improving soil performance.

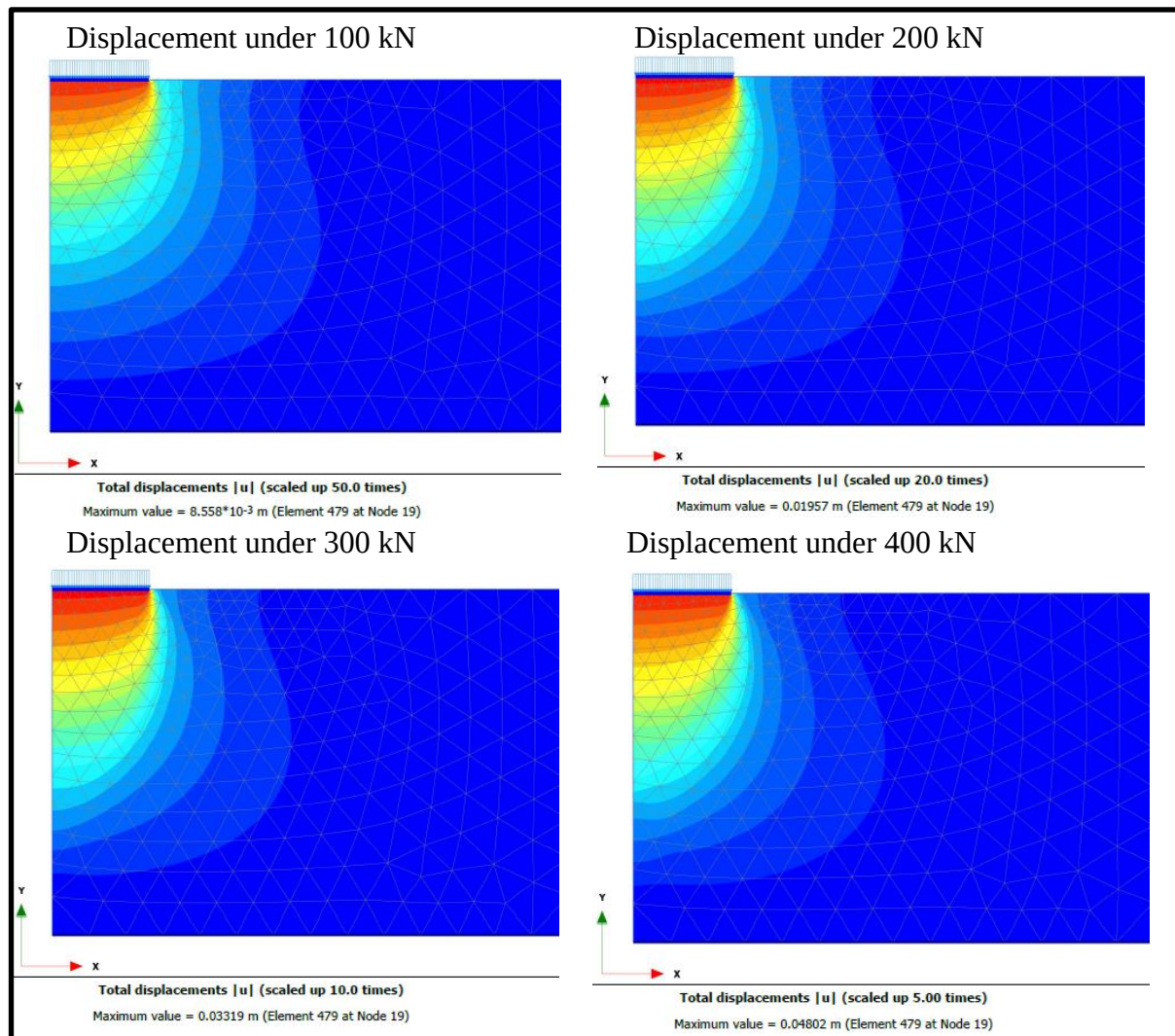
Figure 14 - Total displacement of 5% RCA-treated soil under varying



10% RCA-treated sandy soil

The **10% RCA-treated** sample showed greater improvement in displacement reduction.

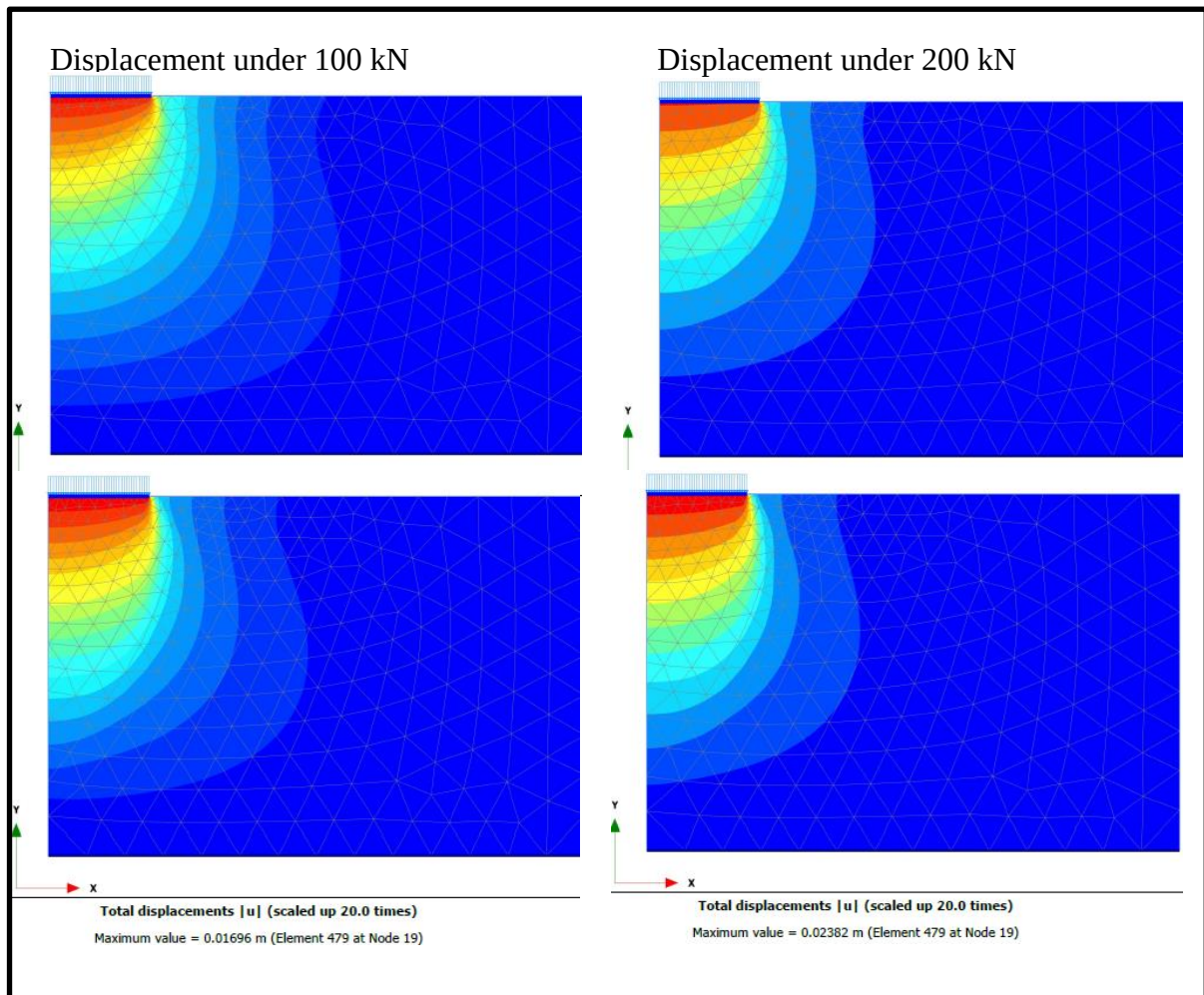
Figure 15 - Total displacement of 10% RCA-treated soil under varying loads



15% RCA-treated sandy soil

The best performance was observed in the **15% RCA-treated** soil, where the displacement was the lowest across all loads.

Figure 16 - Total displacement of 15% RCA-treated soil under varying loads



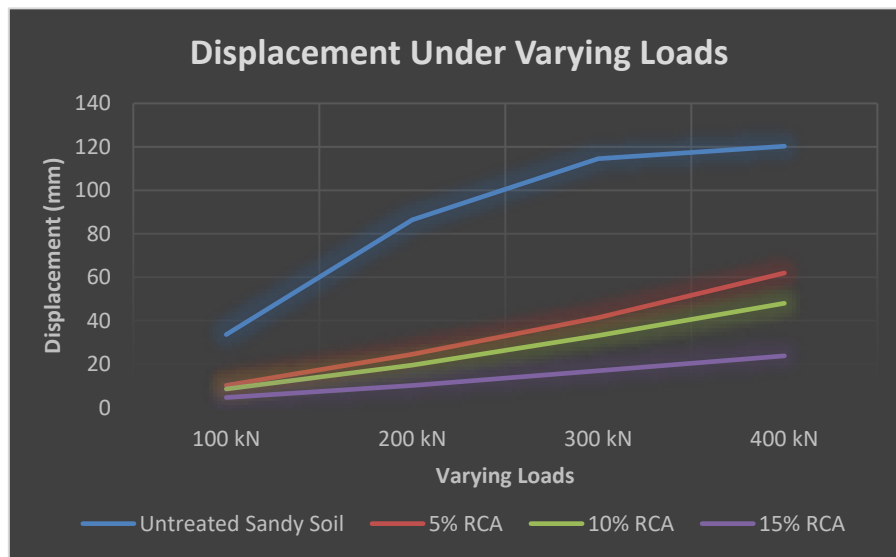
Summary of displacement results

Table 4 - Summary of Displacement Results with decrement percentages

Load (kN)	Untreated Sandy Soil (mm)	5% RCA (mm)	Decrement (%)	10% RCA (mm)	Decrement (%)	15% RCA (mm)	Decrement (%)
100	33.64	10.21	69.65	8.558	74.56	4.642	86.20
200	86.4	24.53	71.61	19.57	77.35	10.16	88.24
300	114.6	41.45	63.83	33.19	71.04	16.96	85.20
400	120.3	61.95	48.50	48.02	60.08	23.82	80.20

As summarized in table.004, the displacement decreases progressively with the addition of RCA. For instance, at load 100 kN in untreated soil, displacement is about 33.64 mm, while it is 4.642 mm in the soil treated with 15% RCA. The displacement being reduced to 86.2%. In a similar vein, at 400 kN of load, the displacement for untreated soil was 120.3 mm, while for 15% RCA-treated soil, it was 23.82 mm, which is a reduction of 80.2%.

Figure 17 - Displacement of Soil Specimens Under Varying Loads



This trend, as illustrated in Fig.017, confirms that RCA improves the soil's resistance to deformation, with the highest improvement manifested in the sample treated with 15% RCA, as its angular shape enhances interlocking within the particles that increase stiffness in the soil, therefore reducing voids and consequently limiting displacement.

Conclusion

The findings of this research work were concluded based on the obtained and calculated results as follows.

Key Findings

RCA significantly improves the geotechnical properties of sandy soils, particularly bearing capacity and shear strength.

Based on the results of this research, the 15% RCA mix was identified as the optimum proportion, offering the highest improvement in load-bearing capacity and the least settlement under structural loads within the tested range.

FEM simulations validated the laboratory results, confirming RCA's effectiveness in stabilizing sandy soils.

Practical Applications

RCA can replace traditional stabilizers in road construction, foundation reinforcement, and other geotechnical applications.

The 15% RCA mix is recommended for infrastructure projects in Sri Lanka, providing a sustainable and cost-effective solution to problematic soils.

Future Research

Conduct long-term field studies to evaluate the durability of RCA-treated soils under varying environmental conditions.

Explore the use of RCA in combination with other stabilizers to enhance its performance further.

Investigate potential environmental impacts, such as leaching contaminants, to ensure safe application of RCA in large-scale projects.

References

- Abdullah, G.M.S., (2022) Using Plaxis 2D finite element modeling to assess bearing capacity of Sultana's soil in Najran Region, Kingdom of Saudi Arabia. *Materials today: proceedings*, [online] 49, pp.2679–2687. Available at: <http://dx.doi.org/10.1016/j.matpr.2021.09.051>.
- Bagriacik, B., (2021) Utilization of alkali-activated construction demolition waste for sandy soil improvement with large-scale laboratory experiments. *Construction and building materials*, [online] 302124173, p.124173. Available at: <http://dx.doi.org/10.1016/j.conbuildmat.2021.124173>.
- Balkis, A., (2019) Çimento Miktarının Farklı Toprakların CBR Değerlerine Etkisi. *European Journal of Science and Technology*, [online] pp.809–815. Available at: <http://dx.doi.org/10.31590/ejosat.588990>.
- Bilgen, G., (2020) Geri Dönüştürülmüş Beton Agregasının Düşük Plastisiteli Bir Kilin Mekanik Özelliklerine Etkisi. *Journal of the Institute of Science and Technology*, [online] 103, pp.1714–1719. Available at: <http://dx.doi.org/10.21597/jist.685938>.
- De Luca, A., Chen, L. and Gharehbaghi, K., (2021) Sustainable utilization of recycled aggregates: robust construction and demolition waste reduction strategies. *International journal of building pathology and adaptation*, [online] 394, pp.666–682. Available at: <http://dx.doi.org/10.1108/ijbpa-04-2020-0029>.
- Dewanda, H., Jaiswal, P. and Reddy, S., (2023) Use of recycled concrete aggregates in stabilization of black cotton soil. *SAFER*. [online] Available at: <http://dx.doi.org/10.7770/safer-v12n-art796>.
- Eka Putri, E., Kameswara Rao, N.S., V. and Mannan, M.A., (2012) Evaluation of modulus of elasticity and modulus of subgrade reaction of soils using CBR test. *Journal of civil engineering research*, [online] 21, pp.34–40. Available at: <http://dx.doi.org/10.5923/j.jce.20120201.05>.
- Espinosa, A.B., López-Ausín, V., Fiol, F., Serrano-López, R. and Ortega-López, V., (2023) Analysis of the deformational behavior of a clayey foundation soil stabilized with ladle furnace slag (LFS) using a finite element software. *Materials today: proceedings*. [online] Available at: <http://dx.doi.org/10.1016/j.matpr.2023.03.721>.
- Garach, L., López, M., Agrela, F., Ordóñez, J., Alegre, J. and Moya, J., (2015) Improvement of bearing capacity in recycled aggregates suitable for use as unbound road sub-base. *Materials*, [online] 812, pp.8804–8816. Available at: <http://dx.doi.org/10.3390/ma8125493>.
- Gupta, N., Kluge, M., Chadik, P.A. and Townsend, T.G., (2018) Recycled concrete aggregate as road base: Leaching constituents and neutralization by soil Interactions and dilution. *Waste management (New York, N.Y.)*, [online] 72, pp.354–361. Available at: <http://dx.doi.org/10.1016/j.wasman.2017.11.018>.
- Hung, V.Q., Jayarathne, A., Gallage, C., Dawes, L., Egodawatta, P. and Jayakody, S., (2024) Leaching characteristics of metals from recycled concrete aggregates (RCA) and reclaimed asphalt pavements (RAP). *Heliyon*, [online] 109, p.e30407. Available at: <http://dx.doi.org/10.1016/j.heliyon.2024.e30407>.

Ismail, S. and Ramli, M., (2013) Engineering properties of treated recycled concrete aggregate (RCA) for structural applications. *Construction and building materials*, [online] 44, pp.464–476. Available at: <http://dx.doi.org/10.1016/j.conbuildmat.2013.03.014>.

Kianimehr, M., Shourijeh, P.T., Binesh, S.M., Mohammadinia, A. and Arulrajah, A., (2019) Utilization of recycled concrete aggregates for light-stabilization of clay soils. *Construction and building materials*, [online] 227116792, p.116792. Available at: <http://dx.doi.org/10.1016/j.conbuildmat.2019.116792>.

Mohammadinia, A., Arulrajah, A., Sanjayan, J., Disfani, M.M., Bo, M.W. and Darmawan, S., (2015) Laboratory evaluation of the use of cement-treated construction and demolition materials in pavement base and subbase applications. *Journal of materials in civil engineering*, [online] 276, p.04014186. Available at: [http://dx.doi.org/10.1061/\(asce\)mt.1943-5533.0001148](http://dx.doi.org/10.1061/(asce)mt.1943-5533.0001148).

Mohd Pauzi, N.I., Ghiasi, V., Razzi, I. and Mat Radhi, M.S., (2024) Utilization of waste aggregate for aggregate construction for improvement of soil bearing capacity. *MATEC web of conferences*, [online] 400, p.02005. Available at: <http://dx.doi.org/10.1051/mateconf/202440002005>.

Molenaar, A.A.A. and van Niekerk, A.A., (2002) Effects of gradation, composition, and degree of compaction on the mechanical characteristics of recycled unbound materials. *Transportation research record*, [online] 17871, pp.73–82. Available at: <http://dx.doi.org/10.3141/1787-08>.

Nanda, S.K., Giri, J.P. and Priyadarshini, M., (2024) Quantitative evaluation of soil stabilization using RCA and GGBS: a statistical perspective. *Journal of building pathology and rehabilitation*, [online] 92. Available at: <http://dx.doi.org/10.1007/s41024-024-00444-0>.

Oh, W.T. and Vanapalli, S.K. (2016) 'Influence of Poisson's Ratio on the Stress vs. Settlement Behavior of Shallow Foundations in Unsaturated Fine-Grained Soils', *Soils and Rocks*. DOI: 10.28927/SR.391071. Available at: <https://www.researchgate.net/publication/352214346>

Park, K., Jun, S. and Kim, D., (2014) Effect of strength enhancement of soil treated with environment-friendly calcium carbonate powder. *TheScientificWorldJournal*, [online] 2014, p.526491. Available at: <http://dx.doi.org/10.1155/2014/526491>.

Pongsivasathit, S., Horpibulsuk, S. and Piyaphipat, S., (2019) Assessment of mechanical properties of cement stabilized soils. *Case studies in construction materials*, [online] 11e00301, p.e00301. Available at: <http://dx.doi.org/10.1016/j.cscm.2019.e00301>.

Singh, S., Singh, S.K., Mahgoub, M., Mir, S.A., Kanga, S., Kumar, S., Kumar, P. and Meraj, G., (2024) Evaluating recycled concrete aggregate and sand for sustainable construction performance and environmental benefits. *CivilEng*, [online] 52, pp.461–481. Available at: <http://dx.doi.org/10.3390/civileng5020023>.

Sivakumar, V., McKinley, J.D. and Ferguson, D., (2004) Reuse of construction waste: performance under repeated loading. *Proceedings of the Institution of Civil Engineers - Geotechnical Engineering*, [online] 1572, pp.91–96. Available at: <https://pureadmin.qub.ac.uk/ws/files/376370/recycled%20material.pdf>.

Tamassoki, S., Daud, N.N.N., Wang, S. and Roshan, M.J., (2023) CBR of stabilized and reinforced residual soils using experimental, numerical, and machine-learning approaches. *Transportation geotechnics*, [online] 42101080, p.101080. Available at: <http://dx.doi.org/10.1016/j.trgeo.2023.101080>.

Tavakol, M., Kulesza, S., Jones, C. and Hossain, M., (2020) Effect of low-quality recycled concrete aggregate on stabilized clay properties. *Journal of materials in civil engineering*, [online] 328, p.04020196. Available at: [http://dx.doi.org/10.1061/\(asce\)mt.1943-5533.0003263](http://dx.doi.org/10.1061/(asce)mt.1943-5533.0003263).

Tsige, D., Korita, M. and Beyene, A., (2022) Deformation analysis of cement modified soft clay soil using finite element method (FEM). *Heliyon*, [online] 86, p.e09613. Available at: <http://dx.doi.org/10.1016/j.heliyon.2022.e09613>.

Valliappan, V. and Vijayasimhan, S., (2024) Reuse of waste materials in geotechnical practice. *MATEC web of conferences*, [online] 400, p.02001. Available at: <http://dx.doi.org/10.1051/matecconf/202440002001>.

Wang, X., Dong, Q., Hu, J., Liu, P., Li, Z., Chen, Y. and Xu, G., (2024) Experimental study on mechanical properties of recycled aggregate mixed soil. *Materials*, [online] 1718, p.444.

INVESTIGATING THE EFFECTS OF VARYING LENGTH AND CONTENT OF COCONUT FIBER ON CONCRETE COMPRESSIVE STRENGTH

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Abstract

The concrete production faces challenges from resource scarcity and environmental impact, emphasizing the need for sustainable alternatives. Coconut coir fibers, an abundant and renewable agricultural byproduct, offer potential to enhance the mechanical properties of concrete while reducing environmental burdens. This study investigates the effects of varying lengths (25, 50, 75, 100 mm) and contents (1%, 2%, 3%, 4%) of coconut coir fibers on the compressive strength of M30-grade concrete. Experimental methods included preparing 17 concrete mixes, including a control, at a water-cement ratio of 0.45. Compressive strength was assessed after 7 and 28 days of curing. Results indicate that incorporating 1% fiber content with a length of 25 mm optimally enhances compressive strength to 20.12 MPa, outperforming conventional concrete. The findings highlight the feasibility of using coconut coir fibers as an eco-friendly reinforcement, contributing to sustainable construction practices.

Key Words: Coconut Coir Fiber, Compressive Strength, Fiber Reinforced Concrete, Sustainable Construction

Introduction

The construction industry is currently facing difficulties related to scarcity of resources and environmental impacts associated with traditional building materials. Concrete, a critical component in construction projects, heavily relies on finite resources, underscoring the urgent need for sustainable alternatives. This study explores the potential of coconut coir fibers as a reinforcement material in concrete to enhance its strength and sustainability. Coconut coir fibers present a cost-efficient alternative. Previous studies have shown that these fibers can boost properties of concrete, such as tensile and flexural strength, positioning them as a promising substitute for traditional materials (Ramli, Abas, & Othuman Mydin, 2014; Naamandadin et al., 2020). However, an excessive amount of fiber may lead to a decrease in compressive strength, attributed to the presence of voids or inadequate bonding.

This research investigates how varying lengths (25 mm, 50 mm, 75 mm, and 100 mm) and contents (1%, 2%, 3%, and 4%) of coconut coir fibers affect the compressive strength and workability of M30-grade concrete. By examining these variables at curing intervals of 7 and 28 days, the study aims to identify how do varying lengths and contents of coconut coir fibers affect the compressive strength and workability of M30 grade concrete?

Methodology

The experimental methodology of this research aimed to examine the effects of substituting coconut coir fibers as fine aggregates on the compressive strength, density, and workability of M30-grade concrete.

The Concrete mixtures were prepared with a standard mix ratio of 1:0.75:1.5 (cement: fine aggregate: coarse aggregate), a water-cement (W/C) ratio of 0.45. and Ordinary Portland Cement (OPC) with a strength class of 42.5R was used.

Coconut coir fibers were sourced from a local coir factory and cut into four lengths: 25 mm, 50 mm, 75 mm, and 100 mm. These fibers were incorporated into the concrete as a substitute for fine aggregates at levels of 1%, 2%, 3%, and 4% by mass. A control mix with 0% fiber content was also prepared for baseline comparison.

The concrete samples were cast into 150 mm x 150 mm x 150 mm cube molds, demolded after 24 hours, and cured in water for periods of 7 and 28 days. Compressive strength tests were conducted using a Compression Testing Machine (CTM) in accordance with ASTM C109. Slump tests, performed to evaluate workability, followed the standards outlined in ASTM C143. Wet and dry densities of the concrete were determined using electronic balances with a precision of 0.1 mg, adhering to ASTM C138 guidelines.

Table 1: Mix Design Sheet

Sample id	Specimen Number	Water (Kg)	Cement (Kg)	Coarse aggregate (Kg)	Fine aggregate (Kg)	Coir content (%)	Coir amount (Kg)	Coir length (mm)
1	Control	0.7	1.27	5.77	2.23	0	0	0
2	M1S1	0.7	1.27	5.77	2.208	1	0.022	25
3	M1S2	0.7	1.27	5.77	2.185	2	0.045	25
4	M1S3	0.7	1.27	5.77	2.163	3	0.067	25
5	M1S4	0.7	1.27	5.77	2.141	4	0.089	25
6	M2S1	0.7	1.27	5.77	2.208	1	0.022	50
7	M2S2	0.7	1.27	5.77	2.185	2	0.045	50
8	M2S3	0.7	1.27	5.77	2.163	3	0.067	50
9	M2S4	0.7	1.27	5.77	2.141	4	0.089	50
10	M3S1	0.7	1.27	5.77	2.208	1	0.022	75
11	M3S2	0.7	1.27	5.77	2.185	2	0.045	75
12	M3S3	0.7	1.27	5.77	2.163	3	0.067	75
13	M3S4	0.7	1.27	5.77	2.141	4	0.089	75
14	M4S1	0.7	1.27	5.77	2.208	1	0.022	100
15	M4S2	0.7	1.27	5.77	2.185	2	0.045	100
16	M4S3	0.7	1.27	5.77	2.163	3	0.067	100
17	M4S4	0.7	1.27	5.77	2.141	4	0.089	100

Thirty-four different mix designs were examined for both 7 and 28 days curing periods. These designs included control cubes for each curing period. The compressive strength of the test specimen was determined according to ASTM C109 using Compressive strength test machine

Results and Discussion

The observed enhancement in compressive strength at 1% fiber content with shorter fibers aligns with theories of improved stress transfer in fibrous matrices. Conversely, higher fiber content likely leads to reduced performance.

Density of Samples

Wet Density

Graph 1 and 2 shows how fiber content and length affect the wet density of Coir Fiber reinforced concrete in 7 and 28 days of curing periods. The solid straight line indicates the density of the control mix. The results of the study on coconut fiber-reinforced concrete indicate that wet density varies with both fiber content and length, with a general trend towards lower values at higher fiber contents.

Figure 1: 7 Days wet density

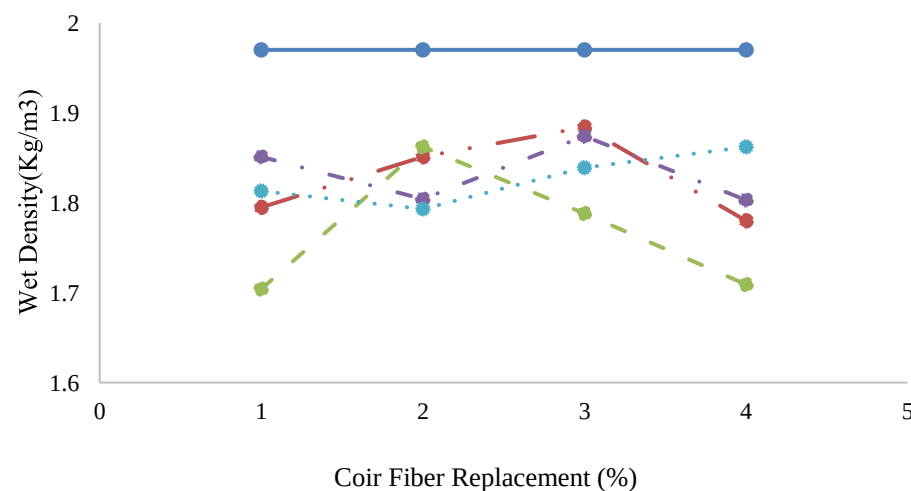
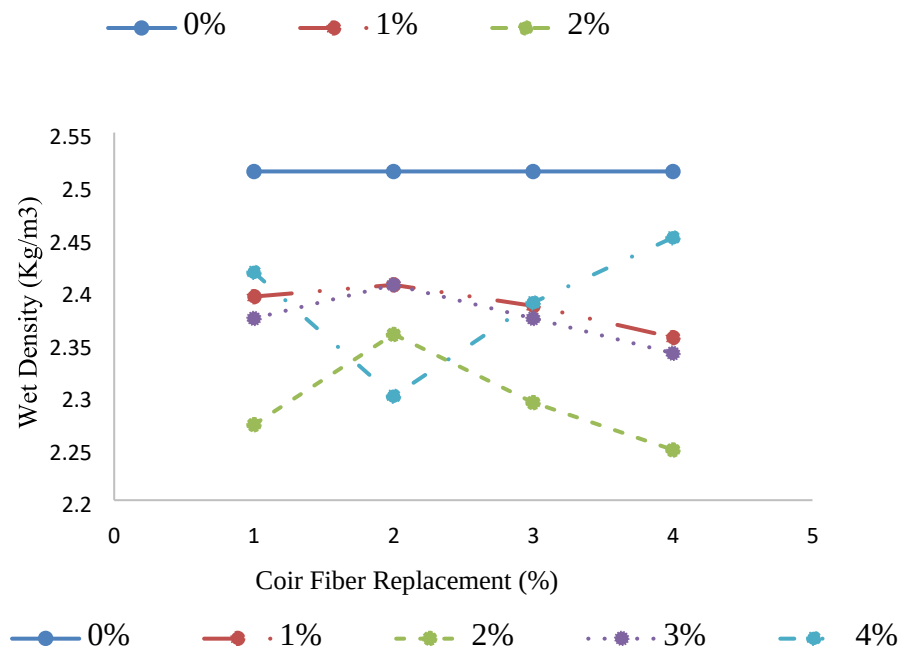


Figure 2: 28 Days wet density



Dry Density

Graph 3 and 4 shows how fiber content and length affect the dry density of Coir Fiber reinforced concrete in 7 and 28 days of curing periods. The solid straight line indicates the density of unreinforced concrete. The results indicate that the density variation with increasing content was more variable, peaking at the point of uniform aggregate distribution.

Figure 3: 7 Days dry density

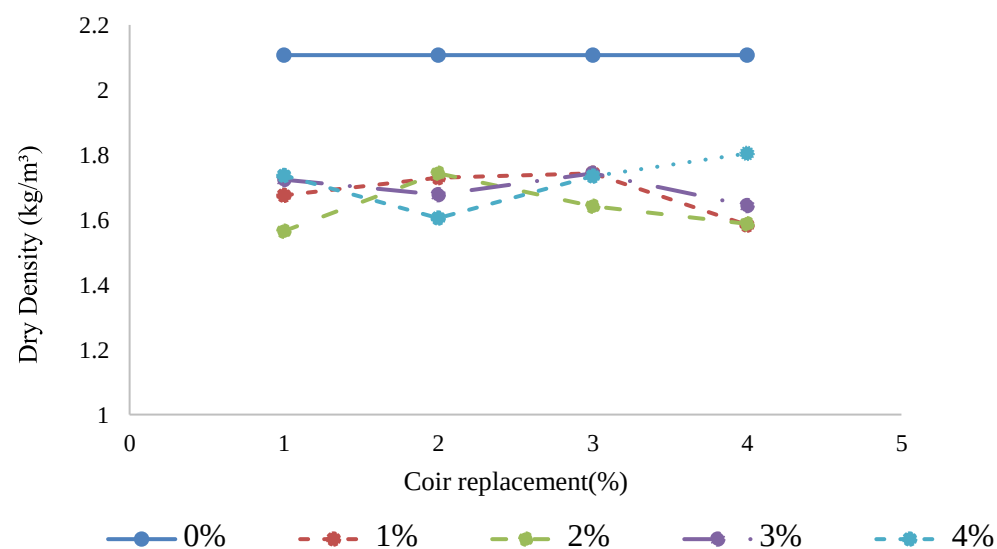
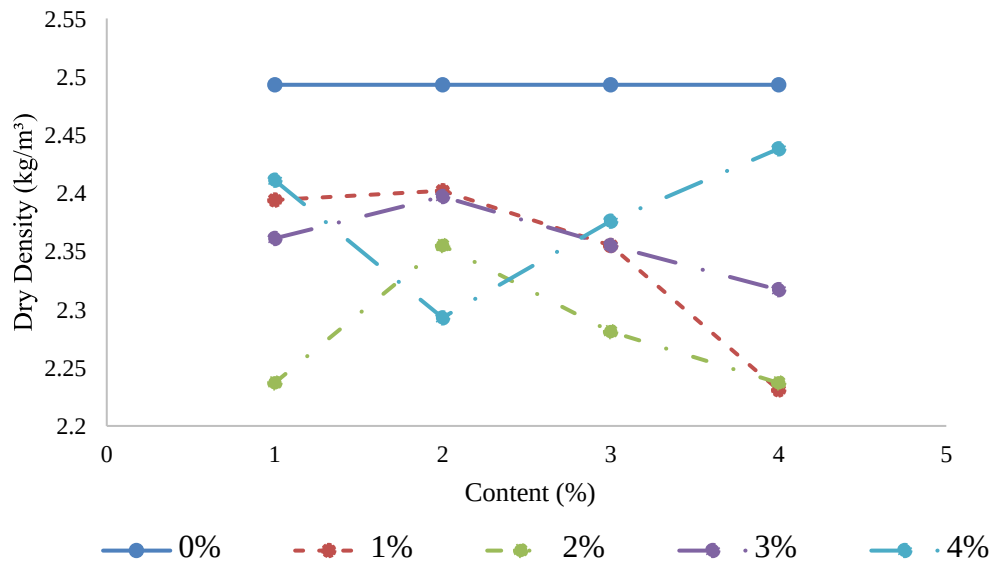


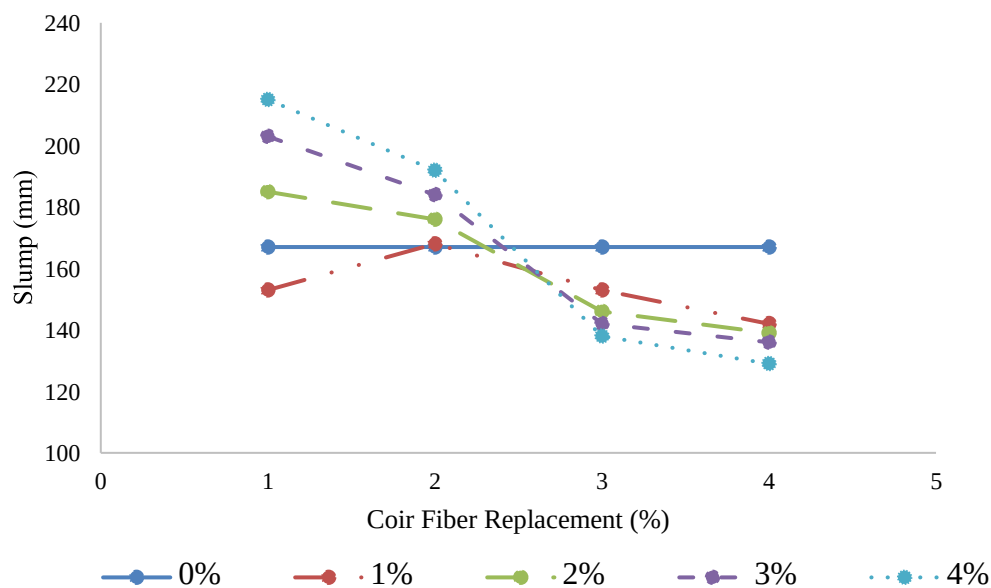
Figure 4: 28 Days dry density



Workability

The slump test results indicate reduced workability in concrete containing coconut coir fibers, with higher fiber content leading to a greater decrease in slump height. This is true for all the mixes, suggesting that while fibers can improve some of concrete's properties, such as its tensile strength and crack resistance, they also stiffen up the mix, making it possibly less workable.

Figure 5: Workability measurements of Slump test



Compressive Strength

The diagrams of the compressive strength vs. fiber length for coconut coir-fiber reinforced concrete demonstrate the influence of fiber content on the mechanical properties and long-term effects.

Figure 6: 7 Days compressive strength

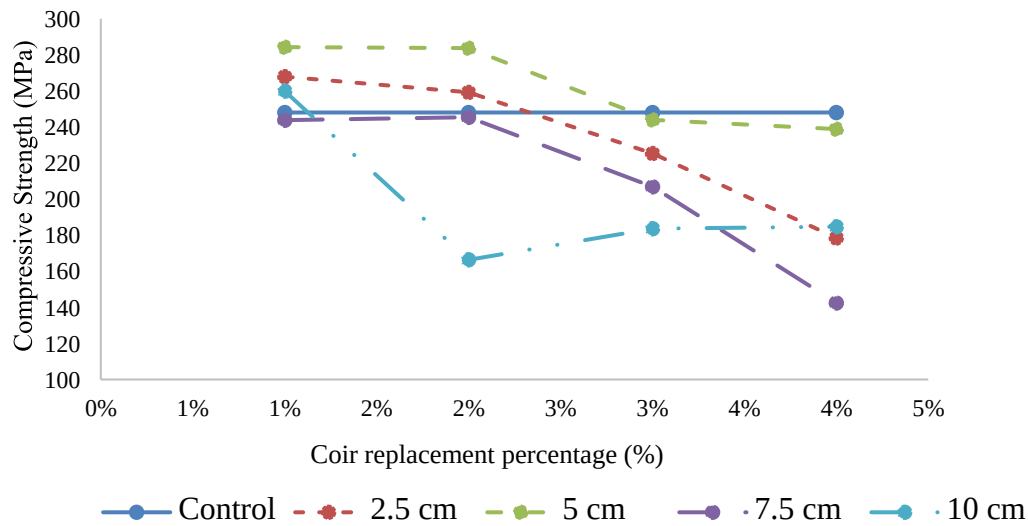
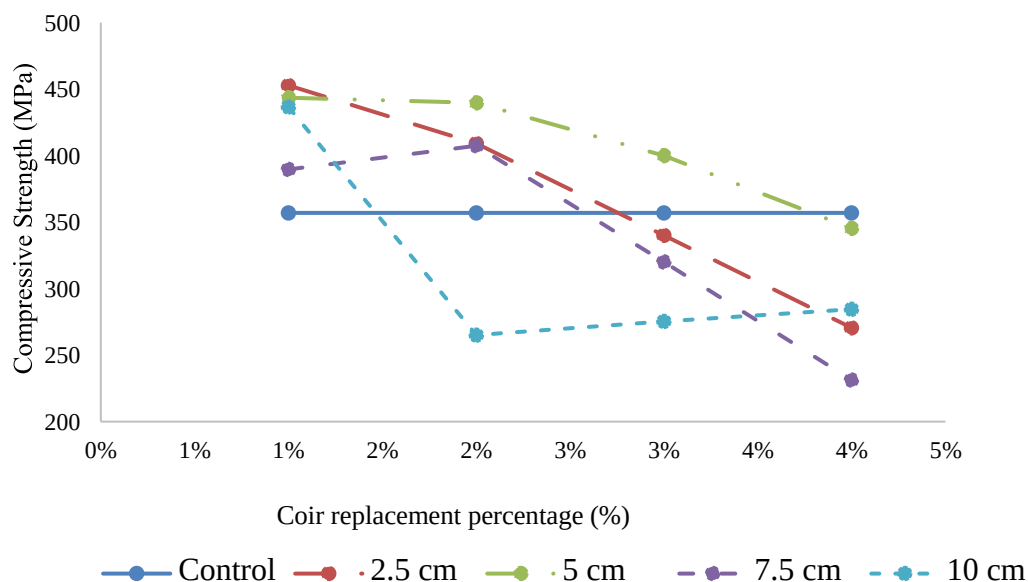
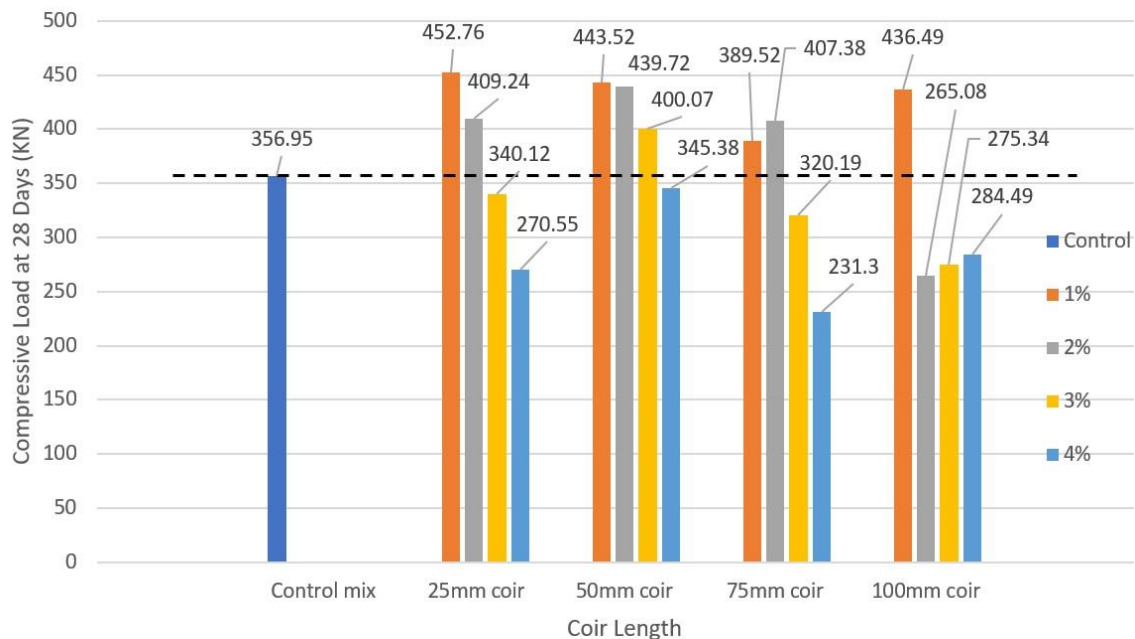


Figure 7: 28 Days compressive strength



In this study, coconut fibers having lengths 25, 50, 75, 100 mm and 1%, 2%, 3%, and 4% content by mass, are incorporated in conventional concrete having mix design ratio of 1:0.75:1.5 for cement, fine aggregates, and coarse aggregate, respectively. The w:c ratio is kept at 0.45.

Figure 8: 28 Days Compressive Load Comparison with Respect to the Control Baseline



Analysis of 7- and 28-days compressive strength graphs revealed that the incorporation of coconut coir fibers had beneficial effect over mechanical properties in concrete up to a limit. As per the graphs, fiber of 1-2% typically increased compressive strength and durability while in case of 3-4%, created a weak transition zones around fibers which eventually resulted decrease on its properties. It was further noted that the length of fibers also had a significant effect with 2.5 cm and 5 cm lengths providing better compromise in strength and workability area.

Slump tests demonstrated a decrease in workability as the fiber content and length increased; however, the concrete still exhibited satisfactory self-consistency. At a fiber content of 4% and a fiber length of 100 mm, a slump measurement of 129 mm was recorded, which is deemed appropriate for construction applications. Although coconut coir fiber-reinforced concrete exhibited favorable performance compared to traditional concrete, mixtures with elevated fiber content or extended fiber lengths experienced a decline in strength relative to the control mix.

Figure 9: Compressive Load Distribution

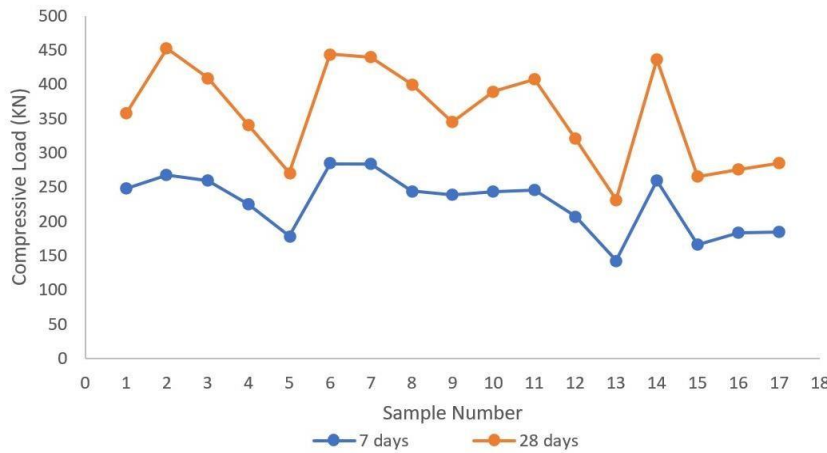
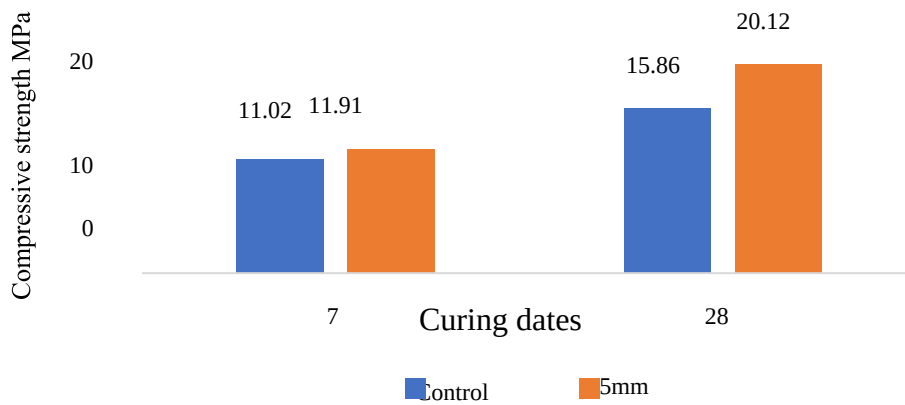


Figure 10: Compressive Strength Comparison



The density analysis reveals that the incorporation of coconut coir fibers led to a decrease in the overall weight of the concrete, likely attributable to the low density of the fibers and the potential formation of voids within the mixture. The control mix, which contained no fibers, displayed the highest density in both wet and dry states under specified conditions. The optimal mix, characterized by a fiber content of 1% and a length of 2.5 cm, exhibited enhanced compressive strength compared to the plain concrete. Conversely, mixes with elevated fiber contents of 3% and 4% experienced a notable reduction in density at all maturation stages, with the 28-day dry density of the control mix recorded at 2.493 kg/cm³, which decreased to 2.231 kg/cm³ for the 1% fiber content with 10 cm fibers. This decline in density became increasingly significant with higher fiber contents and longer fiber lengths.

Conclusion and Recommendation

The research findings indicated that an increase in fiber content (ranging from 0% to 4%) led to a reduction in both wet and dry densities, attributable to the hollow nature of the fibers. Nevertheless, elevated fiber content and extended fiber lengths adversely affected workability, as evidenced by diminished slump test results. Compressive strength assessments demonstrated that optimal performance occurred at moderate fiber contents (1% to 2%) and shorter fiber lengths (approximately 5 cm), which resulted in enhanced compressive strength at both 7 and 28 days. Beyond these optimal levels, a decrease in compressive strength was observed, likely due to the aggregation of fibers and inadequate bonding within the matrix.

Overall, the investigation validated that coconut coir fibers can improve concrete performance when used in moderate amounts, with the compressive strength at 28 days consistently surpassing that at 7 days, which is consistent with the expected behavior of concrete over time.

The experimental parameters were limited to particular fiber contents (0–4%) and fiber lengths, potentially overlooking the comprehensive range of coconut coir applications in concrete. Furthermore, the study did not investigate the effects of additional variables, including fiber treatment, concrete curing conditions, and environmental influences. The observed decrease in workability and strength at elevated fiber contents underscores the difficulties associated with achieving consistent fiber distribution within the concrete matrix. To overcome these limitations and enhance the efficacy of coconut coir fiber-reinforced concrete for wider applications, further investigation is needed. To address workability issues at higher fiber volumes, further investigation into advanced admixtures or alternative mixing methods may enhance both workability and strength.

References

- Ahmad, W., Farooq, S.H., Usman, M., Khan, M., Ahmad, A., Aslam, F., Yousef, R.A., Abduljabbar, H.A. and Sufian, M. (2020). Effect of Coconut Fiber Length and Content on Properties of High Strength Concrete. *Materials*, [online] 13(5). doi:<https://doi.org/10.3390/ma13051075>.
- Awant S, D.V. (2014). Coir Fiber Reinforced Concrete. *Journal of Textile Science & Engineering*, [online] 04(05). doi:<https://doi.org/10.4172/21658064.100013>.
- Hettiarachchi, C. and Thamarajah, G. (2020). Effect of Surface Modification and Fibre Content on the Mechanical Properties of Coconut Fibre Reinforced Concrete. *Advanced Materials Research*, 1159, pp.78–99. doi:<https://doi.org/10.4028/www.scientific.net/amr.1159.78>.
- Kumar, S., Puri, V. and Aggarwal, M.L. (2020). Review of Sustainable Building Materials for Construction Industry. *International Journal of Technical Research & Science*, Special (Issue3), pp.1–8. doi:<https://doi.org/10.30780/specialiss ue- icaccg2020/023>.

- Naamandadin, N.A., Rosdi, M.S., Mustafa, W.A., Shahrol Aman, M.N.S. and Saidi, S.A. (2020). Mechanical behaviour on concrete of coconut coir fiber as additive. *IOP Conference Series: Materials Science and Engineering*, 932(1), p.012098.
doi:<https://doi.org/10.1088/1757899x/932/1/012098>.
- Ramli, M.S., Abas, N.F. and Othuman Mydin, M.A. (2014). Investigation of Mechanical Properties of Coconut Fiber as a Concrete Admixture. *MATEC Web of Conferences*, 17, p.01018. doi:<https://doi.org/10.1051/matecconf/20141701018>.
- Sekar, A. and Kandasamy, G. (2018). Optimization of Coconut Fiber in Coconut Shell Concrete and Its Mechanical and Bond Properties. *Materials*, 11(9), p.1726. doi:<https://doi.org/10.3390/ma11091726>.
- Solangi, G.S.S., Sahito, G.K.S. and Keerio, M.A.K. (2021). The Effects of Coir Fibers on Workability and Strength Properties of Concrete. *Neutron*, 20(2). doi:<https://doi.org/10.29138/neutron.v21i1.103>.
- Sudarshan Dattatraya Kore (2021). Sustainable Production of Concrete using Coir Fibres. *IOP conference series*, 795(1), pp.012006–012006. doi:<https://doi.org/10.1088/17551315/795/1/012006>.
- Syed, H., Nerella, R. and Madduru, S.R.C. (2020). Role of coconut coir fiber in concrete. *Materials Today: Proceedings*, 27, pp.1104–1110. doi:<https://doi.org/10.1016/j.matpr.2020.01.477>.

IDENTIFY THE FACTORS AFFECTING ON PERFORMANCE OF PRIVATE SECTOR QUANTITY SURVEYOR'S IN UAE CONSTRUCTION INDUSTRY

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Abstract

This study identifies factors affecting the service performance of private sector quantity surveyors in the UAE construction industry. Quantity surveyors play a crucial role, and understanding the factors influencing their performance is essential. The UAE's competitive construction sector contributes to a challenging employment climate, which can be improved by addressing internal and external demands for better human resource utilization. The study explores how personal, organizational, and environmental factors impact the performance of private sector quantity surveyors. The data was collected from 122 randomly selected quantity surveyors. Findings indicate that personal, organizational, and environmental factors significantly affect performance, with the environment having the greatest impact. The study suggests that a favorable work environment enhances surveyor performance, recommending that quantity surveyors work in comfortable settings for optimal performance.

Keywords: Employment climate, Quantity surveyors, Work environment.

Introduction

The construction industry significantly contributes to the global economy and socio-economic development (Ofori, 1990). It spans across real estate and infrastructure markets worldwide (RICS, 2018). In the UAE, the construction sector is predominantly staffed by expatriate workers, making employee performance a key determinant of industry productivity (Al Awad, 2010). Quantity surveyors (Qs), identified as cost managers, play a pivotal role throughout a facility's lifecycle—from feasibility studies to demolition—ensuring projects align with client value systems (RICS, 2018). Understanding factors influencing QS performance is crucial for maintaining competitive standards in this industry. According to Hameed, Khan, and Sikandar (2012), high employee performance is essential for organizational success, with effective evaluation processes contributing to operational efficiency.

While numerous studies evaluate employee performance, research specific to Qs in the private sector, particularly in the UAE construction industry, is limited. This gap underscores the importance of this study, which aims to identify the personal, organizational, and environmental factors influencing the service performance of Qs in the UAE. These insights are vital for addressing challenges in the sector and improving service delivery.

The problem lies in the lack of understanding of factors affecting QS performance in a competitive UAE market characterized by job insecurity and an evolving construction

landscape. Addressing these issues requires identifying internal and external needs to enhance human resource utilization. By focusing on QS performance, this research seeks to address gaps in current knowledge and propose actionable solutions for better workforce optimization, contributing to the stability and growth of the UAE construction industry.

The aim of the study is to identify the factors affecting on Quantity surveyors work performance and analyze the significant level of influence on Private sector Quantity surveyor's work performance in UAE construction industry.

The Objectives as follows,

- To identify the factors affecting on employee work performance globally.
- To find out the factors affecting on Private sector Quantity Surveyor's work performance in UAE construction industry.
- To investigate and analyze the significance level of influence to the above identified factors on Private sector Quantity Surveyor's work performance in UAE construction industry.
- To provide recommendations to improve the Quantity Surveyors' work performance, analyzing the level of influence of Private sector Quantity surveyors' work performances in the UAE construction industry.

Methodology

The study employs a robust methodology to identify factors affecting the performance of private sector quantity surveyors (Qs) in the UAE construction industry. The research framework outlines the research approach, techniques for data collection, and analysis methods (Fellows and Liu, 2003). It adopts the interpretivism philosophy, emphasizing the subjective reality of human interactions and behaviours (Easter-Smith et al., 2002).

An inductive approach was used, supported by a structured, close-ended questionnaire to gather quantitative data. The questionnaire was divided into four sections: respondent profiles, personal factors, organizational factors, and environmental factors influencing QS performance. The target population included 230 private sector Qs in UAE, with random sampling used to select participants.

Quantitative data analysis employed techniques like Likert scales and the Relative Importance Index (RII) to determine the significance of identified factors (Nkado, 2001). The methodology also included a literature review for contextual understanding and statistical analyses of survey results.

Data Analysis and Discussion

The influence of eleven personal factors, sixteen organizational factors, and eleven environmental factors were analyzed against the Quantity Surveyor's service performance.

Table 1: Personal factors effect on services performance of Quantity Surveyors in Private sector- UAE construction Industry

S/N	PERSONAL FACTORS FOR SERVICES PERFORMANCE	SA	A	N	D	SD	RII	RII %	M	R
1	Having good working relationship with the co-workers	135	264	78	4	1	0.7902	79%	3.951	1
2	Having challenges, stimulation and rewards for work	120	280	78	4	0	0.7902	79%	3.951	1
3	Determination to do the work best	105	280	78	10		0.7754	78%	3.877	3
4	Opportunity to share the professional opinions at work comfortably	130	232	96	10	1	0.7689	77%	3.844	4
5	Inspiration to do the work best	150	204	99	14	1	0.7672	77%	3.836	5
6	Awareness on the informal processes and structure of the company	130	216	111	6	2	0.7623	76%	3.811	6
7	Encouragement to take initiative and find better way to do things	90	248	102	16	0	0.7475	75%	3.738	7
8	Being proud to be a member of the team	95	220	123	14	0	0.741	74%	3.705	8
9	Satisfaction on the utilization of talents and expertise	90	240	105	14	2	0.7393	74%	3.697	9
10	Awareness on the mission and goals of the company	120	220	72	22	8	0.7246	72%	3.623	11
11	Having a clear link between the work and the mission and goals of the company	90	208	117	16	5	0.7148	71%	3.574	12

As per the Table 1, there are two of higher RII values available which was 0.7902 related to the factors of “Having good working relationship with the co-workers” and “Having challenges, stimulation and rewards for work”. The lowest RII values is 0.7148 on the factor of “Having a clear link between the work and the mission and goals of the company”

Table 2: Organizational factors effect on services performance of Quantity Surveyors in Private sector- UAE construction Industry

S/N	ORGANIZATIONAL FACTORS FOR SERVICES PERFORMANCE	SA	A	N	D	SD	RII	RII %	M	R
1	Availability of tools to perform the duties best	145	264	75	4	0	0.8	80%	4	1
2	Manager treat employee with respect and valued the contribution	125	280	63	12	0	0.7869	79%	3.934	2
3	Respectful Staff	105	292	72	6	1	0.7803	78%	3.902	3
4	Employees are held accountable to reasonable goals and standards	90	288	90	4	0	0.7738	77%	3.869	4
5	Teamwork and collaboration	110	268	81	10	1	0.7705	77%	3.852	5
6	Managers treat subordinates fairly and with respect	105	272	75	12	2	0.7639	76%	3.82	6
7	The pace of work at the company	100	264	93	8	1	0.7639	76%	3.82	6
8	Provides adequate opportunity to interact with other employees on a formal level	85	284	87	10	0	0.7639	76%	3.82	6
9	Awareness on the benefits plan	115	208	123	8	2	0.7475	75%	3.738	9
10	Fair payments for the work	105	232	105	10	3	0.7459	75%	3.73	10
11	Satisfaction with the office perks	125	184	129	12	2	0.741	74%	3.705	11
12	Welcoming at company events, meeting and social interactions	50	316	66	18	2	0.741	74%	3.705	11
13	Competitive salary packages	105	228	99	16	3	0.7393	74%	3.697	13
14	Contribution to the company is valued and appreciated	125	184	129	8	4	0.7377	74%	3.689	14
15	Company's significant attention to the QS s professional growth	115	180	132	14	3	0.7279	73%	3.639	15
16	Satisfaction with the benefits package	140	144	135	18	4	0.723	72%	3.615	16

According to Table 2, the highest RII value was 0.8000 for the factor "Availability of tools to perform duties best," followed by the factors "Manager treats employee with respect and values their contribution" and "Respectful Staff," with RII values of 0.7869 and 0.7803, respectively. The lowest RII values is 0.7230 for the factor of "Satisfaction with the benefits package"

Table 3: Organizational factors effect on services performance of Quantity Surveyors in Private sector- UAE construction Industry

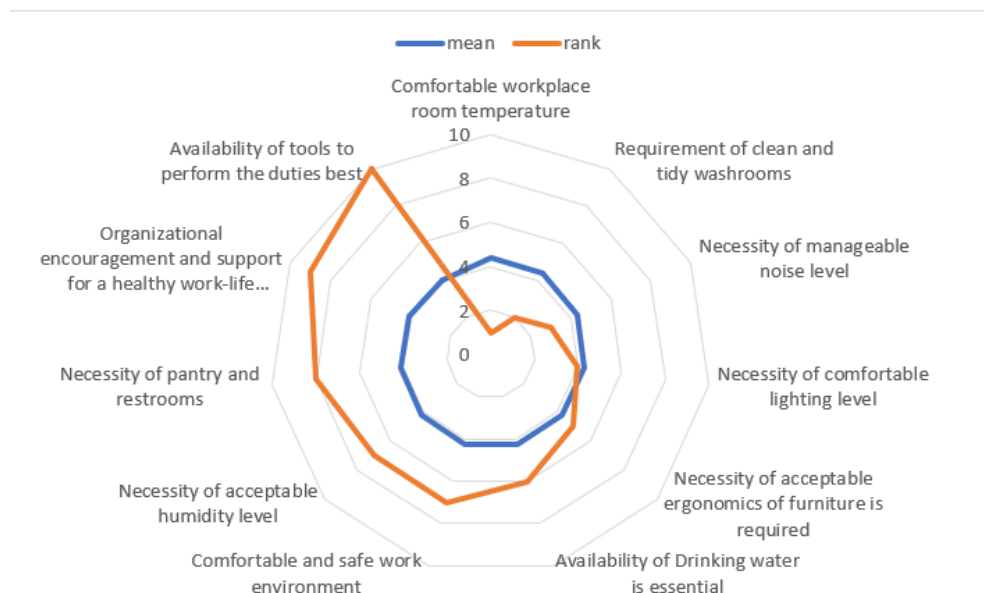
S/N	ENVIRONMENTAL FACTORS FOR SERVICES PERFORMANCE	SA	A	N	D	SD	RII	RII %	M	R
1	Comfortable workplace room temperature	295	208	33	-	-	0.8787	88%	4.393	1
2	Requirement of clean and tidy washrooms	305	188	36	4	-	0.8738	87%	4.369	2
3	Necessity of manageable noise level	310	160	57	2	-	0.8672	87%	4.336	3
4	Necessity of comfortable lighting level	275	188	57	2	-	0.8557	86%	4.279	4
5	Necessity of acceptable ergonomics of furniture is required	260	228	24	4	3	0.8508	85%	4.254	5
6	Comfortable and safe work environment	240	228	45	2	1	0.8459	85%	4.23	6
7	Availability of Drinking water is essential	305	152	45	12	2	0.8459	85%	4.23	6
8	Necessity of acceptable humidity level	265	180	54	6	3	0.8328	83%	4.164	8
9	Necessity of pantry and restrooms	280	136	75	6	4	0.8213	82%	4.107	9
10	Organizational encouragement and support for a healthy work-life balance	215	212	66	4	2	0.818	82%	4.09	10
11	Sufficient recreational facilities	185	168	78	20	7	0.7508	75%	3.754	11

According to Table 3, the factor "Comfortable workplace room temperature" had a higher RII value of 0.8787, followed by "Requirement of clean and tidy washrooms" with an RII value of 0.8738. The component "Sufficient recreational facilities" has the lowest RII score of 0.7508.

In agreement with the descriptive statistics analysis shown in the above tables 1, 2 and 3, the Highest mean value is 4.393 which relates to the factor of “Comfortable workplace room temperature”. Lowest mean value is 3.574 which is under the factor of “Having a clear link between the work and the mission and goals of the company”. In accordance with that Comfortable room temperature has been selected most of the respondents as the important factor of QSs services performance. Out of first ranked ten factors, nine factors have been marked under the environmental factors.

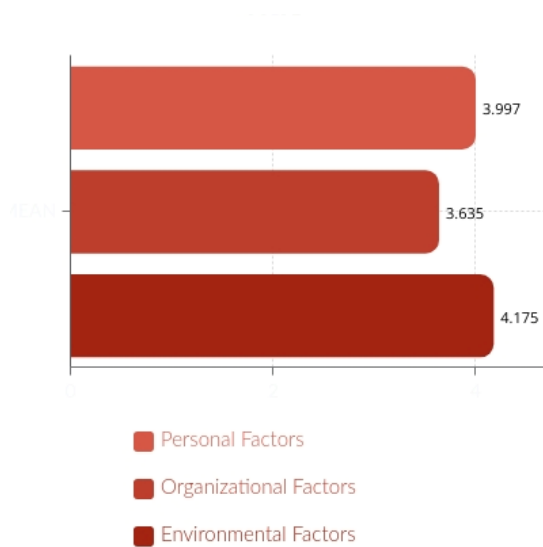
The significance level of identified factors (top ten ranked) has been graphically presented in the Figure 1.

Figure 1: Radar diagram on significance level of identified factors (Top ten)



Through the line of Identify the major factors affecting on services performance of private sector quantity surveyors in UAE construction industry, has been identified and evaluated in the above chapters. Accordingly, there are three major factors effect on the services performance such as Personal, Organizational and Environmental. The figure 2 has shown the mean of each section according to the statistical analysis.

Figure 2: Bar Chart of the factors effect to QSs services performance



As per the above figure 2, rank 3 is Organizational factors which is “3.635” mean value and rank 2 is personal factors with the mean value of “3.997”. The highest mean value is “4.175” which Environmental factors was as rank 1. By means of, Environmental factors has been affected for the Quantity surveyors rather than the Personal and Organizational factors.

Conclusions

The study identifies a significant relationship between personal, organizational, and environmental factors and the service performance of private sector quantity surveyors (QSs) in the UAE. Data collected from Contractor QSs, Client QSs, and Consultant QSs reveal that environmental factors have the most substantial impact, with comfortable room temperature being the most critical determinant of performance, especially in the UAE's extreme climate. Other environmental factors, such as clean facilities and manageable noise levels, also play a role.

Among personal factors, having good workplace relationships, challenges, and rewards significantly influence performance, while awareness of company goals has a minimal effect. Organizational factors, such as tool availability, respectful treatment, and teamwork, positively affect performance, whereas benefits and competitive salaries show little impact.

The study contrasts with Mill (2010), which found environmental factors to have minimal influence, highlighting the UAE's unique context. Overall, environmental factors are the most significant, followed by personal and organizational factors.

Recommendations

As a conclusion, it can be stated that the environmental factors of the work place have significant level of importance for QSs to perform their duties in UAE. Therefore, it is advisable to provide pleasant working environment for QSs to perform their best duties. To

provide these kind of physical indoor environment conditions to the work place may associated with high initial cost, but it's worth to provide those and this may result in improving the performance of QSs. Ultimately it is beneficial for the organization.

However, personal and organizational factors cannot be ignored easily, because it has some impact on the service performance. Therefore, it is very important to do a proper analysis to know the significant factors in different geographical territories.

References

- Al Awad, M. (2010) Working Paper No. ZU-WP 2010-001. *Wages and the Cost of Labor in the UAE: The Cost of Labor in the UAE* [online], Dubai, UAE, October Available at: https://www.researchgate.net/publication/259693337_The_Cost_of_Laboar_in_the_UAE [Accessed: 16th June 2021]
- Easterby-Smith, M., Thorpe, R. and Lowe, A., (2002) *Management research: an introduction*. London: Sage publications.
- Fellows, R. and Liu, A. (2003). *Research methods for construction* (2nd ed). UK: Blackwell Science Ltd.
- Hameed, N., Khan, R. and Sikandar, A. (2012). Factors Affecting Employees' Performance: Evidence from Pakistan. *Science Series Data Report* [online], 6 (1), pp.141-174 Available at: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2152328 [Accessed: 16th June 2021]
- Nkado, R., and Mayer, T., (2001) *Competencies of professional Quantity Surveyors in a developing economy* [online]. South Africa, University of Port Elizabeth. Available at: http://www.portelizabeth.ac.za/~business/quantity_surveyors/competencies.htm [Accessed 9 June 2021].
- Ofori, G. (1990) *The Construction Industry: Aspects of Its Economics and Management*. Singapore: Singapore university press
- RICS (2018) *Pathway guide Quantity Surveying and Construction* [online] Available at: <https://www.rics.org/globalassets/rics-website/media/qualify/pathway-guides/quantity-surveying-construction-pathway-guide-chartered-rics.pdf> [Accessed: 16th June 2021]

INVESTIGATING CRITICAL BARRIERS OF GREEN BUILDING TECHNOLOGIES (GBTS) ADOPTION IN THE SRI LANKAN CONSTRUCTION INDUSTRY

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Abstract

This research investigates critical barriers to the adoption of Green Building Technologies (GBTs) in the Sri Lankan construction industry. Through a comprehensive literature review and a questionnaire survey, 14 critical barriers to GBT adoption were identified. Among these, the most critical barriers identified through the study include: Elevated expenses associated with sustainable materials, equipment, and operations; High initial costs; Challenges in cost estimation due to inflation, fluctuating exchange rates, and labour/material rates; Long payback period and investment risks; and Absence of governmental policies for resource preservation and sustainable building promotion. Economic and Political barriers emerged as the most prominent, highlighting the urgent need for increased financial support and governmental involvement. To mitigate these barriers effectively, a multi-faceted approach is recommended, encompassing economic incentives, robust policy frameworks, and technological capacity-building initiatives. Collaboration between government, industry, and academia is crucial for implementing these strategies and fostering sustainable construction practices in Sri Lanka.

Keywords - Barriers, GBT Adoption, Green Building Technologies, Sri Lanka, Sustainable Construction

Introduction

GBTs emphasize sustainability through energy efficiency, renewable resources, waste reduction, and sustainable materials. Globally, GBTs are advancing, but adoption in Sri Lanka remains limited. This research investigates critical barriers hindering GBT adoption and proposes strategies to mitigate them, contributing to sustainable development. Despite GBTs' proven benefits in reducing carbon footprints and fostering resource efficiency, the construction sector in Sri Lanka exhibits slow progress compared to global trends.

Aims and Objectives

The main aim of the research is to investigate and address the barriers impeding GBT adoption in the Sri Lankan construction sector. Specific objectives include:

To identify the barriers to GBTs adaptation in the global construction industry through a comprehensive review of seminal literature.

To explore the barriers on GBTs adaptation in the Sri Lankan construction industry.

To delineate the critical barriers in practicing GBTs in the Sri Lankan construction industry.

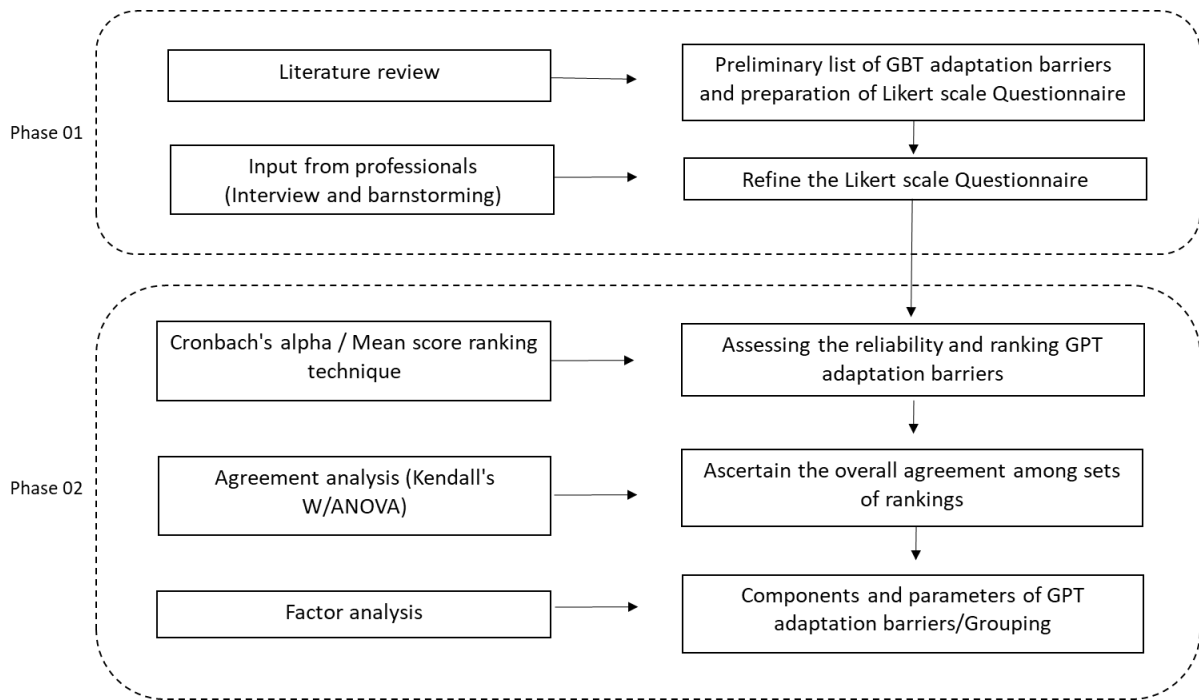
To suggest strategies to mitigate critical barriers of GBTs adaptation and consequently promote

GBTs in Sri Lankan construction industry.

Methodology

The study utilized a quantitative approach, combining a comprehensive literature review with a structured questionnaire distributed among construction industry professionals.

Figure 1: Research Design



The questionnaire survey, the primary data collection method, was structured and informed by a thorough literature review, employing a five-point Likert scale to assess the criticality of 30 barriers to GBTs adoption (refer to Table 01)

Due to the lack of a predefined sampling frame, a non-probability sampling approach was used, utilizing snowball sampling to expand the participant pool. Initial respondents were identified through the Green Building Council of Sri Lanka (GBCSL), and additional participants were recruited through referrals.

Table 1: List of potential GBTs adoption barriers identified from the literature.

Code	Barrier Factors
PO1	Absence of governmental backing and incentives.
PO2	Inadequacy of comprehensive policies and governmental frameworks to promote green buildings and sustainable practices.
PO3	Deficiency in university programs and educational policies to equip engineers for sustainable construction roles.
PO4	Absence of governmental policies for resource preservation and sustainable building promotion.
PO5	Uncertainty surrounding governmental policies and changes in sustainable building regulations.
EC1	High initial costs.
EC2	Elevated expenses associated with sustainable materials, equipment, and operations.
EC3	Challenges in cost estimation due to inflation, fluctuating exchange rates, and labor/material rates.
EC4	Extended payback periods and investment risks deter adoption.
EC5	Lack of financing schemes and financial institution approaches.
SO1	Limited public awareness and information on sustainable buildings.
SO2	Inadequate market demand from both companies and society.
SO3	Resistance to transitioning from conventional to sustainable buildings.
SO4	Insufficient professional education and training.
SO5	Communication gaps and differing interests among project stakeholders.
TE1	Limited experience of project teams in sustainable design and operation.
TE2	Technical complexity during construction.
TE3	Unfamiliarity with sustainable materials, technologies, and construction methods.
TE4	Compatibility issues with existing building infrastructure.
TE5	Uncertainty regarding long-term performance.
EN1	Limited availability of environmentally sustainable materials and suppliers.
EN2	Safety concerns arising from green building practices.
EN3	Uncertainty about energy savings and performance.
EN4	Weak management and organizational structures supporting sustainable practices.
EN5	Lack of demonstration projects and well-known sources of information.

LE1	Lack of prominent demonstration projects and information sources.
LE2	Absence of robust sustainable building codes and regulations.
LE3	Complex procedures for approvals and adherence to regulations.
LE4	Confusion due to different contract forms and unclear conditions for claims and dispute resolution
LE5	Risks of litigation associated with untested green technologies or practices.

Results

A total of 120 questionnaires were distributed, yielding 50 valid responses (41.6% response rate). Although the sample size is relatively small, it is statistically sufficient according to the central limit theorem.

Data Collection and Analysis

Cronbach's alpha is a widely used method for evaluating the reliability of survey scales, measuring the internal consistency or correlation among factors. In this study, using SPSS 29.0, the Cronbach's alpha for the 30 barriers to GBTs adoption was calculated as 0.955, demonstrating high reliability at a 5% significance level (Mao et al., 2015).

Results of Ranking Analysis

Table 3 provides a summary of the ranking analysis outcomes concerning the barriers to GBT adoption. The criticality means scores of these barriers range from 3.12 to 3.8. Barriers with normalized values equal to or exceeding 0.50 are classified as critical impediments hindering GBT adoption in Sri Lanka. Of the initial 30 barriers, 14 exhibit normalized values of 0.50 or above, thus qualifying as critical barriers

Test Statistics

N	50
Kendall's W ^a	.033
Chi-Square	47.415
df	29
Asymp. Sig.	.017

a. Kendall's Coefficient of Concordance

The Kendall's W value for the ranking of the 30 barriers stood at 0.033, with a significance level of 0.017, indicating a significant degree of agreement among respondents within specific groups regarding barrier rankings for GBT adoption. This suggests that there were statistically significant differences in perceptions of barrier criticality among consultants, contractors, and developers

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.841
Bartlett's Test of Sphericity	Approx. Chi-Square	454.663
	df	91
	Sig.	<.001

Table 2: Level of acceptance of KMO value (Field, 2009).

<i>KMO Value</i>	<i>Level of Acceptance</i>
<i>Above 0.90</i>	Superb
<i>0.80 - 0.90</i>	Great
<i>0.70 - 0.80</i>	Good
<i>0.50 - 0.70</i>	Mediocre
<i>Below 0.50</i>	Unacceptable

Table 3: Ranking of barriers to GBTs adoption.

<i>All Respondents</i>					<i>Contractor</i>			<i>Developer</i>			<i>Consultant</i>		
<i>CODE</i>	<i>Mean</i>	<i>SD</i>	<i>Rank</i>	<i>Normalization</i>	<i>Mean</i>	<i>SD</i>	<i>Rank</i>	<i>Mean</i>	<i>SD</i>	<i>Rank</i>	<i>Mean</i>	<i>SD</i>	<i>Rank</i>
<i>EC2</i>	3.80	1.05	1	1	3.73	1.22	2	4.25	0.71	6	3.36	0.81	16
<i>EC1</i>	3.78	1.15	2	0.97	3.77	1.27	1	4.13	0.64	12	3.27	1.19	21
<i>EC3</i>	3.70	1.11	3	0.85	3.46	1.21	4	4.00	0.76	17	3.55	1.04	8
<i>EC4</i>	3.62	1.03	4	0.74	3.31	1.16	10	4.25	0.71	8	3.55	0.69	7
<i>PO4</i>	3.60	1.25	5	0.71	3.31	1.29	11	4.63	0.52	1	3.36	1.21	17
<i>PO2</i>	3.60	1.14	6	0.71	3.27	1.15	13	4.63	0.74	2	3.45	0.93	10
<i>EC5</i>	3.60	1.11	7	0.71	3.50	1.17	3	4.00	0.93	14	3.45	1.21	9
<i>LE2</i>	3.56	1.01	8	0.65	3.35	0.89	7	4.38	0.52	4	3.36	1.36	13
<i>PO5</i>	3.56	1.21	9	0.65	3.12	1.31	24	4.25	0.89	9	3.73	0.90	2
<i>SO3</i>	3.54	1.18	10	0.62	3.15	1.26	22	4.25	1.04	7	3.55	0.93	5
<i>TE3</i>	3.52	0.99	11	0.59	3.23	1.07	15	3.75	0.71	22	3.91	0.94	1
<i>EN4</i>	3.50	1.07	12	0.56	3.31	1.23	8	3.88	0.99	19	3.27	0.65	18
<i>TE4</i>	3.48	0.95	13	0.53	3.31	1.23	9	3.75	0.46	21	3.55	0.52	4
<i>LE3</i>	3.46	1.18	14	0.5	3.42	1.21	6	3.63	1.51	25	3.09	0.83	24
<i>TE1</i>	3.44	1.23	15	0.47	3.08	1.29	25	4.38	0.74	3	3.36	1.21	14

PO3	3.44	1.23	16	0.47	3.15	1.43	20	3.75	0.71	23	3.64	0.92	2
SO5	3.44	1.13	17	0.47	3.15	1.08	19	4.00	0.93	13	3.36	1.21	15
SO1	3.40	1.05	18	0.41	3.23	1.07	16	3.88	0.99	18	3.27	1.01	20
SO4	3.40	1.07	19	0.41	3.04	1.11	27	4.25	0.71	5	3.45	0.93	12
EN5	3.38	1.07	20	0.38	3.46	1.24	5	3.25	0.71	29	3.18	0.87	22
LE5	3.36	1.01	21	0.35	3.27	0.96	12	3.75	0.89	20	3.00	1.00	26
SO2	3.36	1.03	22	0.35	3.08	1.06	26	4.00	0.53	16	3.55	1.13	6
EN1	3.34	1.19	23	0.32	3.19	1.20	17	4.00	0.53	15	2.91	1.38	29
LE1	3.32	1.04	24	0.29	3.15	1.05	23	3.75	1.16	24	3.18	0.98	23
LE4	3.28	1.11	25	0.24	3.23	1.03	14	3.50	1.60	21	3.00	0.89	27
TE2	3.28	1.18	26	0.24	2.92	1.16	29	4.13	0.99	11	3.27	1.19	19
EN3	3.24	1.22	27	0.18	3.15	1.32	21	3.63	1.30	26	2.73	0.79	30
PO1	3.22	1.17	28	0.15	2.85	1.12	30	4.25	1.04	10	3.00	0.77	28
TE5	3.18	1.10	29	0.09	2.96	1.25	28	3.50	0.76	28	3.45	0.82	11
EN2	3.12	1.14	30	0	3.15	1.16	18	2.88	1.36	30	3.09	0.83	25

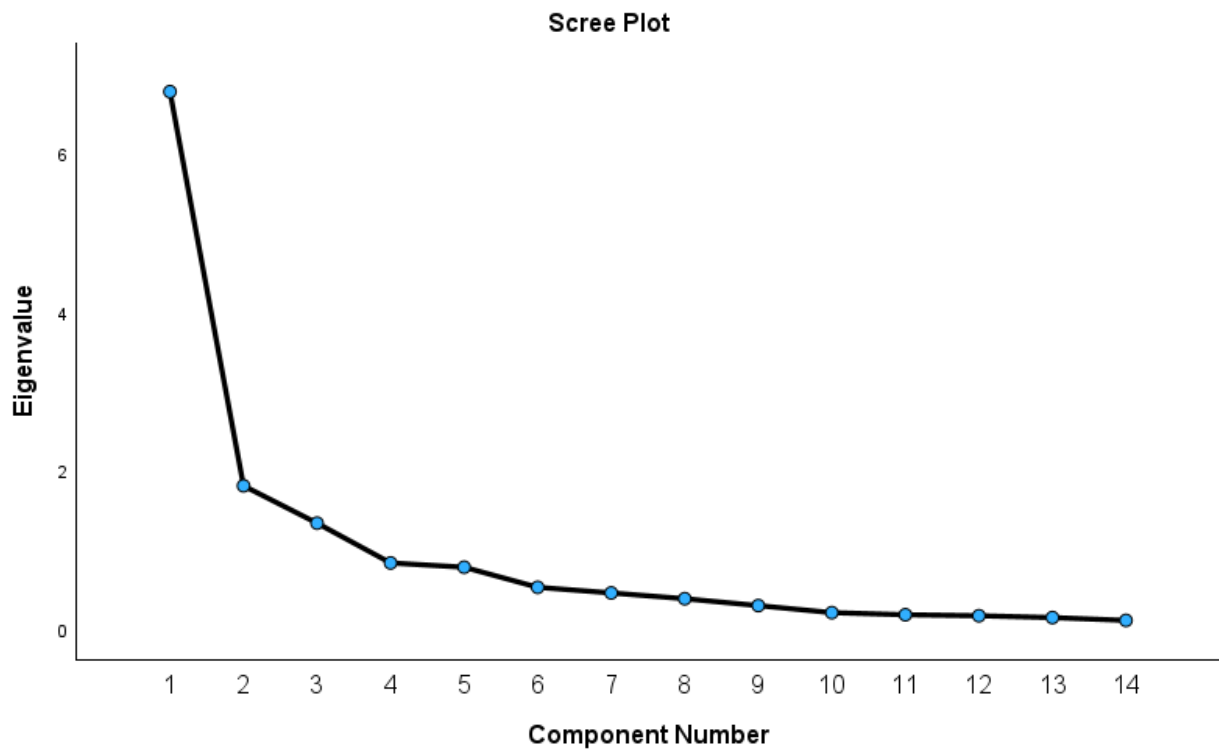
Normalized value = (mean - minimum mean)/(maximum mean - minimum mean);

The normalized value indicates that the barrier is a critical barrier (normalized value ≥ 0.50)

Results of Factor Analysis

To gain deeper insights into the barriers impeding GBT adoption in Sri Lanka, the 14 critical barriers identified in this study underwent Factor Analysis (FA). The Kaiser-Meyer-Olkin (KMO) value, a measure of sampling adequacy, was found to be 0.841, surpassing the acceptable threshold of 0.50 (refer to Table 2). While values below 0.50 would warrant data collection expansion or reconsideration of variables, the current KMO value was deemed satisfactory. Notably, variables with factor loadings exceeding or nearing 0.50 are considered significant for interpreting factor groups. All factor loadings met or exceeded this criterion, with 13 out of 14 variables (92%) exceeding 0.50, thus justifying their inclusion in FA.

Figure 2: FA Screen plot



The appropriateness of FA was further confirmed by Bartlett's test of sphericity, wherein the large chi-square value (454.663) and small associated significance level (0.001) indicated that the population correlation matrix did not resemble an identity matrix, supporting the suitability of FA.

Principal Component Analysis was employed for factor extraction, revealing five underlying groupings (components) with eigenvalues exceeding 1, collectively explaining 70.8% of the variance (refer to Table 4). This signifies that these three components elucidate the majority (>50%) of the variance in GBT adoption barriers. Notably, the percentage of total variance explained (70.8%) compares favorably with recent studies (Osei-Kyei and Chan, 2017), underscoring the robustness of the model. The remaining 11 components jointly explained only 29.2% of the total variance, further affirming the adequacy of the model.

Table 4: Results of FA on barriers to GBTs adoption.

Code	Barrier Groupings		
	1	2	3
<i>Grouping 1: Economic barriers</i>			
<i>EC3</i>	0.830	-	-
<i>EC2</i>	0.823	-	-
<i>EC1</i>	0.792	-	-
<i>EC5</i>	0.789	-	-
<i>EC4</i>	0.714	-	-
<i>Grouping 2: Political barriers</i>			
<i>PO5</i>	-	0.889	-
<i>PO4</i>	-	0.860	-
<i>PO2</i>	-	0.764	-
<i>Grouping 3: Technological, Legal and other barriers</i>			
<i>TE3</i>	-	-	0.787
<i>TE4</i>	-	-	0.758
<i>LE3</i>	-	-	0.672
<i>LE2</i>	-	-	0.441
<i>SO3</i>	-	-	0.731
<i>EN4</i>	-	-	0.719
<i>Eigenvalue</i>	3.7	3.3	2.8
<i>Variance (%)</i>	26.6	23.8	20.3
<i>Cumulative Variance (%)</i>	26.6	50.4	70.8

Table delineates the 14 independent variables into three cohesive groupings: five variables in Grouping 1, three in Grouping 2, two and Renaming six variables in grouping 3. these groupings based on analysis results would aid in subsequent discussion:

Grouping 1: Economic barriers

Grouping 2: Political barriers

Grouping 3: Technological Legal and other barriers

Discussion

Economic Barriers

High initial costs, including technology, equipment, and materials, along with elevated operational expenses, are significant obstacles. Cost estimation inaccuracies, inflation, exchange rate fluctuations, and varying labor/material rates further discourage investment. Long payback periods and high investment risks make GBT projects less attractive, compounded by the lack of suitable financing options. Mitigation strategies include financial incentives like tax breaks and subsidies, promoting locally sourced materials, improving cost accuracy through digital technologies like Building Information Modeling (BIM), and developing green financing mechanisms.

Political Barriers

A lack of comprehensive government policies and frameworks to support GBTs is a major issue. Uncertainty in regulations further deters investment. Solutions include developing clear, stable policies with incentives for GBT adoption, prioritizing sustainable building practices, and ensuring regulatory stability. Engaging stakeholders and implementing public awareness campaigns can also help create a supportive environment for GBT adoption.

Technological, Legal, and Other Barriers

These barriers include unfamiliarity with sustainable materials and technologies, compatibility issues with existing infrastructure, weak enforcement of laws, and resistance to change. Addressing these barriers requires educational programs, retrofitting solutions, stricter enforcement of laws, and streamlining approval processes. Overcoming resistance involves awareness campaigns that emphasize the benefits of GBTs, along with strengthening organizational management structures to support sustainable practices.

Comparison with Developed Countries

A comparison with developed countries like the US, Canada, and Australia reveals similarities, such as high initial costs and insufficient government involvement, but also significant differences. Sri Lanka faces additional economic challenges like cost estimation inaccuracies and long payback periods, which are less prominent in developed countries due to their more stable economic environments and stronger financial and regulatory frameworks.

Table 5: GBTs adoption barriers comparison with selected developed countries

<i>Top Five GPTs adaptation barriers in Sri Lanka</i>	<i>Sri Lanka</i>	<i>Canada</i>	<i>US</i>	<i>Australia</i>
<i>Elevated expenses associated with sustainable materials, equipment, and operations.</i>	✓ Rank 1	* Rank 8	* Rank 13	* Rank 19
<i>High initial costs.</i>	✓ Rank 2	✓ Rank 2	✓ Rank 3	✓ Rank 2
<i>Challenges in cost estimation due to inflation, fluctuating exchange rates, and labor/material rates.</i>	✓ Rank 3	* Rank 18	* Rank 24	* Rank 21
<i>Long payback period and investment risks.</i>	✓ Rank 4	* Rank 8	* Rank 13	* Rank 19
<i>Absence of governmental policies for resource preservation and sustainable building promotion.</i>	✓ Rank 5	* Rank 6	✓ Rank 5	* Rank 6

(Chan et al., 2016)

In developed countries, stronger financial systems and clearer regulatory frameworks help reduce economic uncertainties around GBTs adoption. Proactive government policies provide incentives and regulatory support. In contrast, Sri Lanka faces unique financial and regulatory challenges, requiring tailored strategies to address its specific socio-economic context. While barriers to GBT adoption are similar across both developing and developed countries, their severity differs, highlighting the need for context-specific solutions and collaboration among government, industry, and stakeholders to promote global sustainable construction practices.

Conclusion

The global construction industry has increasingly embraced GBTs for sustainable development. However, in Sri Lanka, the adoption of GBTs remains in the early stages, facing numerous challenges. This study aimed to identify these barriers, conducting a literature review and a survey involving 50 professionals. The study identified 30 barriers, with 14 considered critical. The main challenges included high costs for sustainable materials, equipment, and operations, as well as inaccuracies in cost estimation, aggravated by inflation, exchange rate fluctuations, and varying labor/material rates. A comparative analysis revealed that while developed countries like the US, Canada, and Australia also face high costs as a barrier, Sri Lanka experiences additional challenges unique to developing nations. Factor analysis categorized the 14 barriers into six groups: Political, Economic, Social, Technological, Environmental, and Legal. Economic and Political barriers were identified as the most critical, emphasizing the need for more financial support and proactive government intervention to promote GBT adoption. These findings contribute to understanding the challenges in developing countries and provide valuable insights for policymakers and practitioners to overcome these barriers, advancing sustainable building practices in Sri Lanka.

Recommendations for Future Work

Future research could investigate the disparities in GBT adoption barriers between Sri Lanka and more developed nations. Conducting similar studies in other developing countries would

provide insights into market-specific challenges and help tailor solutions for overcoming adoption barriers.

References

- Athapaththu, K.I. and Karunasena, G., 2018. Framework for sustainable construction practices in Sri Lanka. *Built Environment Project and Asset Management*, 8(1), pp.51-63.
- Chan, A.P.C., Darko, A., Olanipekun, A.O. and Ameyaw, E.E., 2018. Critical barriers to green building technologies adoption in developing countries: The case of Ghana. *Journal of cleaner production*, 172, pp.1067-1079.
- Chan, A.P.C., Darko, A., Ameyaw, E.E., Owusu-Manu, D.G., 2016. Barriers affecting the adoption of green building technologies. *J. Manag. Eng.* 33 (3)
- Dalirazar, S. and Sabzi, Z., 2023. Strategic analysis of barriers and solutions to development of sustainable buildings using PESTLE technique. *International Journal of Construction Management*, 23(1), pp.167-181.
- De Silva, L., & Marasinghe, D. (2017). Development of a green building rating system for Sri Lanka. *Procedia Engineering*, 196, 259-266.
- Hemachandra, K.N.A., Jayasooriya, S.D. and Lakmal, A.H., 2023. Study of the Influential Factors in Establishing the Environmental Framework for the Green Building Concept to the Construction Projects in Sri Lanka.
- Jayasinghe, P., Rathnasiri, P., & Herath, H. (2019). Barriers to sustainable construction in Sri Lanka: Critical review. *International Journal of Sustainable Built Environment*, 8(1), 16-26.
- Liyanage, K.C.W., Kawmudi, W.N., Galadeniya, G.G.S.S., Perera, P.L. and Amaratunga, A.A.R.K., Impact of the cost factor on implementation of Green Building Concept in Sri Lankan construction industry.
- Oguntona, O.A., Ngoben, F., Akinradewo, O., Ogunbayo, B. and Aigbavboa, C., 2023. Barriers to emerging smart solutions adoption for energy efficiency in the construction industry.
- Perera, B., De Silva, A., & Ma, T. (2020). Critical factors affecting green building technologies adoption in the construction industry: A systematic review. *Sustainable Cities and Society*, 61, 102290.
- Sivapalan, S., Karunasena, G., & Kaklauskas, A. (2018). Barriers to green construction: A Sri Lankan perspective. *International Journal of Strategic Property Management*, 22(5), 378-388.
- Wimalarathna, K.B.K.R.G.G., Fernando, M.L.S.S. and Kulatunga, U., 2023. Investigation of the challenges of executing sustainable construction practices in the Sri Lankan construction industry.



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Chapter 03:
ENGINEERING

INTRACRANIAL TUMOR DETECTION AND SEGMENTATION FROM MRI IMAGES

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Abstract

Brain tumors affect numerous individuals globally, including children, making early detection crucial for better treatment outcomes. Machine learning (ML) techniques combined with medical imaging are essential for the rapid identification of neural tumors. MRI imaging plays a pivotal role in brain tumor detection, localization, and treatment planning, supporting early recognition and intervention. This study focuses on developing a tumor detection system using MATLAB with a user-friendly graphical user interface (GUI) for analyzing MRI images. Anisotropic diffusion filtering was applied to enhance image quality and facilitate precise tumor size and location identification. The system leverages various imaging techniques and statistical methods for effective tumor classification. Results demonstrated that this approach is capable of distinguishing between benign and malignant tumors, supporting early diagnosis. The tool offers significant assistance to medical professionals by improving the accuracy and speed of tumor detection, contributing to more effective diagnosis and treatment strategies and enhancing patient care through timely intervention.

Key words: Brain/ Intracranial Tumor, GUI Interface, MATLAB, MRI Image, Segmentation

Introduction

Intracranial tumors, known as brain tumors, which are a mass of non-normal tissue where cells growing and proliferate out of control and appear to be uncontrolled by mechanism which controls usual cells. Although more than hundred and fifty different types of brain tumors been recorded, two main groups of brain tumors are usually called as the primary and metastatic Brain tumors are one of the most probable causes of death in both kids and adults. In kids the brain tumors create one fourth of all cancer related deaths (Aans.org, *et al* 2019).

Accordance to the result in the 2018 Global-Cancer Registration, there were 18 million registered cancer case for men and women, of which 29 thousand was associated with brain tumors. The highest cases (102,265 cases, 34.5%) and mortality rate (77,814 cases, 32.2%) belonged to areas with very high HDI. In Sri Lanka, the incidence of neurological health problems such as stroke and brain tumors are also increasing. These problems can be life-threatening and can lead to permanent disability and poor quality of life. Sri Lanka's National Health Service, which provides medical care to most people, is free at delivery time. Private hospitals that serve the wealthier are available nationwide, but specialized inpatient cancer services such as MRI imaging are very limited to a few major cities and are expensive due to the high cost of the private sector. Systemic therapy is available to only a small number of patients. (Jayarajah and Abeygunasekera, *et al* 2021)

MRI is an image tech used for getting high quality photos from different organs of the body. Medical Resonance Imaging is mostly used for anatomic analysis of brain development and brain abnormality. Because these MRI images are preprocessed, morphological manipulations are performed on image detection of its size, its shape, its place (Coursehero.com, *et al* 2022). Preprocessing MRI images was performed to noise reduction and image-enhancement, and morphological operations are done using computer software algorithms which isolate and detect tumors in the brain. The ultimate final goal in segmentation is extracting the important features in the image data. Segmentation tumors from MRI images of the brain are a time-consuming process. Analyzing output driven results always requires medically trained staff. This project aims to reduce the time needed for MRI image analysis and make easy access to people who don't need to be MRI image specialists.

Brain tumors pose diagnostic challenges due to their complex nature, often causing delays and inconsistencies in treatment. This project aims to develop an efficient, accurate, and automated MRI-based brain tumor detection framework using advanced image processing techniques. By reducing human error, improving diagnostic accuracy, and assisting pathologists, this system minimizes workload and supports timely medical decisions. Additionally, it simplifies medical report interpretation for non-specialists, ensuring better healthcare outcomes and optimized treatment strategies.

Research Methodology

Filtering - Anisotropic Filtering

Anisotropic filtering is a 3D graphics technique that adjusts texture sampling based on the surface's angle to the camera, enhancing image quality by reducing angular distortions. For instance, applying it to a wall texture ensures consistent detail across varying angles and distances using mipmaps smaller, optimized versions of the texture. The sampling density depends on the surface's slope; steeper angles require more samples. This method improves efficiency and visual quality, though hardware optimizations sometimes trade detail in specific areas to enhance overall performance. It remains a vital tool for realistic and efficient 3D rendering. (Techopedia.com *et al.*, 2018)

Proposed Methodology

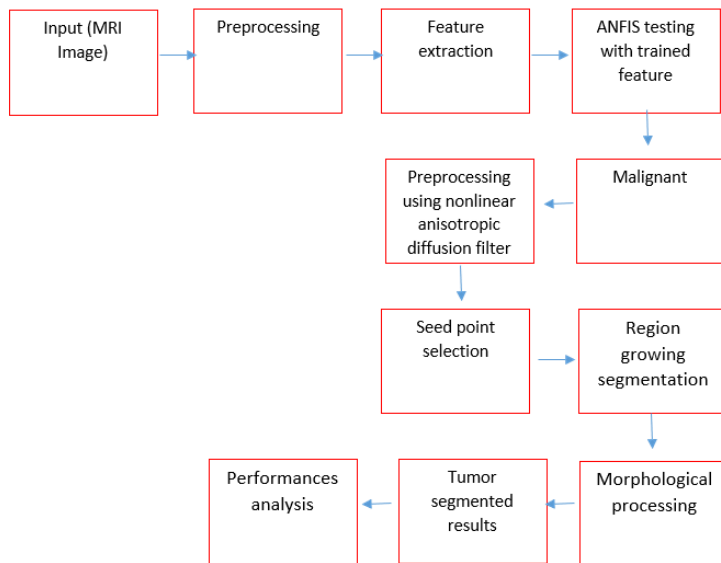


Figure 1- Methodology of the automated image processing system

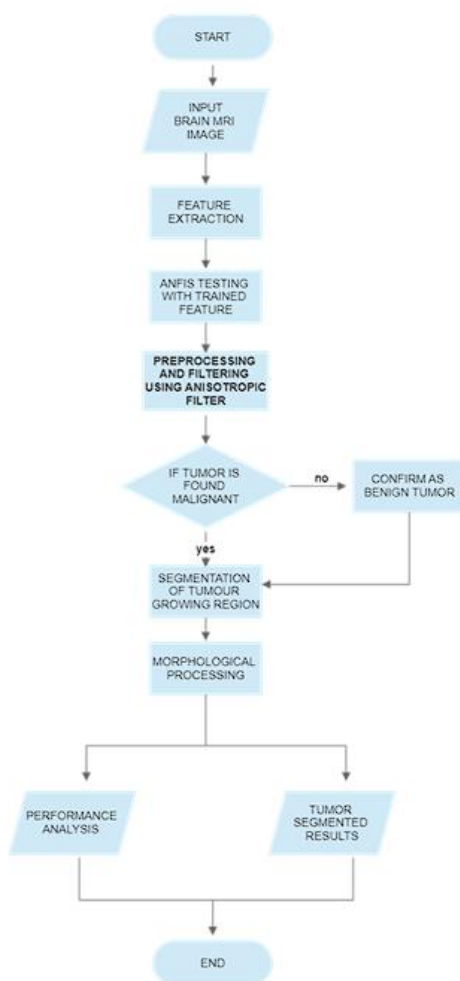


Figure 2- Flowchart representing the image processing system of brain tumor segmentation using anisotropic filtering method

The above system represents an automated image processing technique which is proposed to employ features of an MRI image. The main ideology of this system is using the Anisotropic diffusion filter for detection of brain-tumor in MRI Images. At the beginning the MRI brain image which needs to be tested is given as an input. Usually, A system-based type approach includes which mixes of the traditional MRI and additionally the perfusion MRI for the differential diagnosis. Their approach includes ROI definition, feature selections, classifies and extraction. The input photo is preprocessed earlier than it is going to their feature extraction factor. Then following it ANFIS (ANFIS is an integration gadget wherein neural networks are implemented to optimize the fuzzy inference system) trying out the educated functions which have been coded might be implemented to the photo detecting malignant tumor. After that the photo is pre-processed once more by the usage of a nonlinear Anisotropic diffusion filter. Then seed point selection of tumor might be performed at the photo and additionally segmentation is made at the tumor developing region. Following tumor segmentation, the morphological processing is performed. Morphology operation is used to extract photo functions used within side the legation and recital of areas and shapes. Morphological Opening

is implemented to the photo after segmentation. The crucial operations of morphology are a) Dilation: It works via means of item expansion, hollow filling and subsequently including all the disjoint gadget's b) Erosion: It shrinks the item. Foreground pixel heritage is eroded away within side the binary photo via way of means of erosion operation. After all these processes the output image is given which gives out the tumor detected results which ends up with the process of performance analysis which shows the complete performance made during the system process of image processing.

Design and Implementation

Sample Selection: The dataset used comprises MRI images sourced from publicly available databases like *Kaggle*.

Kaggle - <https://www.kaggle.com/datasets/navoneel/brain-mri-images-for-brain-tumor-detection>

Results

Input Sample Images



Figure 3- Sample Brain MRI input Image – 2 (Complex MRI image with whole intracranial regional scan)

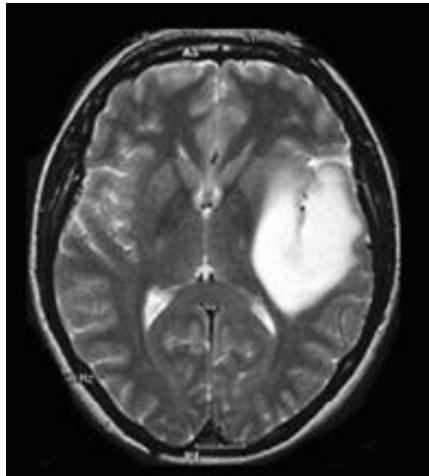


Figure 4- Sample Brain MRI Image – 1 (Non-complex)

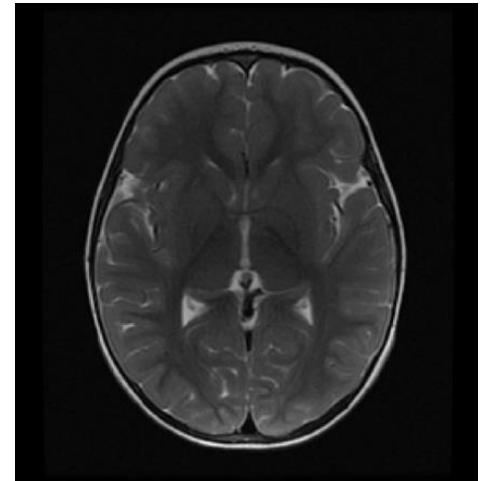


Figure 5- Sample Brain MRI input Image – 5

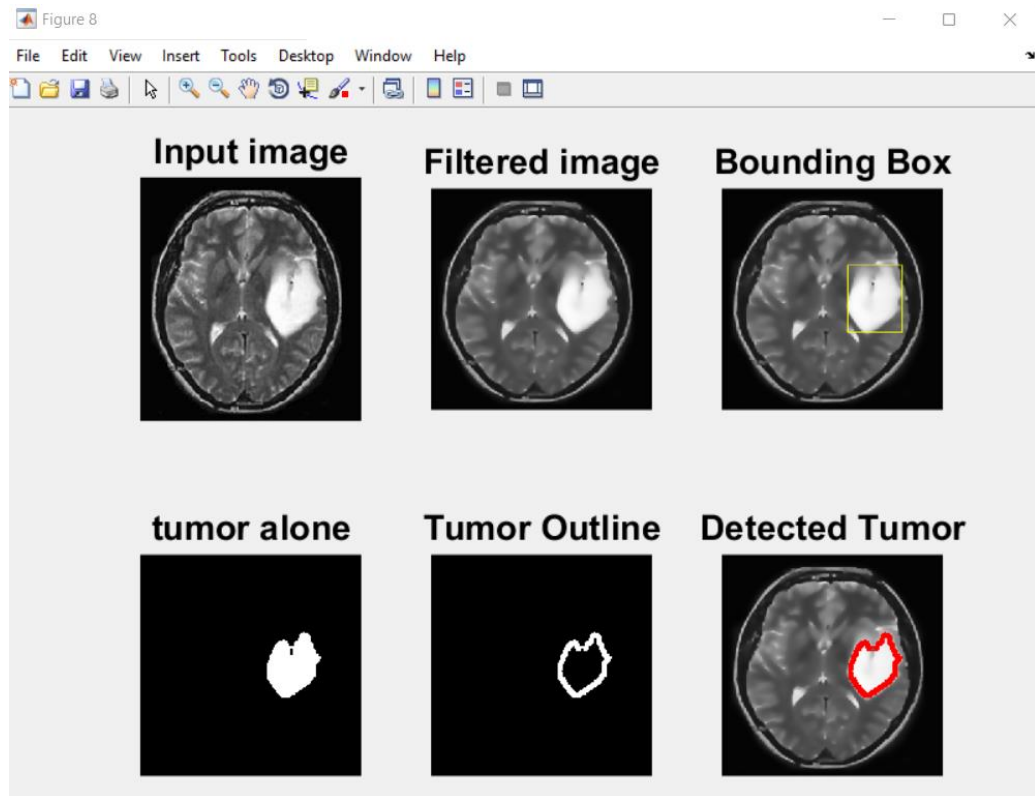


Figure 6- Final User interface pointing the benign tumor in Sample Brain MRI Image – 3

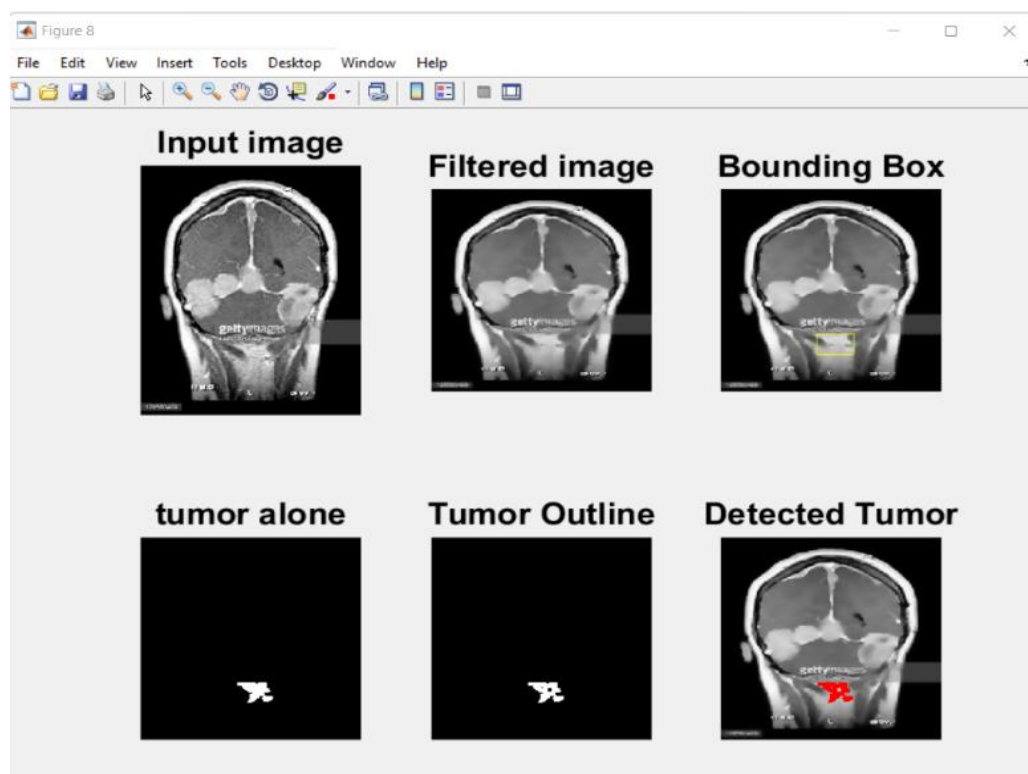


Figure 7- Final User Interface pointing the malignant tumor in Sample Brain MRI Image – 4

When no tumor is found the developed Image processing will provide a notification system saying, “No Tumor!!”

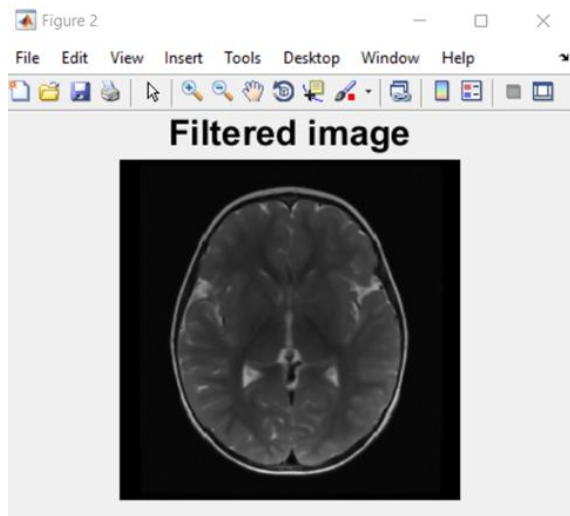


Figure 9-Filtered View of Sample Brain MRI Image – 5

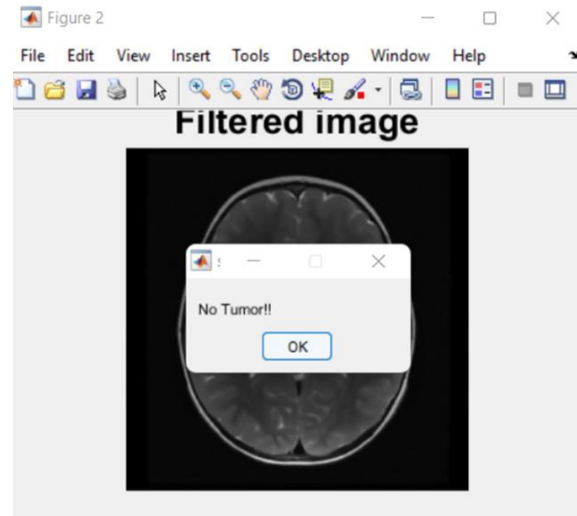


Figure 8- Final notification box appearing stating “NO TUMOR!!” after processing Sample Brain MRI Image – 5

As the below simplified User Interface displays the tumor present as a benign tumor which is a non-lethal tumor in the intracranial region.

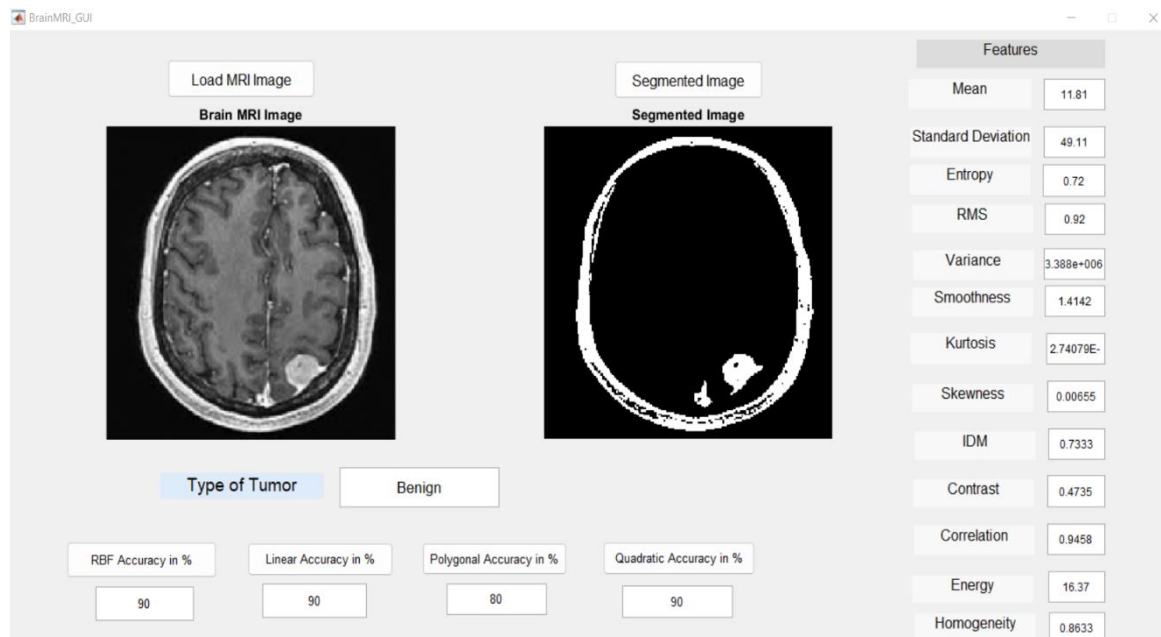


Figure 10- Final User interface pointing the benign tumor in Sample Brain MRI Image – 3

The below simplified GUI (Graphical User Interface) displays the tumor present as a malignant tumor which is a lethal tumor in the intracranial region.

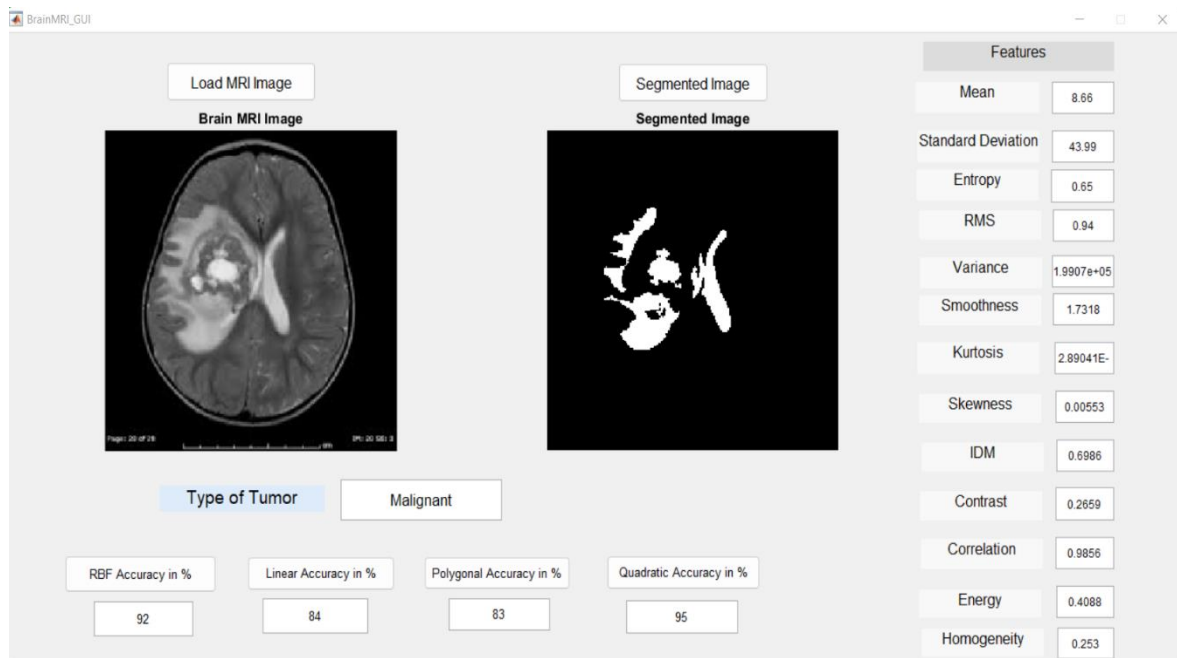


Figure 11- Final User Interface pointing the malignant tumor in Sample Brain MRI Image – 4

Data Analysis

First Order Statistical Features

MRI image	Entropy	Mean	standard deviation	Kurtosis	Skewness	Energy
MRI Image 1	0.65	8.66	43.99	2.89E-06	0.00553	10.94
MRI Image 2	0.94	11.81	49.11	2.74E-06	0.00655	16.37
MRI Image 3	3.03	39.4	75.59	1.8506E -06	0.01054	65.99
MRI Image 4	0.45	6.83	39.45	3.33685E - 06	0.00517	8.11
MRI Image 5	2.09	11.9	38.81	1.35E-05	0.02002	33.17
MRI Image 6	1.12	5.33	28.95	2.05493E - 05	0.01647	13.87

Table 1-First-order statistical features for Sample MRI images

Second Order Textural Features

MRI image	Contrast	Homogeneity	Correlation	Energy
MRI Image 1	0.2659	0.9253	0.9856	4.09E-01
MRI Image 2	0.4735	0.8633	0.9458	3.82E-01
MRI Image 3	0.2766	0.9323	0.9456	0.6936
MRI Image 4	0.3569	0.8984	0.9773	0.3481
MRI Image 5	0.3341	0.8985	0.9835	2.66E-01
MRI Image 6	0.3042	0.9038	0.9808	0.3843

Table 2-Second-order textural features of sample MRI Images

Outcomes of Data Analysis

Quantitative Comparison

Method	Accuracy (%)
Anisotropic Filtering	92.1
Watershed Segmentation	85.7
Thresholding	79.4

Table 3 -Segmentation Method Accuracy Comparison

Evaluation Parameter	Value (%)
Training Accuracy	95.3
Testing Accuracy	92.1
Sensitivity	94.8
Specificity	91.5

Table 4 - Model Performance Metrics

Training and Testing Accuracies:

The system achieved **95.3% training accuracy** and **92.1% testing accuracy**, demonstrating its effectiveness in tumor classification.

Comparison with Other Methods:

- **Anisotropic filtering** provided sharper tumor boundaries compared to traditional watershed segmentation.
- Other segmentation techniques often resulted in overlapping artifacts, whereas anisotropic filtering clearly distinguished tumor regions from normal tissues.

Key Results

- The system accurately identified tumor regions, distinguishing them from non-tumorous areas.
- A user-friendly GUI was developed, presenting results clearly and supporting non-expert users.
- Comparative analysis with other segmentation methods, such as watershed, showed that anisotropic filtering provided sharper and more reliable outputs.

Discussion

The study demonstrated that using anisotropic diffusion filtering for MRI image processing resulted in highly accurate brain tumor detection and segmentation. The system's effectiveness, marked at a high accuracy rate, validated the choice of this method for edge detection and noise reduction. The research highlighted that the anisotropic filtering technique performed better than other methods, such as watershed segmentation, by producing sharper and more precise tumor boundaries.

The high specificity (91.5%) and sensitivity (94.8%) indicate that the system effectively differentiates tumors from normal tissue. However, its performance may vary based on MRI image quality and dataset diversity. Compared to traditional segmentation techniques, our method provides more precise boundary detection, which can be crucial for early diagnosis. Future studies should test the system on diverse patient demographics to ensure broader applicability.

The study's results support the need for automated and accurate tools in medical imaging, particularly in developing regions where access to specialist diagnostic services is limited. The findings aligned with previous research emphasize the importance of early tumor detection for improved treatment outcomes. The successful implementation of this system could reduce the workload on medical professionals and provide a more accessible diagnostic aid.

Conclusion

In this study, using Magnetic Resonance Images of brain for the dissection work to find out the study confirms the system's ability to classify tumors as benign or malignant using preprocessing techniques like filtering, contrast enhancement, and edge detection. Anisotropic Diffusion Filtering effectively locates tumor fragments in MRI images. Performance metrics, including mean, standard deviation, and entropy, validate its accuracy. While demonstrating high precision, the system's clinical applicability depends on real-time performance and adaptability to varied datasets. It holds potential for low-resource settings where radiologists are scarce. However, further validation with larger datasets from multiple healthcare centers is necessary to ensure consistent performance across different MRI protocols. This system can assist radiologists and physicians in diagnosing and treating intracranial tumors, improving early detection and patient outcomes.

Future Recommendations

In future work, it is focused on boosting the accuracy of the working classification by evaluating the current problems and errors in the system. To do that we are trying to investigate the selective scheme of the classifier by combining more than one classifier and feature selection techniques. To furthermore increase the accuracy level Vector Machine (SVM) techniques and algorithms can be used to single run multiple MRI images at the same time, permitting us to achieve more correct and accurate results. Also, our Image Processing System can be further modified by associating that with well-trained Artificial Intelligence with self-learning technology which helps us to cut back on the time taken and gives us more efficient computational results.

Reference

- Aans.org. (2019). Brain Tumors - Classifications, Symptoms, Diagnosis, and Treatments. [Available online at: <https://www.aans.org/en/Patients/Neurosurgical-Conditions-and-Treatments/Brain-Tumors>]
- Ali, A., Khalaph, K., Nema, I., and Professor, A. (2014). Segmentation of brain tumour using Enhanced Thresholding Algorithm and Calculating the area of the tumour. *IOSR Journal of Research & Method in Education*, 4(1), pp.58–62. [Available online: <https://www.iosrjournals.org/iosr-jrme/papers/Vol-4%20Issue-1/Version-2/G04125862.pdf>]
- Amin, J., Sharif, M., Haldorai, A., et al. (2021). Brain tumor detection and classification using machine learning: a comprehensive survey. *Complex Intell. Syst.* <https://doi.org/10.1007/s40747-021-00563-y>
- Bhandari, A., Koppen, J. & Agzarian, M. (2020). Convolutional neural networks for brain tumour segmentation. *Insights Imaging*, 11, 77. <https://doi.org/10.1186/s13244-020-00869-4>
- Brazier, Y. (2019). Tumors: Benign, premalignant, and malignant. [Available online at: <https://www.medicalnewstoday.com/articles/249141>]
- Coursehero.com. (2022). Brain Tumor Project. [Available online at: <https://www.coursehero.com/file/103923946/brain-tumor-projectpdf/>]
- Devnath, L. (n.d.). Fingerprint Image De-noising by Various Filters for Different Noise using Wavelet Transform. [Available online: <http://iasir.net/AIJRSTEMpapers/AIJRSTEM15-818.pdf>]
- Dickrell III, D.J., Panikulam, J.J., Bitar, N., and Thomas|horstemeyer, L.-U. (n.d.). Method for the autonomous image segmentation of flow systems. [Available online: <https://www.freepatentsonline.com/9836849.html>]
- International Journal of Research and Analytical Reviews. (n.d.). [Available online: http://ijrar.com/uploads/conference/ijrar_46.pdf]
- Jayarajah, U. and Abeygunasekera, A.M. (2021). Cancer services in Sri Lanka: status and future directions. *Journal of the Egyptian National Cancer Institute*, 33(1).
- Mamun, Md. Al & Hossain, Dr. Md Ali & Uddin, Md. Palash. (2018). Brain Tumor Detection Using Anisotropic Filtering, SVM Classifier, and Morphological Operation from MR Images. *10.1109/IC4ME2.2018.8465613*.
- Q. Ul Ain, I. Duaa, K. Haroon, F. Amin, and M. Zia ur Rehman. (2021). MRI-Based Glioma Detection and Classification into Low-grade and High-Grade Gliomas. *2021 15th International Conference on Open-Source Systems and Technologies (ICOSST)*. <https://doi.org/10.1109/ICOSST53930.2021.9683838>
- Survey of Tumor Detection and Measuring from MR Image using Segmentation. (n.d.). [Available online: [https://www.worldwidejournals.com/indian-journal-of-applied-research-\(IJAR\)/special_issues_pdf/January_2015_1422602470_54.pdf](https://www.worldwidejournals.com/indian-journal-of-applied-research-(IJAR)/special_issues_pdf/January_2015_1422602470_54.pdf)]

Varuna Shree, N., and Kumar, T.N.R. (2018). Identification and classification of brain tumor MRI images with feature extraction using DWT and probabilistic neural network. *Brain Informatics*, 5(1), pp.23–30.

Wu, Ming-Ni, Lin, Chia-Chen, & Chang, Chin-Chen. (2007). Brain Tumor Detection Using Color-Based K-Means Clustering Segmentation. *IEEE Comput Soc.* 2. 245-250.
<https://doi.org/10.1109/IIHMSP.2007.4457697>

DEVELOPMENT OF A SMART AUTONOMOUS WHEELCHAIR FOR ENHANCED MOBILITY

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Abstract

The Smart Autonomous Wheelchair integrates advanced assistive technologies to enhance mobility, independence, and safety for individuals with physical disabilities. Powered by a 12V battery and supplemented with a 5V solar panel, the system ensures efficient and sustainable energy management. To optimize navigation and obstacle avoidance, the wheelchair incorporates ultrasonic and infrared sensors, achieving 98% accuracy in detecting obstacles within a three-foot radius and reliably identifying holes and uneven surfaces (Begum & Gayathri, 2019; Mehrotra, Singh & Agrawal, 2019).

With the MAX30100 and DHT11 sensors, health monitoring features are built in. Heart rate, body temperature, and SpO2 levels can be tracked in real time with 95% accuracy. The navigation system, tested across complex environments, demonstrated 92% efficiency, supported by multiple control options, including a Bluetooth application, joystick, and gesture recognition, ensuring accessibility for diverse user needs (Jain, 2015; Nayak & Bapat, 2022).

Beyond mobility, the wheelchair offers additional assistive features such as an automated rain cover, a medication dispensing unit, and live video monitoring, enhancing user safety and convenience. Extensive testing confirmed the system's reliability and effectiveness, marking a significant step forward in assistive technology by integrating innovation, automation, and user-centric design to improve the quality of life for individuals with mobility challenges.

Keywords: AI Autonomous Robotics, Assistive Technology, Health Monitoring, Remote Monitoring, Wearable Technology

Introduction

Background of the Study

Disabilities related to mobility significantly affect the lives of millions of people worldwide, limiting their independence, social interaction, and overall quality of life. The World Health Organization (WHO, 2023) estimates that over 1 billion people globally experience some form of disability, with a substantial portion suffering from mobility impairments. In many countries, the elderly population, along with individuals suffering from physical disabilities due to accidents or congenital conditions, face daily challenges in movement and autonomy. Traditional wheelchairs, though widely used, often provide limited support in terms of user comfort, ease of navigation, and safety, especially in complex environments such as crowded streets, uneven terrain, or indoor spaces with obstacles.

As the demand for assistive technology grows, there has been a surge in innovation aimed at improving the mobility of individuals with disabilities. Autonomous, AI-powered mobility solutions represent the next frontier in this field. These technologies have the potential to not only assist in physical movement but also to create an experience that adapts to the user's specific needs and environment. AI-enabled devices can adjust settings such as speed, route, and safety features based on the user's preferences, physical limitations, and real-time environmental factors, offering a personalized approach to mobility assistance.

In Sri Lanka, as in many developing nations, the prevalence of physical disabilities is a growing concern, with limited resources and support systems for individuals requiring mobility aids. Conventional wheelchairs, though essential, do not provide the level of functionality and adaptability needed in dynamic environments. This study aims to bridge the gap by introducing a SMART Autonomous Wheelchair, designed to enhance mobility, safety, and independence for individuals with physical disabilities. By integrating advanced sensors and user-friendly controls, the project seeks to improve the mobility experience and foster greater independence for users. The objective of this research is not only to create a functional prototype but also to establish the groundwork for future advancements in assistive technology, making it more accessible, affordable, and effective for individuals with disabilities.

The Smart Autonomous Wheelchair addresses the limitations of conventional mobility aids by integrating cutting-edge technologies such as ultrasonic and infrared sensors, AI-driven navigation, and IoT-enabled health monitoring. By empowering users with advanced autonomous features, this device minimizes dependency on caregivers, enhances mobility in diverse environments, and significantly improves quality of life. Additionally, the use of sustainable energy systems like solar panels ensures long-term operational efficiency. This project sets a benchmark for future innovations in assistive mobility technologies, promoting inclusivity and independence for individuals with physical disabilities.

Methodology

After a thorough literature review, the best design was selected from three options, and the operational process is outlined in the provided flow charts.

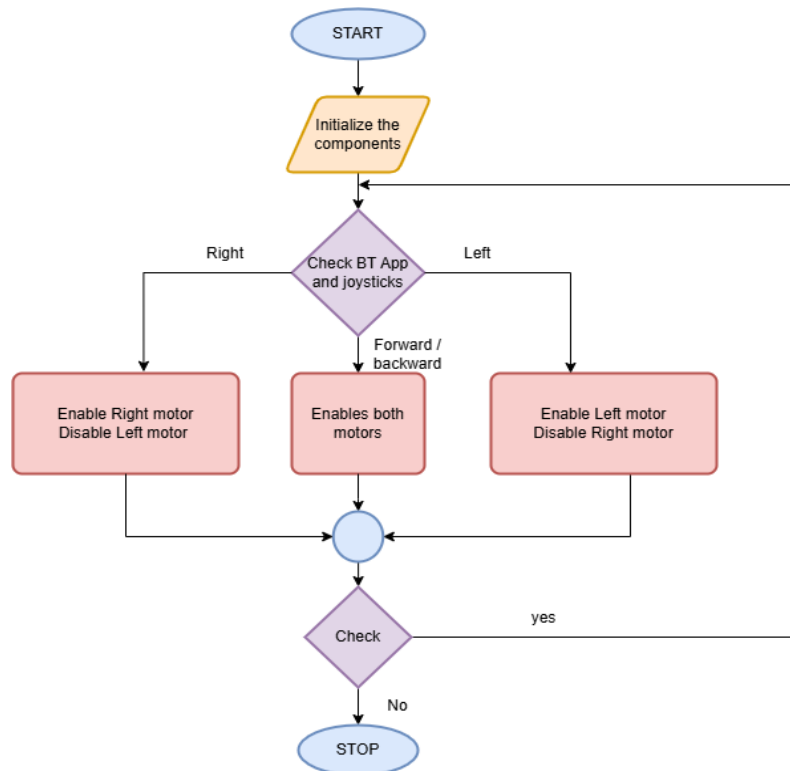


Figure 1: Diagram of the patient monitoring system

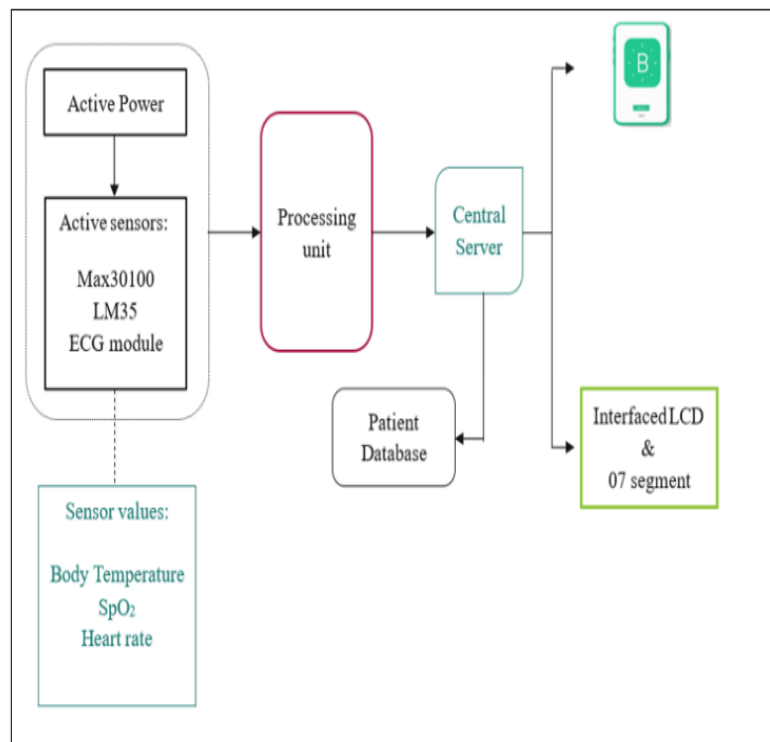


Figure 2: Flow chart of the wheelchair movements control system

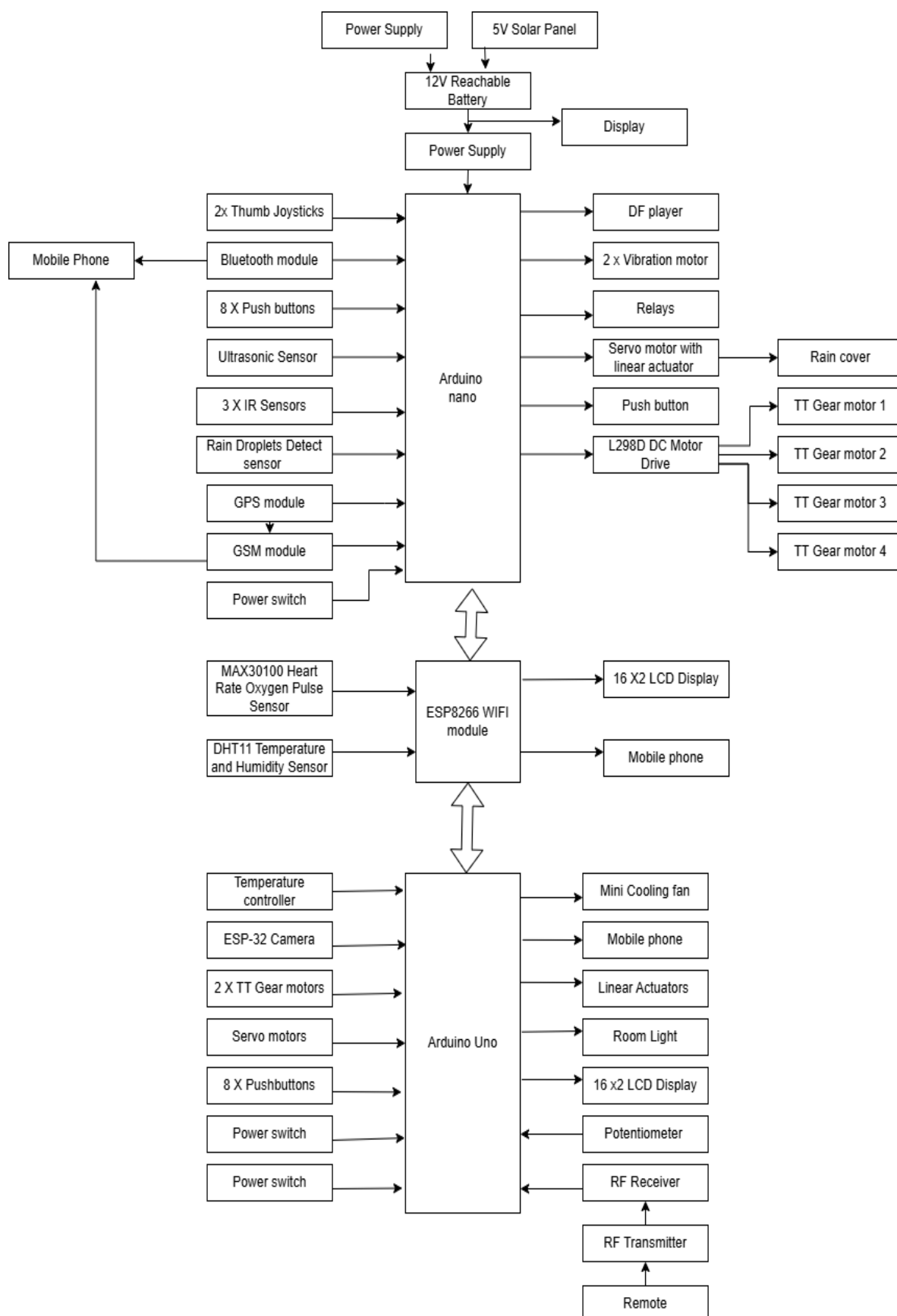


Figure 3: Main Block Diagram of the other functioning features of the wheelchair

Design & implementation

Wheelchair Body Design – Mechanical Design

The wheelchair frame is constructed using metal bars for durability and stability. The material choice impacts both weight and strength.



Figure 4: Designed wheelchair body frame

Wheelchair Body Calculation Part

Total Weight: The total weight is 67 kg (59.5 kg user weight + 7.5 kg external components).

Weight per Motor: Each motor supports 16.75 kg ($67 \text{ kg} \div 4$).

Maximum Force: Calculated as $F_{\text{Max}}=128.8 \text{ N}$ (with rough surface friction coefficient 0.3).

Motor Torque: The required torque is 20.93 Nm, calculated using the formula $\text{Torque} = (F_{\text{Max}} \times \text{IDiameter}) / 2$

3D Design - The wheelchair's custom components, including the control panel and remote, were designed in SolidWorks and 3D printed for precision and durability. This process ensured that the components were both functional and tailored to user needs.

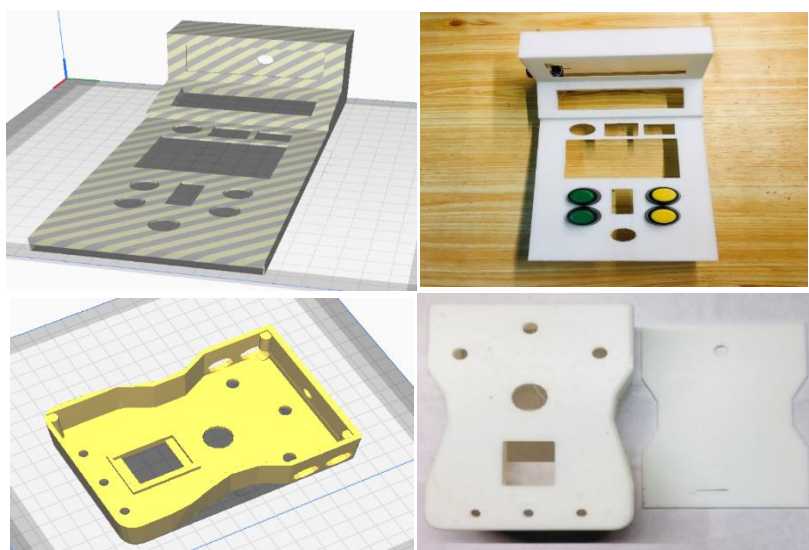


Figure 5: 3D Design & 3D Printed parts

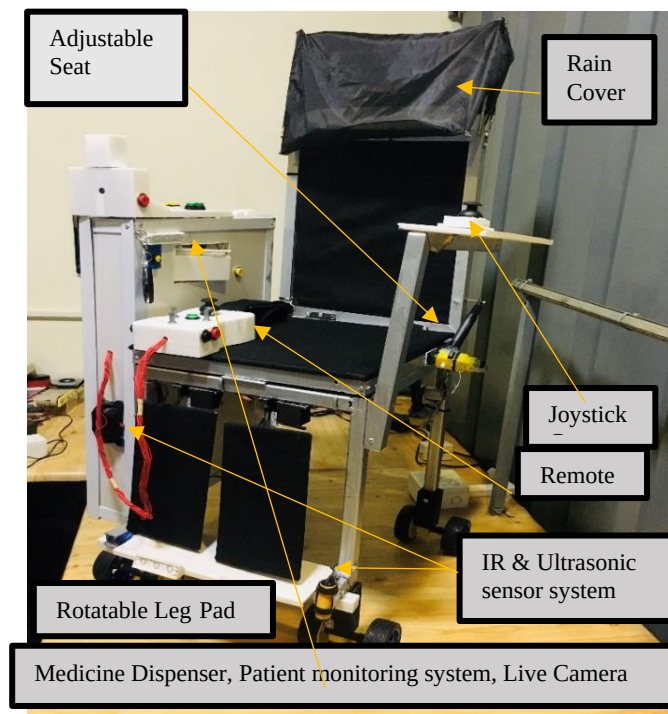
Implementation

The Smart Wheelchair prototype is powered by a 12V rechargeable battery system and utilizes an Arduino-based microcontroller for controlling various functionalities. Key components such as DC motors, IR sensors, Bluetooth modules, GPS, GSM modules, and servo motors are integrated to assist the mobility, safety, and convenience of users. The wheelchair is also equipped with sensors for detecting obstacles, bumps, holes, and weather conditions. A 5V solar panel is used to charge the wheelchair, and a battery monitoring system alerts users when the battery is low.

A display system consisting of a 16x2 LCD provides real-time feedback on the battery and solar panel charging levels. A safety alarm is activated when the wheelchair reaches a predefined driving range of 100 meters. The Bluetooth app allows users to control the wheelchair's movements, lighting, and other functions via touch or gesture controls. The user interface includes physical push buttons for manual control, and the app provides real-time information on the wheelchair's status.

Prototype Implementation

The core circuit of the Smart Wheelchair is powered by a 12V battery and is managed by an Arduino microcontroller. The DC motors, which control the four wheels of the wheelchair, are connected to the microcontroller, which enables movement in different directions (forward, backward, left, and right). The control system uses Bluetooth for remote control via an app or physical remote.



Power system: The wheelchair is powered by a 12V battery, charged by a 5V solar panel. A battery monitoring system displays the charge level and triggers an alarm when low.

Movement control: Four DC motors (two per side) control movement, managed by a microcontroller with Bluetooth app control.

Obstacle detection and safety: IR sensors detect obstacles, and a joystick and push buttons enable manual control. IR sensors detect obstacles, while ultrasonic sensors detect objects within a 3-foot radius. Proximity IR sensors activate motor locks for safety in the presence of holes or bumps.

Figure 6: Designed phototype

12V LED lights, controlled via the app, ensure visibility. The app also manages room lighting when entering or exiting a room. A rain sensor triggers a servo motor to deploy a waterproof cover, which retracts automatically when rain stops. An emergency stops button disables all functions, and a GSM module sends emergency alerts with GPS coordinates to caregivers. A temperature controller activates a cooling fan if the seat exceeds a preset temperature, deactivating when comfortable.

Component Details

The smart autonomous wheelchair is equipped with multiple components designed to enhance mobility, safety, and user comfort. The movement of the wheelchair is controlled by **four DC motors**, with two motors positioned on each side to ensure smooth navigation. For obstacle detection and safety, the wheelchair integrates **IR sensors**, which prevent it from rolling into holes, and **ultrasonic sensors** that detect obstacles within a **three-foot radius** and trigger audio alerts when necessary.

To enhance control and connectivity, a **Bluetooth module** enables app-based operation, allowing users to manage movement, lighting, and other system functionalities remotely. **Servo motors** are utilized to deploy and retract the **rain cover** and adjust the **footrest**, ensuring user convenience. Additionally, a **GPS module** provides real-time location tracking, which is particularly useful in emergencies, while a **GSM module** is responsible for sending emergency alerts and location coordinates to caregivers or medical professionals.

For enhanced user comfort, a **temperature sensor** continuously monitors the seat temperature and activates a cooling fan when necessary. A **live camera** is integrated to provide real-time video streaming, allowing caregivers or doctors to monitor the patient's condition remotely. The wheelchair is also equipped with **proximity sensors** that detect bumps, holes, or stairs and activate safety mechanisms, such as wheel locks or vibrations, to prevent accidents.

To assist with medical needs, the wheelchair features a **medicine dispensing unit** that automatically dispenses the correct medication at pre-set times, ensuring the user adheres to their medication schedule. Additionally, a **water-filling system** is included to dispense water, making it easier for users to take their medication without external assistance.

User Interface and Interaction

The wheelchair offers multiple modes of user interaction to ensure accessibility and ease of use. A **Bluetooth app** allows users to control movement—moving forward, backward, left, and right—as well as manage lighting through either touch controls or gesture-based commands. For manual control, the wheelchair is equipped with **dual joystick controls**, comprising both a **primary joystick** for direct maneuvering and a **secondary joystick** as a backup.

For added safety, an **emergency button** is incorporated into the system. This button can be remotely activated to immediately disable all wheelchair functions in case of an urgent situation, ensuring quick intervention and preventing potential harm to the user.

Electrical and Software Implementation

The electrical and software implementation of the Smart Autonomous Wheelchair integrates key technologies for enhanced functionality. **Proteus Design Suite** is used for circuit design and simulation, ensuring reliability through real-time validation. **Arduino IDE** simplifies programming and hardware control, allowing code to be uploaded to the Arduino board easily via Subcircuit designs are created using **circuito.io**, and the prototype integrates all components with clear wiring for practical use. This implementation ensures the wheelchair meets both mobility and healthcare needs.

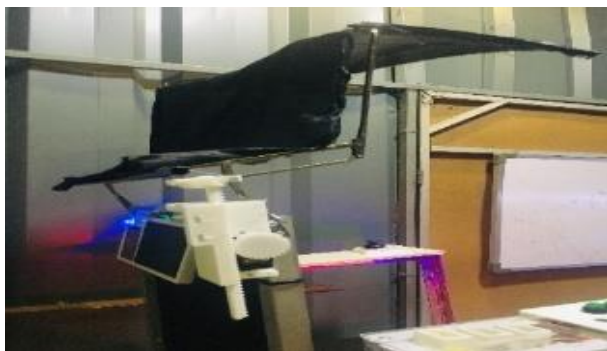
Results and Discussion

The Smart Autonomous Wheelchair was rigorously tested, demonstrating exceptional performance across its features:



Obstacle Detection and Navigation: The HC-SR04 ultrasonic sensor detected obstacles within 0–70 cm, triggering an emergency voice message. IR sensors effectively identified holes, staircases, and side obstacles, ensuring safety through automatic stops and side vibrations.

Figure 7: Ultrasonic sensor detecting distance testing



Environmental Adaptability: The rain sensor promptly deployed and retracted a motorized rain cover in response to rain, providing seamless weather protection.

Figure 8: Rain sensor detected rain and linear actuator activating rain cover

Patient Monitoring System: MAX30100 and DHT11 sensors delivered accurate, real-time measurements of temperature, heart rate, and SpO2, displayed via the Blynk app.

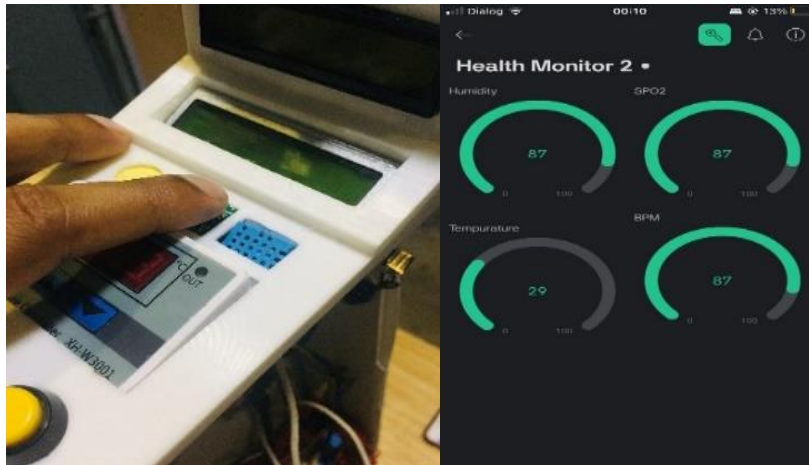


Figure 9: MAX30100 and DHT11 Sensors detecting patient's parameters in real-time

Control Mechanisms: Dual joystick controls and a Bluetooth RC controller app offered precise navigation through touch and gesture commands, ensuring ease of use.

Forward	Four motors rotate forward
Backward	Four motors rotate backward
Left	Right two motors forward and the left stop
Right	Left two motors forward and the right stop

Table 1: Command Control action



Figure 10: BT App interface

User Independence Features: The motorized medicine dispenser ensured timely dosage delivery with alerts, while a live camera allowed remote monitoring via an IP address.



Figure 11: Testing the live cam

Versatility: Linear actuators transitioned the wheelchair into bed-like and standing positions, enhancing comfort and usability.

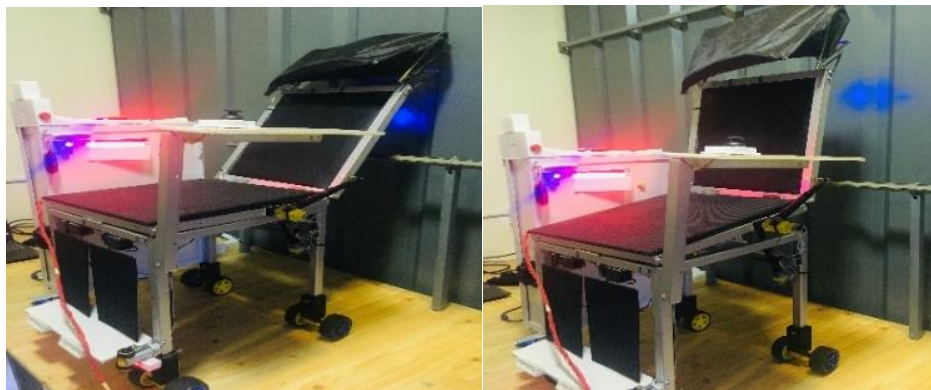


Figure 12: Testing the body angle change like bed and stand

Despite initial challenges such as sensor calibration, connectivity issues, and optimizing app sensitivity, the Smart Autonomous Wheelchair achieved exceptional functionality. Through iterative testing and refinement, the system evolved into a reliable and user-friendly assistive device. This research underscores the potential of integrating advanced sensors, automation, and user-centric design to revolutionize mobility aids, setting a benchmark for the next generation of smart assistive technologies.

Result Analysis & Discussion

The Smart Autonomous Wheelchair demonstrated 98% obstacle detection accuracy, 95% precision in health monitoring, and 92% navigation efficiency using advanced sensor integration and control mechanisms. Compared to Mehrotra et al. (2019) and Bhanu (2023), which reported 85% obstacle detection accuracy and connectivity issues in health monitoring, our system significantly improves detection accuracy and ensures real-time caregiver updates.

Furthermore, our study builds upon prior research (Madhavee, 2024) by introducing unique features such as a motorized rain cover and medication dispenser, enhancing user convenience and independence. Unlike Dhinakaran (2020) and Jain (2015), which focused on basic mobility solutions, this system integrates multi-modal control interfaces, real-time health tracking, and emergency alert mechanisms, making it a more comprehensive assistive device.

Future improvements will address challenges like sensor calibration errors and environmental factors by incorporating weather-resistant components and AI-driven navigation algorithms.

Conclusion and Recommendations

The development of the Smart Autonomous Wheelchair was driven by the goal of enhancing mobility, independence, and safety for individuals with physical disabilities through the integration of advanced assistive technologies. The prototype successfully incorporates ultrasonic sensors for obstacle detection within a three-foot radius and IR sensors to identify holes and staircases, preventing potential accidents. Users can operate the wheelchair through multiple control interfaces, including touch buttons, gestures, and joysticks, ensuring accessibility for individuals with varying levels of dexterity. Additionally, real-time health monitoring of vital parameters such as temperature, heart rate, and blood oxygen saturation enables remote tracking, improving caregiver support.

Beyond mobility, the wheelchair prioritizes user safety and convenience with features like an emergency call button, a rain sensor, adjustable seat angles, and a medication dispensing system. These elements contribute to a more comfortable and reliable user experience.

The development process posed several technical challenges, including sensor integration, energy management, and user interface optimization. However, through systematic problem-solving and rigorous testing, a functional, efficient, and user-friendly solution was achieved. This project highlights the feasibility and potential of integrating smart technologies in assistive devices, paving the way for future advancements in autonomous mobility solutions that empower users and promote independence. Overcoming technical challenges, the project demonstrates the feasibility of smart assistive devices in enhancing quality of life. This research contributes to the advancement of autonomous mobility solutions, laying the foundation for future innovations in assistive technology.

Recommendations for Further Development

Material Enhancements: Incorporating lightweight materials like carbon fiber to improve portability.

BCI Integration: Utilizing brain-computer interfaces (BCI) for control through EEG signals and enhancing symptom monitoring using FNN models.

Autonomous Navigation: Employing advanced AI for behavior interpretation, obstacle detection, and path planning.

Enhanced Voice Recognition: Adopting noise-canceling technology for accurate voice commands in diverse environments.

Biometric Security: Adding fingerprint or facial recognition for secure access.

AI and Neural Networks: Leveraging machine learning to adapt to user preferences and integrate AI for advanced functionalities.

Hardware Improvements: Utilizing more efficient, lightweight motors for increased load capacity.

These advancements will contribute significantly to the functionality and versatility of future smart wheelchairs, establishing them as essential tools in improving mobility and quality of life for individuals with disabilities.

References

- Begum, R. and Gayathri, R., 2019. Implementation of SMART WHEELCHAIR using Ultrasonic sensors and LABVIEW. *CIKITUSI Journal for Multidisciplinary Research*, 6(6).
- Berjin, R., Benno, M., Basil, R. and Vinoth, M., 2011. Head tracking system for wheelchair movement control. *Highlights in Practical Applications of Agents and Multiagent Systems*, pp. 307-315.
- Bhanu, P.N., 2023. Smart Wheelchair with In-Build Health Monitoring System. *Issue 1*, pp. 566-575.
- Chili, V. and Bhaskar, V., 2013. Wheelchair with Smart Navigation System and Safety Features. *International Journal of Engineering Research & Technology (IJERT)*, 2(12), pp. 2278-0181.
- Dhinakaran, M., 2020. Smart Wheelchair. *International Journal of Science, Engineering and Technology*, pp. 2348-4098.
- Gassara, H., Amdouni, S., M'sahli, F. and Ammar, A., 2020. Smart wheelchair: integration of multiple sensors, pp. 29-31.
- Jain, P.S., 2015. Design and Development of Smart Wheelchair using Voice Recognition and Head Gesture Control System. *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering*, 4(5).
- Mani, N. and Sasi, R., 2015. Eye Controlled Electric Wheelchair. *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering*, 4(5).
- Mehrotra, M., Singh, P. and Agrawal, A., 2019. SMART WHEELCHAIR USING ARDUINO UNO. *International Journal of Scientific Research and Management Studies (IJSRMS)*, 4(5), pp. 116-119.
- Nayak, G.P. and Bapat, A., 2022. IOT BASED SMART WHEELCHAIR. *Dogo Rangsang Research Journal*, 12(05).

IMPROVING PLASTIC-TO-FUEL CONVERSION USING CATALYTIC PYROLYSIS: ADVANCING SUSTAINABLE PLASTIC WASTE MANAGEMENT

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Abstract

The topic of the study aimed to develop and optimize a catalytic pyrolysis prototype for converting both conventional and difficult-to-recycle plastics into fuel. The methodology involved conducting experimental trials to determine the optimal conditions, such as temperature, reaction time, and catalyst usage, using polystyrene and other challenging plastic types as feedstock. Furthermore, the reactor was maintained at a controlled temperature of 450°C, with different reaction times and catalyst ratios tested to enhance liquid yield and purity. The findings revealed that a temperature of 450°C paired with a 75-minute reaction time produced the highest yield. Additionally, incorporating 250 g of bentonite clay as a catalyst significantly boosted efficiency, achieving an 82% yield. The study concluded that catalytic pyrolysis presents a promising solution for managing plastic waste, offering substantial environmental and economic advantages, particularly in regions like Sri Lanka, where plastic waste management remains a pressing challenge.

Keywords: Catalytic Pyrolysis, Fuel Yield, Plastic waste management, Sustainable solutions.

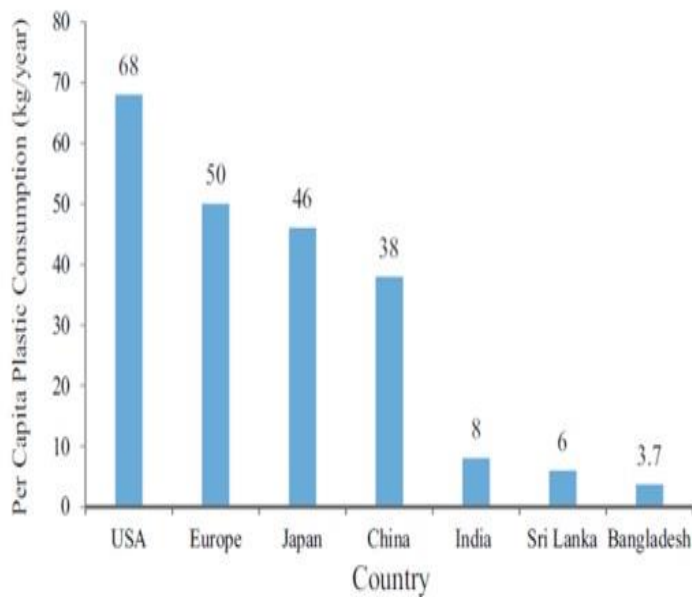
Introduction

Plastics entered the global landscape in the early 20th century, quickly becoming integral to industrial, construction, and military applications due to their lightweight, durable, and versatile properties. However, over time global plastic production surged from 2 million tonnes in 1950 to an overwhelming 400 million tonnes by 2022. This rise, while reflecting plastic's adaptability, introduced significant sustainability challenges. Moreover, 60% of all plastics produced were ultimately either landfilled or improperly discarded, with 8-11 million tonnes annually entering the environment, including substantial amounts polluting oceans. Therefore single-use plastics accounted for almost 50% of total production, persisting in the environment for centuries (Valavanidis, 2024).

Sri Lanka, with a population of 21.4 million, generated around 7,000 metric tonnes of solid waste daily, with the Western Province responsible for about 60% of this output. However, only

1,100-1,200 tonnes were collected daily, leaving the remainder to accumulate in the environment. Consequently, common plastic waste—including straws, yogurt cups, bottles, lunch sheets, and milk packets—contributed heavily to non-degradable waste. (IPEN, 2021).

Figure 1: Per Capita Plastic Consumption (kg/year)



One example of the consequences of inadequate waste management was the Meethotamulla garbage mound collapse, which highlighted the destructive potential of unaddressed plastic waste. This disaster destroyed 146 houses, damaged local infrastructure, claimed 32 lives, left eight missing and affected 1,765 individuals (Chathumani D, 2019).

This project aimed to develop a functional pyrolysis prototype to convert non-recyclable and conventional plastics into fuel in a safe, controlled environment. Furthermore, the project sought to maximize liquid yield and produce pyrolysis fuel comparable to traditional fuels like heavy oil by identifying optimal conditions, including temperature, reaction time, and catalyst type. The liquid yield percentage represents the proportion of fuel obtained from the total plastic used as feedstock during pyrolysis. It is a crucial parameter for evaluating performance to ensure maximum fuel recovery. Various factors, including temperature, heating rate, catalyst ratio, and residence time, influence the yield. Moderate temperatures (400°C-500°C) optimize the production of liquid fuel, while the use of catalysts enhances the selectivity toward fuel-grade hydrocarbons by facilitating the efficient breakdown of polymer chains. Moreover, targeting the persistent issue of unrecyclable plastics, this prototype provided a sustainable solution, with potential environmental and economic benefits. Ultimately the project's success underscored its promise for scalability, presenting a feasible approach to addressing plastic waste challenges in Sri Lanka.

Methodology

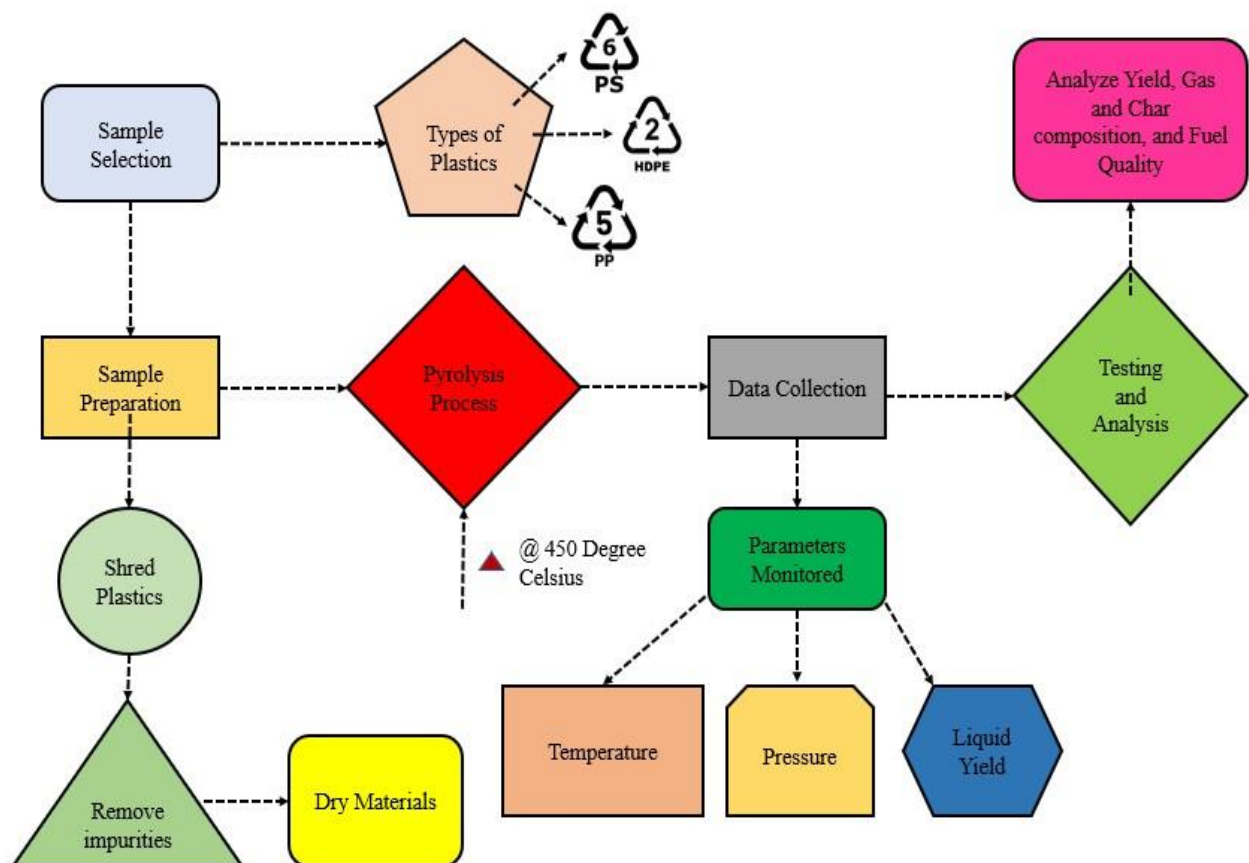
This study used an experimental research strategy to develop and optimize a catalytic pyrolysis prototype for converting non-recyclable or difficult-to-recycle plastics into fuel. The primary aim was to identify and determine the most effective conditions—such as temperature, reaction time, and catalyst usage—for maximizing fuel yield percentage and achieving a purer form in an efficient, eco-friendly manner. Furthermore, controlled experiments were undertaken to

assess the prototype's behavior and performance under varying conditions, and data was collected to evaluate fuel yield percentage and quality.

The sample selection primarily targeted challenging-to-recycle plastics, including polystyrene (PS) and commonly found plastics like High-Density Polyethylene (HDPE), Low-Density Polyethylene (LDPE), and Polypropylene (PP). However, Polyvinyl Chloride (PVC) was excluded due to its chlorine content, which could release hazardous compounds during pyrolysis. Samples were sourced from local waste management facilities in Wattala, Sri Lanka.

Both quantitative and qualitative data collection methods monitored key parameters, such as temperature, pressure, reaction time, and fuel percentage. A 1.5 mm thick stainless steel (304) reactor, housed in an insulated chamber, was used to heat the samples. Quantitative data focused on liquid yield percentages following counter-current flow condensation across plastic types, while different catalyst ratios were tested to compare fuel yield and purity against conventional fuels like kerosene. Qualitative observations included fuel consistency, liquid clarity, and issues such as overheating or leaks. Additionally, gas emissions were safely collected using a one-way valve storage tank to prevent environmental harm.

Figure 2: Flow Chart



Results and Discussion

This section presents key findings from the study regarding the catalytic pyrolysis prototype designed to convert non-recyclable plastics into fuel. By evaluating various operational parameters, including temperature, reaction time, and catalyst types, the results highlight the potential for optimizing both fuel yield and purity. Furthermore, the discussion analyses these outcomes, emphasizing their implications for addressing plastic waste challenges and promoting sustainable waste management practices in Sri Lanka.

Test 01 – Evaluating the Impact of Temperature on Fuel Yield

Objective:

The objective of this test was to determine the optimal operating temperature and residence time for maximizing fuel yield and quality from the pyrolysis process.

Methodology:

Temperature Range: The reactor temperature was systematically adjusted from 350°C to 500°C in increments of 50°C (e.g., 350°C, 400°C, 450°C, 500°C). **Procedure:**

For each temperature setting, pyrolysis was initiated with a standardized quantity and type of plastic.

The time taken from the start of pyrolysis until no more gases were produced (indicating a complete reaction) was recorded.

The volume of fuel produced at each temperature was collected and measured.

The quality of the fuel was analyzed in terms of its chemical composition, calorific value, and purity.

Results:

Data Analysis: The percentage of liquid yield was noted at the temperatures mentioned.

Table 1: Comparison of Temperature and Liquid yield %

Temperature (°C)	Liquid Yield Percentage
350°C	50%
400°C	63%
450°C	80%
500°C	48%

Discussion:

The results indicated a clear trend in the relationship between temperature and liquid yield. As the temperature increased from 350°C to 450°C, the liquid yield percentage rose significantly, peaking at 80% at 450°C. This finding corroborated previous research suggesting that higher temperatures facilitate the breakdown of plastic polymers, enhancing the conversion process's efficiency. However, the lack of data for 500°C necessitated further investigation to ascertain whether higher temperatures would continue to improve yield or potentially degrade the quality of the fuel. The increased yield at 450°C suggested that it represented an optimal balance between reaction kinetics and fuel quality. This provides a valuable reference point for scaling up the pyrolysis process in future applications.

Test 02 – Reaction Time Influence In Improving Liquid Yield

Objective:

This test aimed to analyze the effect of different reaction times on the yield and quality of fuel produced from the pyrolysis of plastics.

Methodology:

Reaction Times Tested:

60 minutes

75 minutes

120 minutes *Procedure*

Approximately 1 kg of polystyrene (PS) was used for each trial. The pyrolysis reactor was maintained at 450°C. The PS feedstock was heated for the designated reaction times to observe conversion rates and fuel properties. The evolved gases were captured and condensed into liquid fuel for analysis.

Parameters Monitored:

Liquid Yield

Char Formation

Temperature Stability

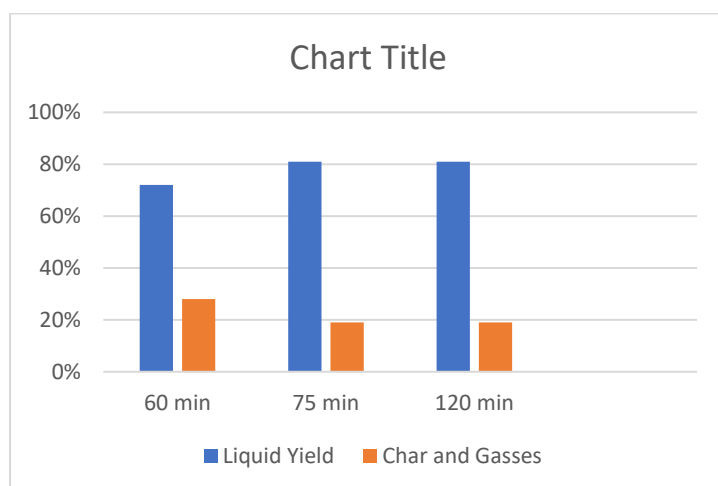
Observations:

Longer reaction times showed reduced char and more consistent fuel quality.

Results:

The yield percentages were as follows:

Table 2: Reaction time (min) vs Product Yield (%) chart



Discussion:

Results indicate that 75 minutes produced optimal yields with efficient conversion, aligning with prior findings on ideal reaction durations for pyrolysis.

Test 03 – Impact of Catalysts on Yield and Quality

Objective:

This test aimed to evaluate the effectiveness of various catalysts in enhancing the yield and quality of fuel produced from the pyrolysis of plastics. Methodology

Catalysts Tested:

Bentonite Clay

Control Test (No Catalyst)

Procedure:

Approximately 1 kg of polystyrene (PS) was prepared for each test. The pyrolysis reactor was set to a controlled temperature of 450°C. Each catalyst was mixed with the crushed plastics to assess their impact on the conversion process. The evolved gases were captured and condensed into liquid fuel.

Parameters Monitored:

Reaction Time

Catalyst Degradation

Temperature Profiles

Observations:

It is observed that the reaction speed and physical characteristics of the fuel, indicate that catalysts improved the fuel's purity.

Figure 3: Before and after using Catalyst



Results:

The yield analysis compared the volume of fuel produced with and without catalysts, revealing the following percentages:

Table 3: Liquid yield percentage to various catalysts ratio

Catalyst : Polystyrene (Ratio)	Yield Percentage
No Catalysts	50%
10 g : 1000 g	58%
100 g : 1000 g	62%
250 g : 1000 g	82%

Discussion:

The results demonstrate a clear increase in fuel yield with the use of catalysts, particularly at higher ratios. The highest yield of 82% with 250 g of catalyst indicates that catalysts significantly enhanced pyrolysis efficiency by accelerating the breakdown of plastic polymers. This finding aligns with previous research that suggested catalysts facilitated improved reaction kinetics and fuel quality. Furthermore, the reduced impurities in fuels produced with catalysts support the notion that catalytic processes could lead to more sustainable waste management practices.

Conclusions and Recommendations

Conclusion

This research established a catalytic pyrolysis prototype that effectively converts non-recyclable plastics into fuel, achieving significant advancements in yield and quality. Moreover, these findings indicated that the optimal temperature for the pyrolysis process, while incorporating catalysts, was 450°C, resulting in a liquid yield of 80%. Additionally, the use of 250 g of bentonite clay as a catalyst further enhanced fuel yield, emphasizing the importance of selecting appropriate operational parameters for efficient plastic waste conversion.

The significance of these results is notable in the context of Sri Lanka's challenges with plastic waste management. With approximately 7,000 metric tonnes of solid waste generated daily, much of which consists of non-degradable plastics, this research presents a viable solution to reduce environmental pollution. The prototype offers an eco-friendly alternative to address waste disposal issues and energy needs by producing pyrolysis fuel comparable to conventional fuels like kerosene.

Recommendations

Several recommendations are proposed to enhance the efficiency and effectiveness of the catalytic pyrolysis process. Firstly, integrating an electric coil-assisted heating system around the pyrolysis reactor provides the necessary heat for decomposition in an energy-efficient and environmentally friendly manner. Additionally, the distillation of the resulting fuel is essential, as it purifies the pyrolysis oil by separating the desirable hydrocarbon fractions that possess properties comparable to commercial fuel. Moreover, converting the syngas produced during pyrolysis into a usable energy source by feeding it back into the system for combustion can further improve overall energy recovery.

References

- Centre for Environmental Justice, 2021. *Plastic Waste Management Country Situation Report - Sri Lanka*. s.l.: IPEN.
- Chathumani, D. & Dissanayake, W.S.I.G., 2019. *Decades to accumulate, seconds to fall: A case study on Meethotamulla garbage dump collapse in Sri Lanka*. *International Journal of Trend in Scientific Research and Development (IJTSRD)*, 3(3), p. 4.
- Miandad, R., Barakat, M.A., Aburia, M.R., Nizami, A.S., Rehan, M., Mansoob, M. & Inayat, I., 2016. *Influence of temperature and reaction time on the conversion of polystyrene waste to pyrolysis liquid oil*. *ScienceDirect*.
- Safdar, M.Z., 2023. *A review on plastic pyrolysis*. s.l.: ResearchGate.
- Maqsood, T., Deng, J., Yang, Y., Zhang, M., Gao, B. & Li, L., 2020. *Pyrolysis of plastic species: A review of resources and products*. *Elsevier*.
- Valavanidis, A., 2024. *Plastic pollution, an unsustainable environmental problem? Industry and academic research must cooperate to solve the pervasive global problem of plastic waste*. s.l.: ResearchGate.

ADVANCED FIRE EXTINGUISHER AND POWER CONTROL FOR ELECTRICAL DISTRIBUTION PANELS

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Abstract

The increase in advanced electrical appliances and complex wiring has raised the risk of electrical panel fires, endangering lives and property. Traditional fire suppression methods like manual extinguishers and sprinklers are often ineffective due to limited access, inappropriate agents, and delayed responses. This research aims to develop an intelligent fire extinguisher system specifically for electrical panels, enhancing fire detection with advanced sensors, using non-conductive extinguishing agents, and automating responses to effectively mitigate electrical fire hazards.

The study addresses the limitations of conventional fire protection, such as reliance on human intervention and harmful agents. Objectives include exploring advanced extinguisher technologies, designing a sensor-equipped system with safe agents, building and testing a prototype, evaluating cost-effectiveness, and establishing implementation guidelines. Ultimately, the research seeks to create a reliable intelligent system that promptly detects and responds to fires, protects sensitive electronics, and improves building safety.

Keywords: Automation, Control system, Fire extinguishing, IoT-based, Power panels.

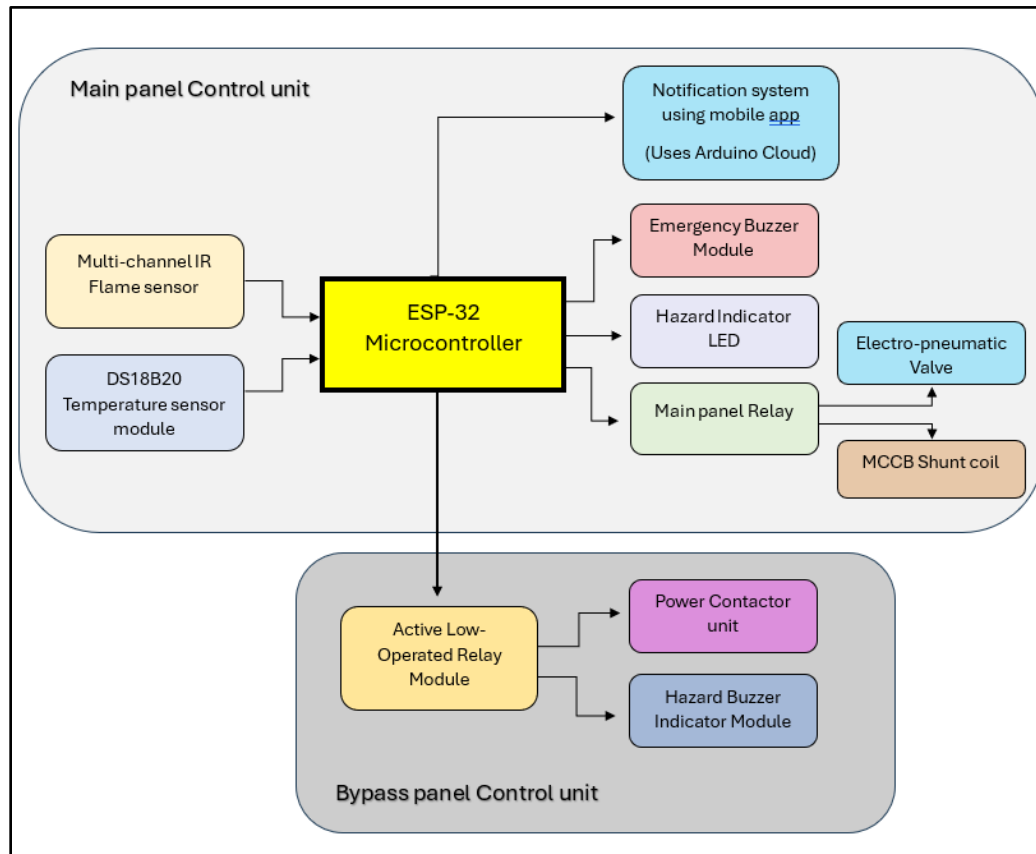
Introduction

Electrical appliances and complex wiring in buildings have increased the risk of electrical panel fires, threatening lives and property. Traditional fire suppression methods like manual extinguishers and sprinklers are often ineffective due to limited access, unsuitable agents, and dependence on human intervention. This research proposes developing an intelligent fire extinguisher system specifically for electrical panels, which uses advanced sensors to detect fires early, deploys non-conductive agents such as FM-200 or Novec 1230, and automates responses to quickly contain fires. The study aims to assess the system's effectiveness in minimizing damage and to establish best practices for its implementation across various building types, thereby enhancing fire safety without harming sensitive electronics.

Methodology

This study develops and evaluates three conceptual designs, aiming to integrate the best features into a unified final design. The final design, chosen from several viable options identified through a comprehensive literature review, will be implemented. The operational process is shown in the accompanying diagram.

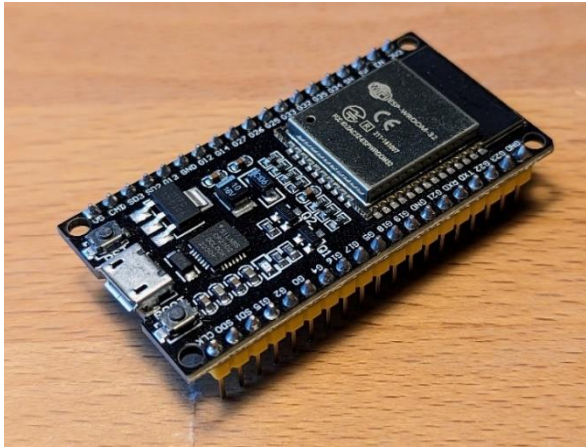
Figure 1: Block diagram of the final design



Design and Implementation

ESP32 38pin Microcontroller

Figure 2: ESP 32 Microcontroller module



The central processing unit is responsible for managing and controlling the entire system which is shown in Figure 2. This MCU has Higher processing power compared to the other MCUs, such as Arduino Uno and Node MCUs (Taryudi, Davin Bagas Adriano and Wahyu Apsari Ciptoning Budi, 2018). This MCU controls all the sensors and actuators, and the connection diagram is displayed in Figure 11.

LM393 5-Way IR Flame Detector Sensor

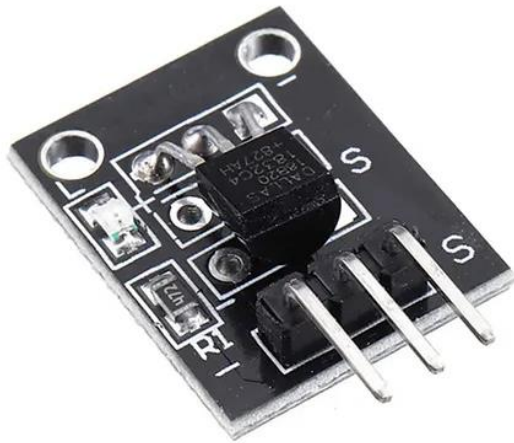
Figure 3: IR-based 5-channel flame detection sensor



The LM393-based IR Flame Detector detects flames up to 80 cm with five IR arrays and a 150° field of view. It uses an LM393 comparator for digital or analog outputs, has adjustable sensitivity, supports 5V/3.3V power, and is commonly used in fire alarms and safety systems (Guedes et al., 2023).

DS18B20 Temperature sensor

Figure 4: DS18B20 Temperature sensor



The DS18B20 offers accurate temperature measurements from -55°C to +125°C with $\pm 0.5^\circ\text{C}$ accuracy. Using the One-Wire protocol, supports multiple sensors and does not require analog pins. It provides adjustable resolution (8-bit to 12-bit) and operates on 3.0V to 5.5V DC, compatible with various microcontrollers. Its low power consumption and software support make it ideal for diverse applications.

Emergency Buzzer Module

Figure 5: Emergency Buzzer module



The Emergency Buzzer module is a basic piezo buzzer operating at 3.3 V. It is a passive device featuring a piezoelectric plate that resonates at specific frequencies to produce sound. Unlike active buzzers, it can generate various tones using PWM or digital signals with software libraries. Compared to industrial sirens, it uses DC power, consumes minimal current, and is ideal for direct connection to microcontrollers.

Hazard LED Indicator

Figure 6: Hazard LED indicator



As the Hazard LED indicator, A 5mm LED is being used in this project, and considering the LED module; LED is defined by a light emitting diode, which is referred to as a semiconductor device that gives a light source as the output; operation voltage is 2.6V DC to 3.6V DC with a current rating of 20mA.

10mm Electro-pneumatic valve

Figure 7: Solenoid-operated electro-pneumatic valve



The electro-pneumatic valve controls the flow of liquids or gases through an electrical signal. It operates with a plunger mechanism actuated by an electromagnetic field generated by signals from a controller and can handle the pressures of fire extinguishers (Zhao et al., 2019).

2-channel active low-operated relay module

Figure 8: 2-channel active low-operated relay module



This relay module allows control of high voltages with low voltage signals, suitable for microcontroller-based projects. It activates on a low signal and typically requires a high (3.3V) signal. This safety feature ensures automatic function activation, like engaging a secondary power panel during microcontroller failures. Handling up to 250V AC and 10A,

100A Power contactor (10A for demonstration purposes)

Figure 9: 4-Pole 230v operated contactor

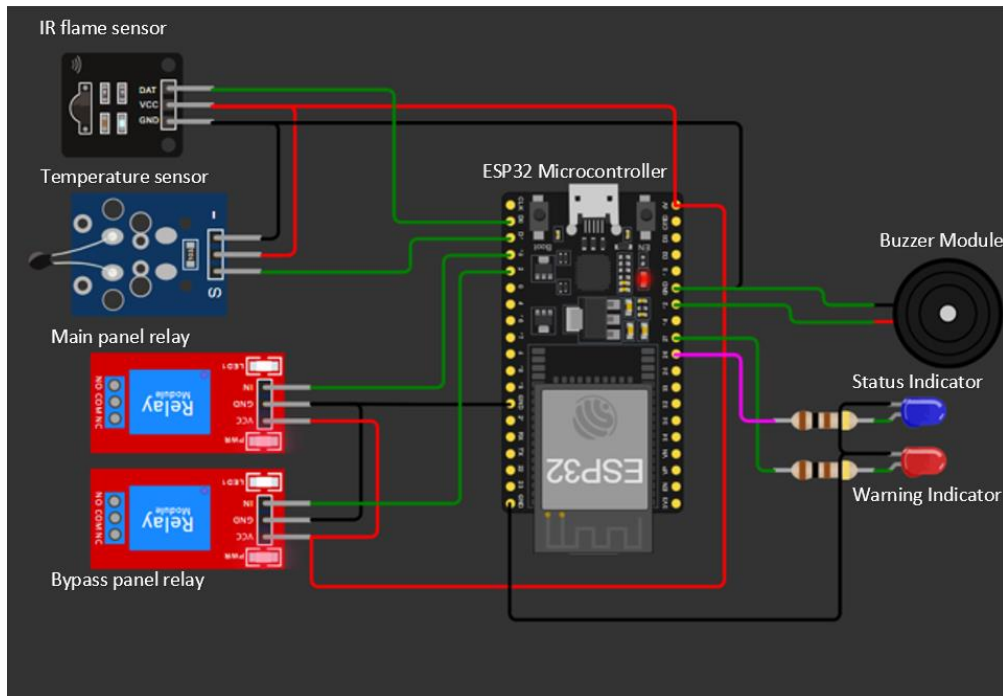


A contactor is an electrical switch essential for industrial applications like motor and power control systems. It handles high voltages, such as 3-phase 415V, and significant currents, differentiating it from relay modules. This project utilizes a contractor to manage the three-phase supply effectively. (Denor, 2022).

Prototype Implementation

This Control Interface diagram emphasizes all the sensor actuators with the connection to the microcontroller unit.

Figure 10: Control interface diagram of the project



Protection Functions

Monitoring Temperature and Fire Hazards

The system monitors for temperature spikes, sparks, and flames. Under normal conditions, both main and bypass relays are OFF, with the Blue LED and buzzer blinking at a 10ms:5000ms ratio to indicate normal operation.

High-Temperature Conditions

When abnormal temperatures are detected, the MCCB remains ON to ensure uninterrupted power. The Red Warning LED blinks (250ms cycle), and an emergency buzzer alerts personnel. Both main and bypass relays stay OFF to avoid unnecessary solenoid relay and power module activation.

Fire Conditions

The IR sensor validates fire detection for 1000ms to avoid false alarms. Confirmed fires activate the bypass relay, switching to an alternative power source and triggering the buzzer. The main panel relay turns ON, causing the MCCB to trip and the solenoid valve to release fire extinguisher gas. The Red Warning LED continues blinking until the system is reset.

Mobile App and Notifications

A mobile app provides real-time monitoring and instant notifications for system states—normal, high temperature, and fire. It displays system status, sends push alerts for high temperatures, and notifies users of fires for quick response. This remote monitoring enhances safety and ensures optimal system performance.

Results and Discussions

Under the Test and analysis, there are three main concerns in this project: the behavior of the system under normal conditions, how the system responds to temperature changes, and how the system responds to fire conditions.

Comparison between three conditions

Figure 11: Comparison between three conditions

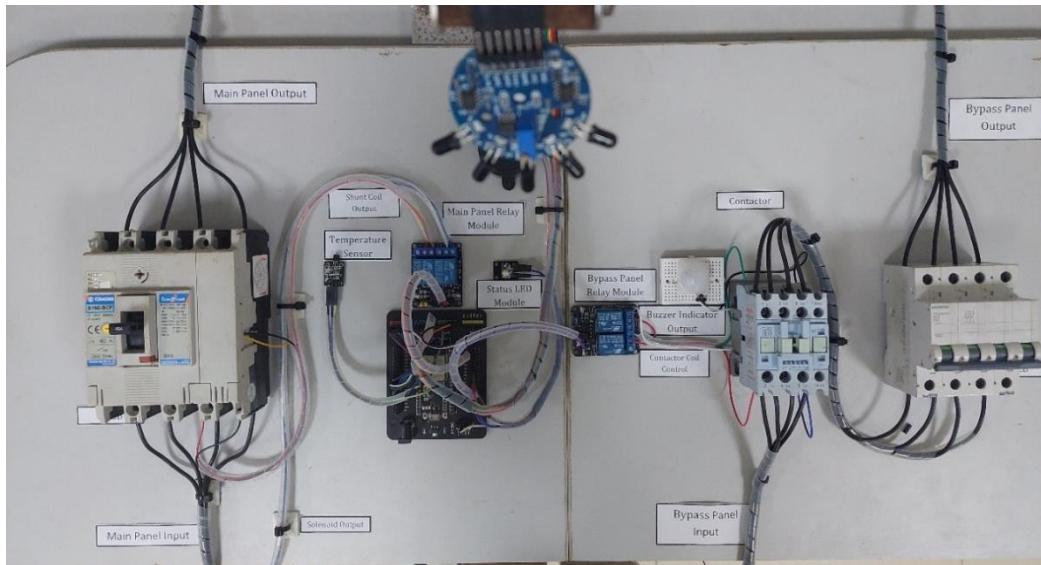
Output	Normal Condition	High Temperature	Fire Detection
Status LED	Blink	OFF	OFF
Warning LED	OFF	Blink	Blink
Emergency Buzzer	OFF	OFF	Blink
Bypass panel relay	OFF	OFF	ON
Bypass contactor	OFF	OFF	ON
Buzzer indicator	OFF	OFF	ON
Main panel relay	OFF	OFF	ON
Shunt coil relay	OFF	OFF	ON
Fire extinguisher relay	OFF	OFF	ON

System Behavior under Normal Conditions

Under normal conditions, the MCCB of the main panel stays on, ensuring continuous power flow. The temperature sensor monitors for changes, while the Status LED blinks briefly, and the emergency buzzer emits periodic tones to confirm proper system operation. All relay modules, including the main and bypass relays, remain inactive, keeping the power contactor and buzzer indicators off, ensuring uninterrupted operation without alerts or interventions.

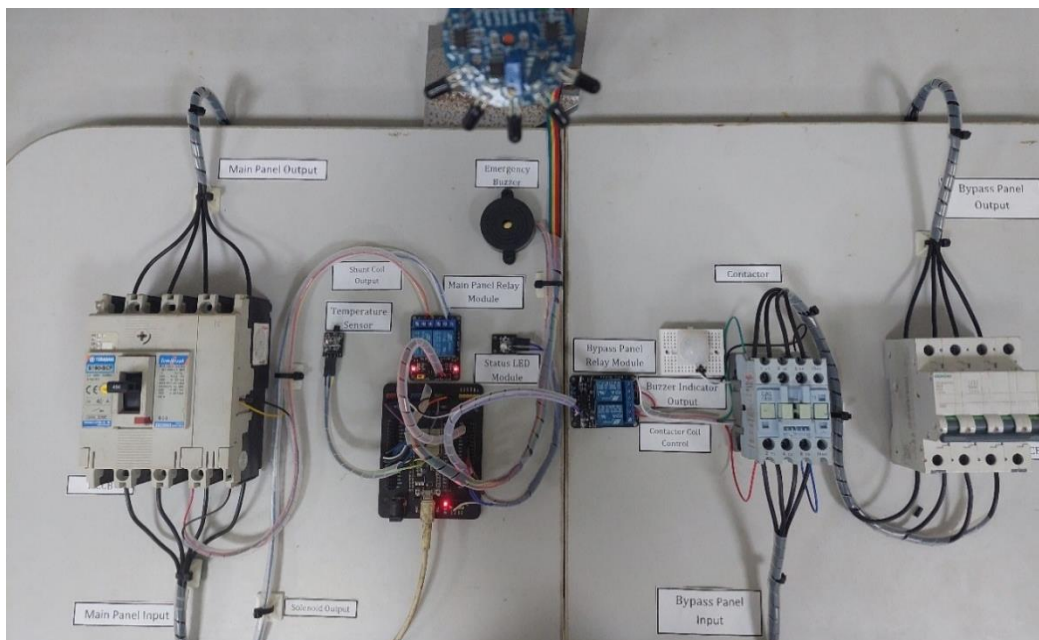
Initial State of the system: Before powering up the system (Figure 12)

Figure 12: Initial State of the prototype



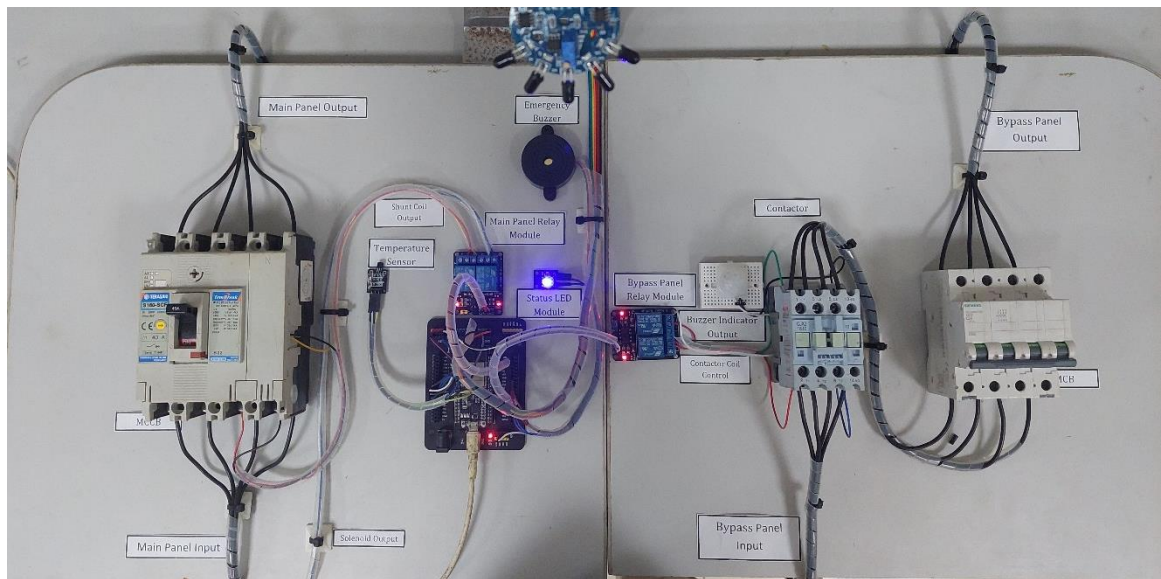
After the system powered up (Figure 13)

Figure 13: Initial state when system powered on



In normal conditions, the Status LED (Blue LED) and Buzzer will Blink. (Figure 14)

Figure 14: Represent the normal condition



The mobile app shows the Normal condition as MCCB ON state, Bypass panel OFF state, and Panel temperature as Green icon, which means the temperature is in normal condition. (Appendix A - Figure 23)

System Behaviors under High-Temperature Situations

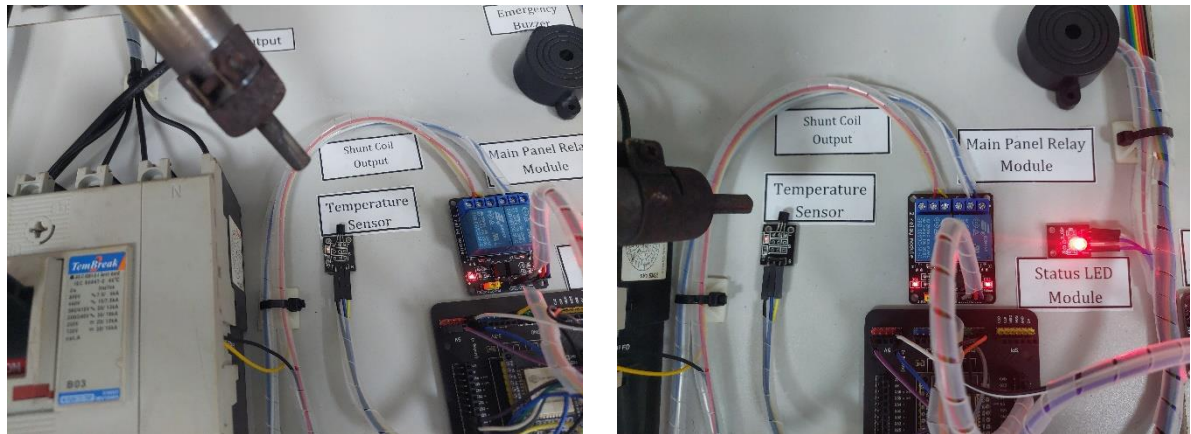
When abnormal temperatures are detected, the MCCB stays ON to maintain power flow. The temperature sensor triggers the Red Warning LED to blink at 250ms intervals and activates the emergency buzzer with alternating 1000 KHz and 2000 KHz tones, alerting personnel. Both main and bypass relays remain OFF, preventing activation of the solenoid relay, power contactor, and buzzer indicators. High temperatures were tested using a DC soldering station's hot air blower (Figure 15).

Figure 15: Using the hot air to simulate the high temperature



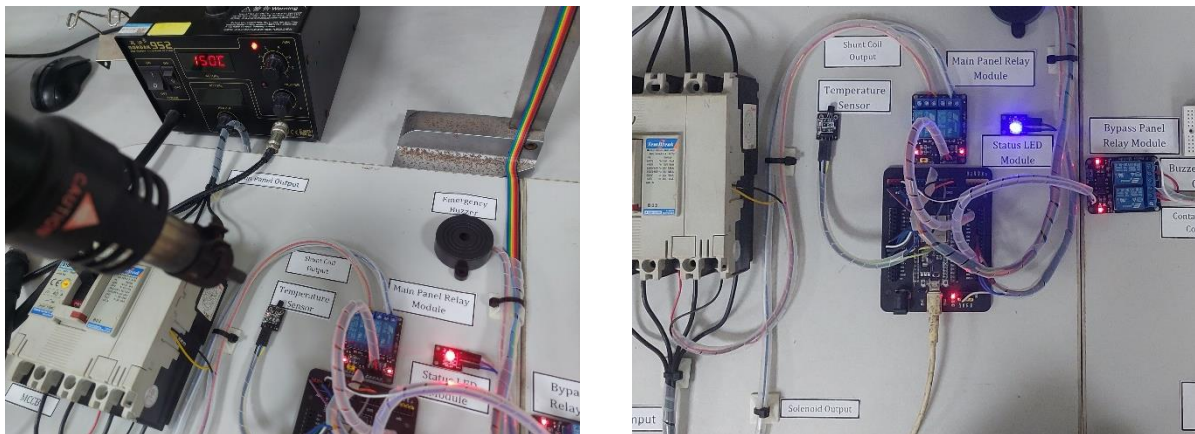
Applying the High temperature to the Temperature sensor (Figure 16) and take back to normal (Figure 17)

Figure 16: System response over high heat



Warning LED returns to normal condition when the heat is removed (Figure 17)

Figure 17: System response when lowering the heat back to normal



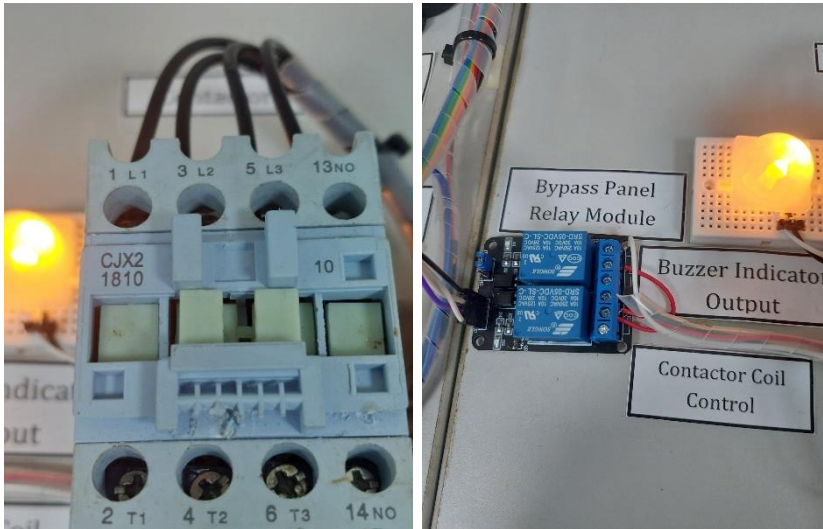
Also, the mobile app shows the High-temperature condition as MCCB ON state, Bypass panel OFF state, and Panel temperature as Red icon, which indicates High temperature (Appendix B - Figure 24).

System behaviors under a Fire situation

When a fire is detected, the IR sensor validates the alert for 1000 ms to avoid false alarms. Once confirmed, the system activates the bypass relay to switch to an alternate power source and triggers the buzzer to alert personnel. Simultaneously, the main panel relay turns ON, tripping the MCCB and releasing fire extinguisher gas via the solenoid valve, cutting power and extinguishing the fire. The

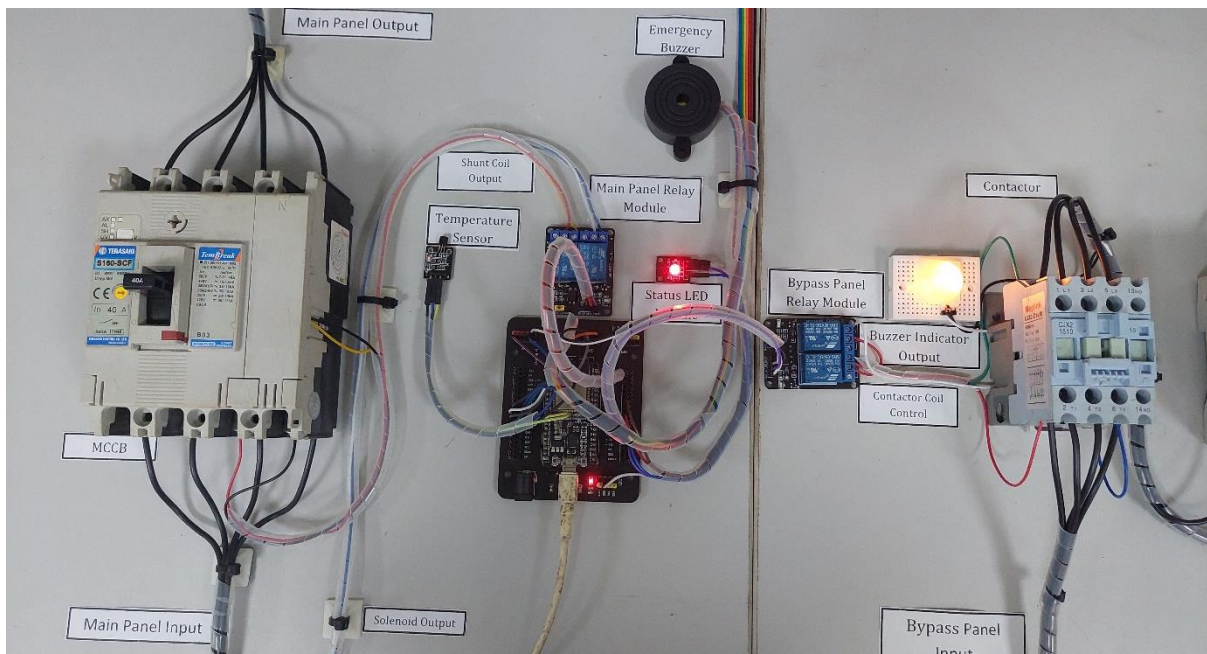
Warning LED blinks until the system is reset. Fire detection was tested successfully using a gas lighter (Figure 19).

Figure 18: Contactor response for the flame detection



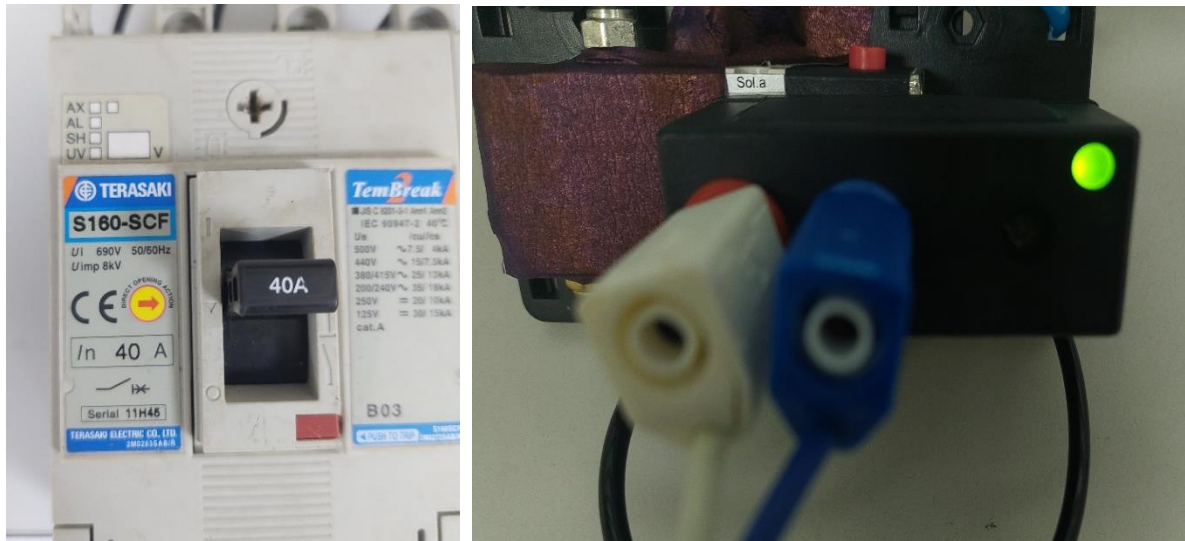
After a 1000ms delay, the Main Panel relay module turned ON while tripping the MCCB and turning ON the Solenoid valve. (Figure 20 and Figure 21)

Figure 19: The System response after a 1000ms delay from the fire detection



In this case, the assumption has been made that when the solenoid is ON, the fire extinguisher gas will be provided to the panel through the Electro-pneumatic valve.

Figure 20: Status of MSSC and Elctro-pneumatic relay after fire detection



The mobile app displays the fire condition as MCCB OFF and Bypass Panel ON. Since the gas lighter used in the demonstration did not raise the temperature above 55°C, the app shows a green icon, indicating normal temperature (Appendix C - Figure 25).

Figure 22: Reaction time for fire suppression



The experiment compared human and prototype reaction times in fire scenarios. While humans initially took 78 seconds, improving to 57 seconds after three attempts, the prototype consistently responded in just three seconds. This demonstrates the system's superior performance and validates its functionality.

Conclusion and recommendations

Conclusion

The study highlights the challenges of suppressing electrical panel fires, which pose severe risks and disrupt operations. Current technologies are insufficient, leading to delays in power restoration and increased costs for industries relying on continuous power.

This project developed a robust solution to minimize risks while maintaining a steady power supply during fire incidents. Using project management principles, the research concluded with an effective fire suppression system ensuring safety and operational continuity.

Recommendations

While the Smart Fire Extinguisher System for electrical panels was successfully developed, several areas for improvement were identified:

Centralized Fire Extinguisher Line: Integrating a centralized extinguisher system could enhance convenience compared to individual units for each panel.

Wireless Communication: Replacing the wired connection for bypass panel signals with NRF24L01 transceivers would allow remote control and greater flexibility.

Enhanced Power Handling: Utilizing motorized MCCBs instead of standard ones could improve system control and manage higher output loads more effectively.

Auto Transfer Switch (ATS): Incorporating an ATS control system in future upgrades would streamline power switching during fire incidents.

Advanced Mobile Dashboard: Upgrading to a paid version of the mobile web dashboard would unlock additional features and support more users.

References

Ajmera, P. (2018). A Review Paper on Infrared Sensor. *International Journal of Engineering Research & Technology*, [online] 5(23). doi:<https://doi.org/10.17577/IJERTCONV5IS23007>.

Ali, W., Ghulam Dustgeer, Muhammad Awais and Munam Ali Shah (2017). IoT based smart home: Security challenges, security requirements and solutions. *IEEE*. [online] doi:<https://doi.org/10.23919/iconac.2017.8082057>.

Asif, O., Mohammad Bellal Hossain, Hasan, M., Mir Toufikur Rahman and Muhammad (2014). Fire-Detectors Review and Design of an Automated, Quick Responsive Fire-Alarm System Based on SMS. *Int'l J. of Communications, Network and System Sciences*, [online] 07(09), pp.386–395. doi:<https://doi.org/10.4236/ijcns.2014.79040>.

Baraneetharan, E. and Selvakumar, G. (2015). Implementation of GSM-Based Automatic Change over System for Electric Generators. *International Journal of Innovative Research in Science, Engineering, and Technology*, [online] 4(6). Available at: https://www.researchgate.net/profile/Baraneetharan-Ethirajan/publication/344138644_Implementation_of_GSM_Based_Automatic_Change_over_System_for_Electric_Generators/links/5f55164492851c250b98b9db/Implementation-of-GSM-Based-Automatic-Change-over-System-for-Electric-Generators.pdf.

Campbell, S. (2015). *Make an Arduino Temperature Sensor (Thermistor Tutorial)*. [online] Circuit Basics. Available at: https://www.circuitbasics.com/arduino-thermistor-temperature-sensor-tutorial/#google_vignette [Accessed 28 Jan. 2024].

Denor (2022). *Electrical Standards For Contactors AC1, AC2, AC3, AC4, DC1, DC2 DC3 – Denor – Modular Contactor Manufacturer*. [online] Denor.com. Available at: <https://denor.com/electrical-standards-for-contactors-ac1-ac2-ac3-ac4-dc1-dc2-dc3.html> [Accessed 13 Jan 2024].

Devasia, A. (2022). *Specialized Fire Detection Systems - Vanguard Fire and Security*. [online] Vanguard. Available at: <https://vanguard-fire.com/specialized-fire-detection/> [Accessed 6 Jan. 2024].

Diarah, R., C.O. Osueke, Adekunle, A., Adebayo, S., Adedayo Banji Aaron and Olaluyi Olawale Joshua (2023a). Types of Temperature Sensors. *IntechOpen eBooks*. [online] doi:<https://doi.org/10.5772/intechopen.110648>.

Diarah, R., C.O. Osueke, Adekunle, A., Adebayo, S., Adedayo Banji Aaron and Olaluyi Olawale Joshua (2023b). Types of Temperature Sensors. *IntechOpen eBooks*. [online] doi:<https://doi.org/10.5772/intechopen.110648>.

Edworthy, J. (2016). *Improving Auditory Warning Design: Relationship between Warning Sound Parameters and Perceived Urgency - Judy Edworthy, Sarah Loxley, Ian Dennis, 1991*. [online] Human Factors. Available at: <https://journals.sagepub.com/doi/abs/10.1177/001872089103300206> [Accessed 11 Jan. 2024].

Eko Premunanto, Muhtadin Muhtadin and Febrian, W. (2019). Integrated Smart Safety Home System based on Wireless Sensor Network and Internet of Things as Emergency Preventive Efforts in Settlement Areas. [online] doi:<https://doi.org/10.1109/cenim48368.2019.8973328>.

Fire Statistics of 2020 and Case Studies on Fire Incidents MAJ Md Faizal bin Mazlan Senior Fire Investigator Fire Investigation Unit. (n.d.). Available at: https://www.scdf.gov.sg/docs/default-source/scdf-library/fssd-downloads/fsm/fsm-briefing-slides/fsm-briefing-2021/fsm-briefing-2021_fire-statistics-of-2020-and-case-studies-on-fire-incidents.pdf.

Fire Statistics of 2020 and Case Studies on Fire Incidents MAJ Md Faizal bin Mazlan Senior Fire Investigator Fire Investigation Unit. (n.d.). Available at: https://www.scdf.gov.sg/docs/default-source/scdf-library/fssd-downloads/fsm/fsm-briefing-slides/fsm-briefing-2021/fsm-briefing-2021_fire-statistics-of-2020-and-case-studies-on-fire-incidents.pdf.

- Gigi (2021). *What is an AMG8833? Features and Demo - Latest Open Tech From Seeed*. [online] Latest Open Tech From Seeed. Available at: <https://www.seeedstudio.com/blog/2021/01/29/what-is-an-amg8833-features-and-demo/> [Accessed 28 Jan. 2024].
- Guedes, M., Junior, César, B., Charlie Salvador Gonçalves and Marcos (2023). Fire Detection System for Urban Structures with Integrated Use of Multisensors in Embodied Technology. *RGSA*, [online] 18(2), pp.e04202–e04202. Doi:<https://doi.org/10.24857/rgsa.v18n2-028>.
- Gunasekera, M.Y. and A.A.P. de Alwis (2008a). Process industry accidents in Sri Lanka: Analysis and basic lessons learned. *Process Safety and Environmental Protection*, [online] 86(6), pp.421–426. doi:<https://doi.org/10.1016/j.psep.2008.05.002>.
- Gunasekera, M.Y. and A.A.P. de Alwis (2008b). Process industry accidents in Sri Lanka: Analysis and basic lessons learned. *Process Safety and Environmental Protection*, [online] 86(6), pp.421–426. doi:<https://doi.org/10.1016/j.psep.2008.05.002>.
- Jason, P. and Karl, J. (2019). A Wireless Sensor Network for Fire Detection and Alarm System. [online] doi:<https://doi.org/10.1109/icoict.2019.8835265>.
- Khan, F., Xu, Z., Sun, J., Fazal Maula Khan, Ahmed, A. and Zhao, Y. (2022). Recent Advances in Sensors for Fire Detection. *Sensors*, [online] 22(9), pp.3310–3310. doi:<https://doi.org/10.3390/s22093310>.
- Muhammed Fatih Pekşen, Ulaş Yurtsever and Yılmaz Uyaroğlu (2024). Enhancing electrical panel anomaly detection for predictive maintenance with machine learning and IoT. *Alexandria Engineering Journal /Alexandria Engineering Journal*, [online] 96, pp.112–123. doi:<https://doi.org/10.1016/j.aej.2024.03.106>.
- Ochiai, Y., Takemura, K., Ikeda, A., Takamatsu, J. and Ogasawara, T. (2014). Remote control system for multiple mobile robots using touch panel interface and autonomous mobility. [online] doi:<https://doi.org/10.1109/iros.2014.6943017>.
- Oh, K. and Lee, W. (2016). *A Study on the Calibration Technique of RTD and Thermocouple System*. [online] ResearchGate. Available at: https://www.researchgate.net/publication/317278138_A_Study_on_the_Calibration_Technique_of_RTD_and_Thermocouple_System [Accessed 18 Feb 2024].
- Pan, S. and Kofi A.A. Makinwa (2022). *Resistor-based Temperature Sensors in CMOS Technology*. Springer Nature.
- Pang, B., Kristof T'Jonck, Claeys, T., Davy Pissoort, Hallez, H. and Jeroen Boydens (2021). Bluetooth Low Energy Interference Awareness Scheme and Improved Channel Selection Algorithm for Connection Robustness. *Sensors*, [online] 21(7), pp.2257–2257. doi:<https://doi.org/10.3390/s21072257>.

- Real-time environmental monitoring, visualization, and notification system for construction H&S management: LSBU Open Research. (2014). *Lsbu.ac.uk*. [online]
doi:https://openresearch.lsbu.ac.uk/download/db0bda18ca7062e9e642fb566299e4dbdf95154e4998547df1cf886c2bace048/1190920/2014_4.content.00814.pdf.
- Rehman, A., Masood, N., Arif, S., Shahbaz, U., Sarwar, F., Maqsood, K., Imran, A. and Pasha, M. (2012). Autonomous fire extinguishing system. [online]
doi:<https://doi.org/10.1109/icrai.2012.6413387>.
- Safe and Sound Security. (2023). *Infrared Sensor: What is it & How does it work?* [online] Available at: <https://getsafeandsound.com/blog/infrared-sensor/> [Accessed 6 Jan. 2024].
- Sahid, D. and Mudrik Alaydrus (2020). Multi-Sensor Fire Detection in Low Voltage Electrical Panel Using Modular Fuzzy Logic. [online] doi:<https://doi.org/10.1109/bcwsp50066.2020.9249400>.
- Wang, J., Sepehr Roudini, Hyer, E.J., Xu, X., Zhou, M., Lorena Castro Garcia, Reid, J.S., Peterson, D.A. and Silva (2020). Detecting nighttime fire combustion phase by hybrid application of visible and infrared radiation from Suomi NPP VIIRS. *Remote sensing of environment*, [online] 237, pp.111466–111466. doi:<https://doi.org/10.1016/j.rse.2019.111466>.
- Zhang, F., Li, M., Liang, P., Zhang, K., and Chou, Y. (2012). The design and implementation of an intelligent inspection robot system using combined flame sensors and infrared sensors. [online]
doi:<https://doi.org/10.1109/msna.2012.6324572>.
- Zhao, G., Xu, G., Jin, S., Zhang, Q., and Liu, Z. (2019). Fire-Extinguishing Efficiency of Superfine Powders under Different Injection Pressures. *International journal of chemical engineering*, [online] 2019, pp.1–7. doi:<https://doi.org/10.1155/2019/2474370>.
- Zhou, B., Li, W., Ka Wing Chan, Cao, Y., Kuang, Y., Liu, X. and Wang, X. (2016). Smart home energy management systems: Concept, configurations, and scheduling strategies. *Renewable & Sustainable Energy Reviews*, [online] 61, pp.30–40. doi:<https://doi.org/10.1016/j.rser.2016.03.047>

Appendix

Appendix A - Mobile application interface for normal condition

Appendix B - Mobile app response when detecting High-temperature conditions

Appendix C - Mobile app response when detecting Fire conditions

Appendix A

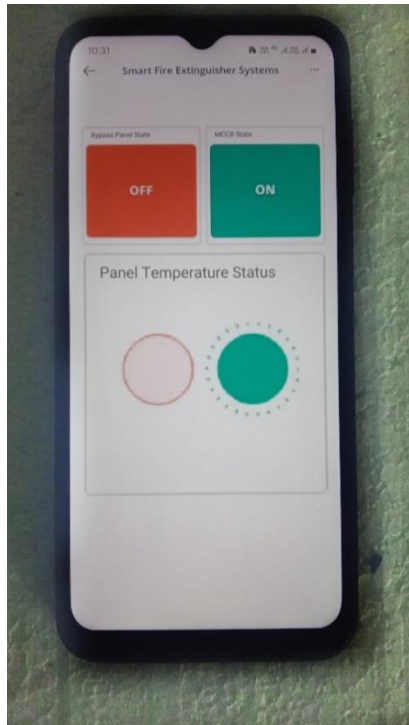


Figure 23: MCCB is ON
and Panel Temperature is
Normal

Appendix B

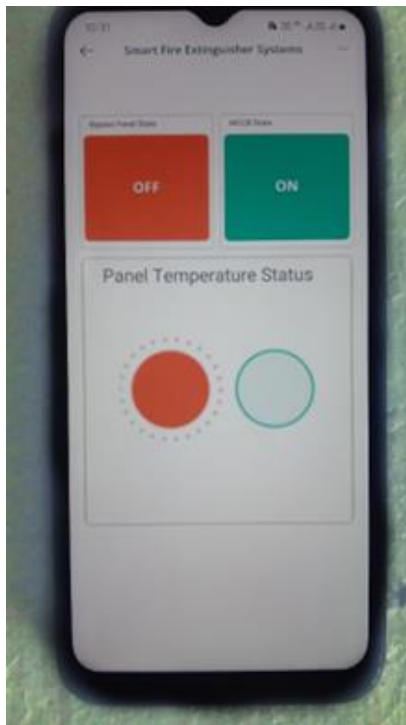


Figure 24: MCCB is ON,
and Panel Temperature is
Abnormal

Appendix C

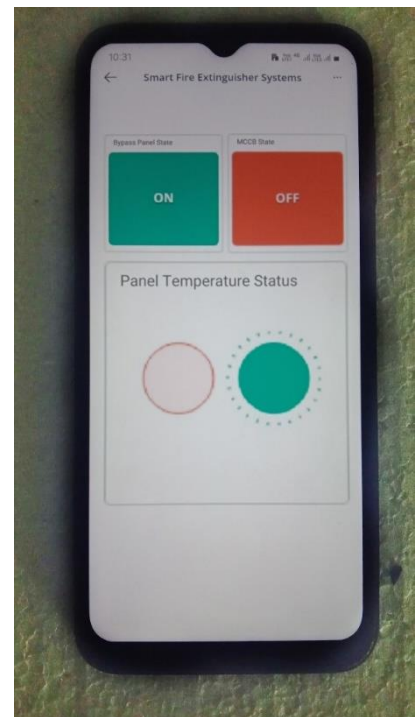


Figure 25: MCCB is OFF,
Bypass Panel activated

MULTIFUNCTIONAL COMMUNICATION SYSTEM FOR VISUALLY AND HEARING IMPAIRED PERSONS

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Abstract

Millions worldwide face hearing and visual impairments, often leading to social isolation due to barriers in communication, education, and employment. Approximately 2.2 billion people experience some form of visual impairment (World Health Organization, 2023), while an estimated 1.5 billion individuals live with hearing loss (AccessiblyApp, 2023). This study proposes a real-time multifunctional communication system for visually and hearing-impaired individuals, converting input messages into text, Braille, and speech outputs to foster inclusivity. In Sri Lanka, where educational institutions struggle to support children with special needs, the project emphasizes enhancing care facilities and schools within financial and technological constraints.

The primary objective is to develop a hand gesture recognition system using American Sign Language (ASL) as the core communication medium, paired with a Braille input/output mechanism akin to the Mountbatten Brailier. The project entails a comprehensive literature review, design, and testing of prototypes addressing societal communication gaps.

Despite challenges like training, high costs, and gesture complexity, this initiative holds promise for improving the quality of life for the visually and hearing impaired in Sri Lanka and beyond.

Keywords: Sign Language, Braille, Hand Gestures, Neural Networks

Introduction

Rationale of the topic

The combination of hearing and visual disabilities known as deaf blindness severely restricts socialization, employment opportunities, education, and independence. Muteness is a disability that prevents someone from speaking, while deafness is a disability that affects hearing and renders a person unable to hear. As of 2020, over 1.5 billion people worldwide (nearly 20% of the global population) experience some degree of hearing loss, with approximately 430 million having disabling hearing loss; this number is projected to exceed 700 million by 2050 (WHO, 2021). An estimated 49.1 million people are blind (0.62% of the global population), while 221.4 million have moderate vision impairment (2.81%) and 33.6 million have severe vision impairment (0.43%) (Bourne et al., 2021). Additionally, deafblindness—a combination of hearing and visual impairments—affects between 0.2% and 2% of the global population, often leading to higher rates of poverty, unemployment, and lower educational outcomes (WFDB, 2018). Because the available technology is so limited, the majority of the deaf-blind

community is compelled to live alone or with minimal opportunities. Scientific advancements often fail to provide comfort for deaf-blind individuals, leading to their lack of benefits, especially in Sri Lanka. They struggle to communicate effectively with those unaware of sign language, often underestimated unless close to hearing, visual, or speaking disabilities.

The project aims to improve communication between disabled people in Sri Lanka. It will use a device to accept input messages from different abled senders and transform them based on their needs. The outputs will include a textual display for the individuals who are able to see, and a tactile Braille plate for both vision and hearing individuals. The project aims to address the issue of special need students being isolated from society, and while recent studies on wearable and non-wearable devices have laid the groundwork for development, no evidence suggests commercialization. Here a proper literature survey is conducted to identify the Sign and Braille languages. Also, the different techniques used to recognize those languages and the methods to implement those in real life scenarios. Individuals with disabilities, such as blindness, deafness, and muteness, face significant communication challenges due to the general public's limited awareness and use of sign language and Braille.

As a result, the visually and hearing impaired community often finds itself confined to specific groups, restricting their opportunities and social interactions. To address this issue, three conceptual designs were evaluated to determine the most effective solution, leading to the implementation of both hardware and software, followed by testing and analysis. The proposed approach integrates sign language recognition with Braille using advanced technologies like Raspberry Pi and machine learning, offering an innovative communication bridge. By breaking down barriers and enhancing accessibility, this solution has the potential to significantly improve the quality of life for individuals with hearing and vision impairments, fostering greater inclusion in society.

Methodology

This prototype is designed to assist individuals with visual and hearing impairments by supporting multiple input and output modes. It processes hand gestures via a trained model using a camera and converts Braille inputs into text. The outputs include a textual display for visually abled users, and a tactile Braille plate for those with dual impairments. Users can select their preferred output, with options to choose multiple outputs simultaneously.

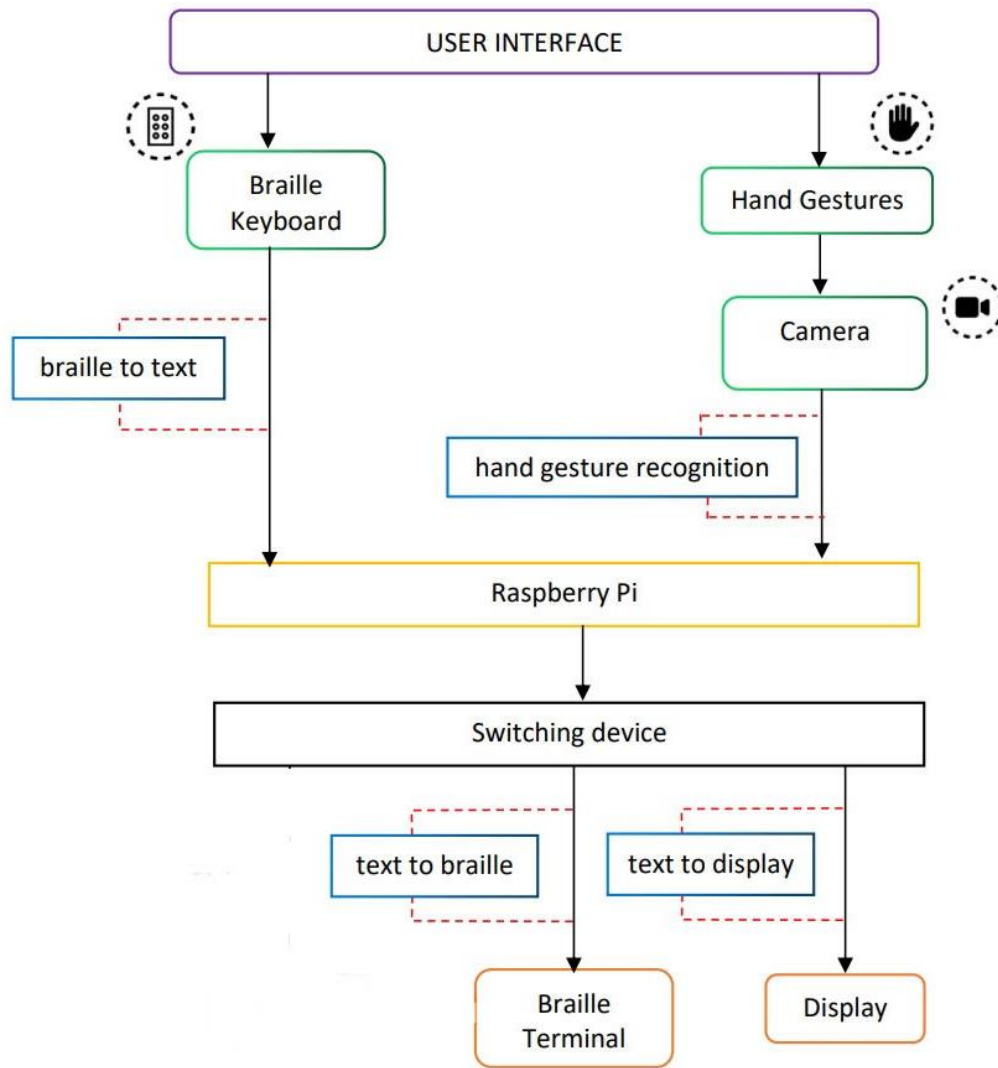


Figure 1: Block Diagram of the Proposed Design

Hardware Implementation

The hardware implementation integrates components like Raspberry Pi 4, an LCD display, a webcam, a Braille keypad, and other accessories.

Braille Input

A simulation for the Braille input keyboard was first designed using Proteus. The setup includes a Raspberry Pi and an LCD on the left, with a common power supply and switch box on the right. Six push buttons on the Braille keyboard are connected to the GPIO pins (GPIO5, GPIO6, GPIO12, GPIO13, GPIO24, and GPIO25) of the Raspberry Pi, which serves as the microcontroller for input and output data transmission.

Braille Output

The Braille input keyboard enables visually impaired users to read the text output on both an LCD screen and a Braille output terminal. Solenoids, specifically 12VDC Push-Pull solenoids, are used to produce tactile Braille dots for the user to touch. In the prototype, this process is demonstrated using six LED bulbs instead of solenoids.

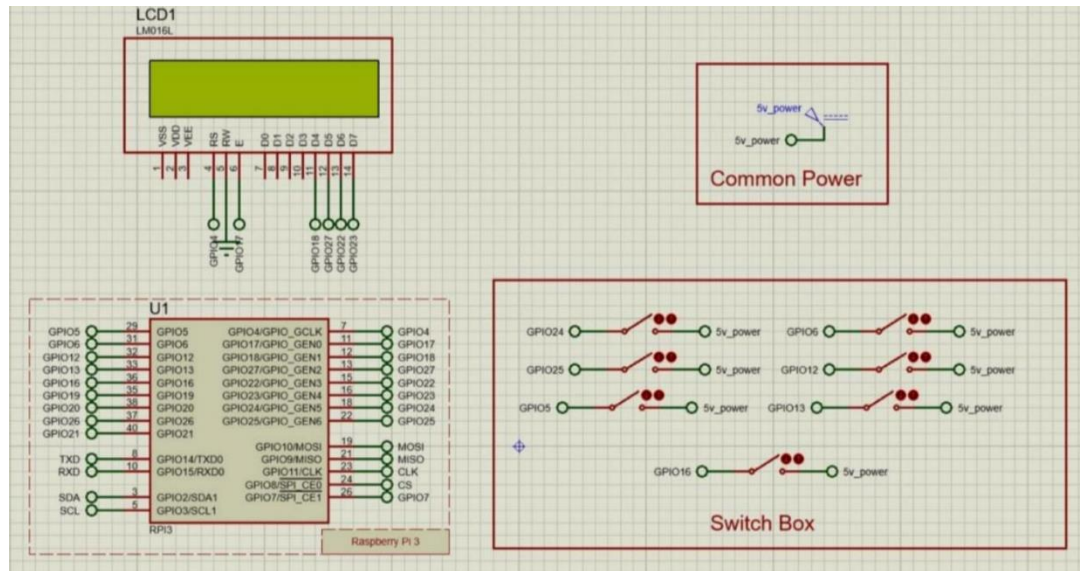


Figure 2: Simulation Design

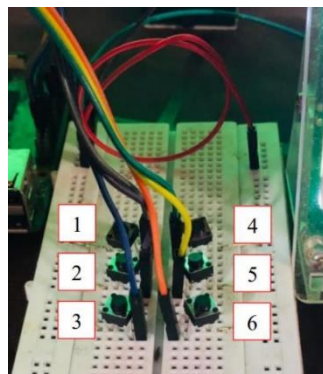


Figure 3: Push Button Connection

Software Implementation

The software development utilizes Python and Proteus for processing and simulation.

Hand Gesture Recognition

The Hand Gesture Recognition process is divided into three stages:

1. Data collection and storage in directories.
2. Model training.
3. Live hand gesture prediction for real-time recognition.

These components work together to create a versatile communication system for users with visual and hearing impairments.

The process of collecting, training, and predicting hand gestures for a recognition system involves several key steps. First, data is gathered through a webcam using OpenCV's `cv2.VideoCapture()` method, where images of hand gestures are captured and processed. These images are pre-processed by flipping, resizing, and converting them to grayscale, followed by thresholding to enhance the distinction between the object and background. A dictionary is used to store the captured images in folders for each class, and relevant key bindings are assigned to capture data when specific keys are pressed.

For model training, TensorFlow and Keras are employed to develop a Convolutional Neural Network (CNN) using the Sequential model. The CNN consists of convolution, pooling, flattening, and fully connected layers. Key components include ReLU and Softmax activation functions, with max-pooling applied to reduce image size. The model is compiled with the Adam optimizer and categorical crossentropy loss function for multiclass classification. Image augmentation is used to prevent overfitting, and the trained model is saved in JSON format.

In real-time prediction, the trained model is imported and used with `predict()` to classify incoming hand gestures, mapping the gesture data to predicted labels. This system allows for dynamic, live recognition of hand gestures with a focus on efficiency and accuracy.

Three conceptual designs were thoroughly analyzed and evaluated before finalizing and implementing the proposed design.

Braille Software Implementation

The Braille software implementation for the Raspberry Pi involves configuring GPIO pins to manage inputs from switches and control an LCD display. The "import time" library adds delays, while "import RPi.GPIO as GPIO" enables access to the GPIO pins. The Raspberry Pi is set to board mode to prevent pin reuse, and timing constants are used to control pulse timing. The GPIO pins for the LCD (LCD_E, LCD_RS, LCD_D4-D7) and switches are configured, with the LCD displaying data formatted based on predefined constants.

The program checks the bits in an 8-bit binary variable to determine which LCD data lines to activate. The LCD's enable pin is toggled using the `lcd_toggle_enable()` method, ensuring data is processed correctly. The switch states are read every 0.2 seconds to stabilize against electrical noise, with switch combinations corresponding to Braille patterns for letters (a-z) and numbers (0-9). These patterns are associated with switch states through conditional statements, allowing the system to convert Braille inputs into readable text. This method ensures accurate handling of Braille inputs for users.

Results and Discussion

The prediction window for live gestures associated with the letters A, and B are displayed in the given figures respectively. When a gesture is made inside the ROI, the model will predict it. The anticipated

motion is shown in real time on the frame. The number in red is the 3 second timer where if the person holds the gesture for 3 seconds the programme considers it and locks it to create a word.

The user has to choose the desired output method after turning on the device. The toggle switches are available for choosing the preferred output method, braille, and display output.

The results for trained datasets of hand gestures were displayed on the LCD screen and live prediction screen during dataset testing. The Braille input, provided through push buttons, was displayed using 6 LEDs in this device instead of solenoids in the prototype. Additionally, the letters recognized by the camera were also shown on the display.

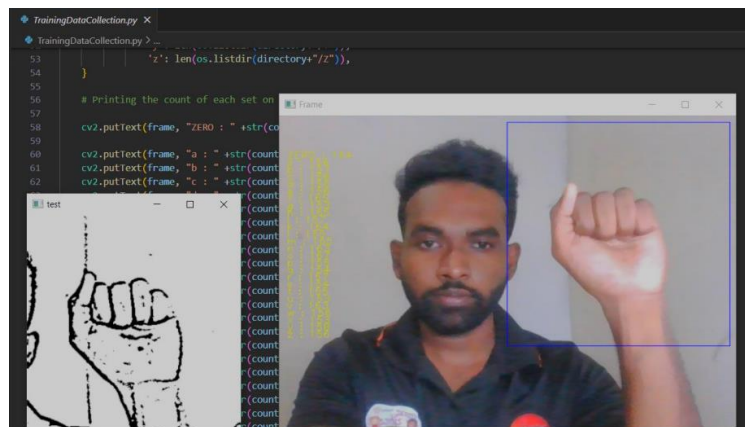


Figure 4: Capturing Training Dataset for letter “A”

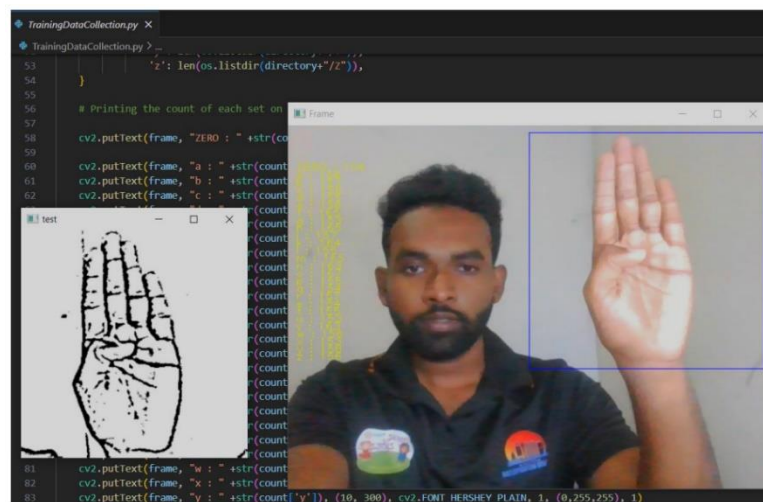


Figure 5: Capturing Training Dataset for letter “B”



Figure 6: Predicting the live gesture for letter “A”

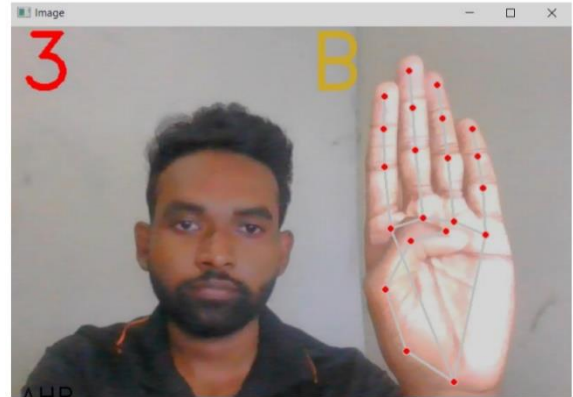


Figure 7: Predicting the live gesture for letter “B”



Figure 8: Switches of the Outputs



Figure 9: Device Turned ON



Figure 10: Braille Input and Display Output for Letter 'a'



Figure 11: Braille Input and Display Output for Letter 'b'

Conclusion

This project aimed to develop a prototype combining hand gesture recognition (HGR) and Braille inputs to enhance communication for the visually and hearing impaired. The system processes hand gestures and Braille inputs, delivering outputs visually on an LCD display, and via a Braille terminal. Machine learning techniques for HGR were explored, involving data collection, preprocessing, model development, and analysis. Research on Braille grades and input-output methods also shaped the design.

Challenges included the high computational demands of training models, leading to the use of low-power neural networks. Some datasets were unsuitable, requiring new datasets for gesture recognition. Due to the high cost and unavailability of solenoids, the Braille terminal was demonstrated using LEDs. Similar patterns for numbers and letters in Braille necessitated the use of a switch for differentiation.

Despite these challenges, the project met its objectives, offering a cost-effective solution to bridge communication gaps for Sri Lanka's impaired communities. While limitations such as gesture recognition accuracy, training requirements, and high initial costs remain, the prototype demonstrates significant potential to improve the quality of life for hearing and visually impaired populations both locally and globally.

To improve gesture recognition, advanced computer vision techniques and efficient model training methods like transfer learning should be explored. Incorporating haptic feedback and enabling multiple-user recognition will enhance interaction. Integration of virtual assistants like Siri or Google Assistant can further support users. For visually impaired individuals, a speaker for voice output will make message delivery easier. The system should support multiple languages, including regional sign languages, as well as English, Chinese, French, and Spanish. Finally, accessibility audits and user testing will ensure compliance with industry standards, improving inclusivity and usability for diverse users.

References

- ActiveState (n.d.). *How to use a model to do predictions with Keras*. [online] ActiveState. Available at: <https://www.activestate.com/resources/quick-reads/how-to-use-a-model-to-do-predictions-with-keras/>.
- Bourne, R.R.A., Adelson, J., Flaxman, S., Briant, P., Bottone, M., Vos, T., Naidoo, K., Braithwaite, T., Cicinelli, M., Jonas, J., Limburg, H., Resnikoff, S., Silvester, A., Nangia, V. and Taylor, H.R. (2020). Global Prevalence of Blindness and Distance and Near Vision Impairment in 2020: progress towards the Vision 2020 targets and what the future holds. *Investigative Ophthalmology & Visual Science*, [online] 61(7), pp.2317–2317. Available at: <https://iovs.arvojournals.org/article.aspx?articleid=2767477> [Accessed 15 Aug. 2023].
- Buyuksahin, U. (2014). *Vision-Based Sensor Technologies – Webcam: A Multifunction Sensor*. [online] Elsevier, pp.375–392. doi:<https://doi.org/10.1016/B978-0-08-096532-1.01314-5>.

Cheok, M.J., Omar, Z. and Jaward, M.H. (2017). A review of hand gesture and sign language recognition techniques. *International Journal of Machine Learning and Cybernetics*, 10(1), pp.131–153. doi:<https://doi.org/10.1007/s13042-017-0705-5>.

Egmont-Petersen, M., de Ridder, D. and Handels, H. (2002). Image processing with neural networks—a review. *Pattern Recognition*, 35(10), pp.2279–2301. doi:[https://doi.org/10.1016/s0031-3203\(01\)00178-9](https://doi.org/10.1016/s0031-3203(01)00178-9).

Herazo, J. (n.d.). *Sign language recognition using Deep Learning*. [online] Medium. Available at: <https://towardsdatascience.com/sign-language-recognition-using-deep-learning6549268c60bd> [Accessed 14 Aug. 2023].

IBM Cloud Education (2020). *What are Convolutional Neural Networks?* [online] [www.ibm.com](https://www.ibm.com/cloud/learn/convolutional-neural-networks). Available at: <https://www.ibm.com/cloud/learn/convolutional-neural-networks> [Accessed 15 Aug. 2023].

Islam, Md.M., Siddiqua, S. and Afnan, J. (2017). *Real time Hand Gesture Recognition using different algorithms based on American Sign Language*. [online] IEEE Xplore. doi:<https://doi.org/10.1109/ICIVPR.2017.7890854>.

Leading Accessibility Widget for ADA & WCAG Compliance - Accessibly (2024) Accessibly. Available at: <https://accessiblyapp.com/blog/most-common-disabilities-world> [Accessed 17 August 2023].

Mašić, V. (2020). Neuroplasticity and Braille Reading. *Acta Clinica Croatica*, 59. doi:<https://doi.org/10.20471/acc.2020.59.01.18>.

National Institute on Deafness and Other Communication Disorders (2019). *American sign language*. [online] NIDCD. Available at: <https://www.nidcd.nih.gov/health/american-sign-language> [Accessed 15 Aug. 2023].

Nithyakalyani.K, S.Ramkumar and K.Manikandan (2020). Design And Implementation Of Sign Language Translator Using Microtouch Sensor. *INTERNATIONAL JOURNAL OF SCIENTIFIC & TECHNOLOGY RESEARCH*, [online] 9(01), pp.1784–1786. Available at: <https://www.ijstr.org/final-print/jan2020/Design-And-Implementation-Of-Sign-Language-Translator-Using-Microtouch-Sensor.pdf> [Accessed 11 Sep. 2023].

P. H. Zope and Harshal Dahake (2016). Design and Implementation of Messaging System Using Braille Code for Virtually Impaired Persons. *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering*, [online] 05(07), pp.5977–5984. Available at: https://www.ijareeie.com/upload/2016/july/23_Design.pdf [Accessed 11 Sep. 2023].

Tao, W., Lai, Z.-H., Leu, M.C. and Yin, Z. (2018). American Sign Language Alphabet Recognition Using Leap Motion Controller. *Proceedings of the 2018 IISE Annual Conference*. [online] Available at: https://www.researchgate.net/publication/328135237_American_Sign_Language_Alphabet_ [Accessed 15 Aug. 2023].

TensorFlow. (n.d.). *The Sequential model | TensorFlow Core*. [online] Available at: https://www.tensorflow.org/guide/keras/sequential_model [Accessed 20 Aug. 2023].

Versloot, C. (2022). *Machine learning articles*. [online] GitHub. Available at: <https://github.com/christianversloot/machine-learning-articles/blob/main/how-to-predict-new-samples-with-your-keras-model.md> [Accessed 23 Aug. 2023].

Vision Impairment and blindness (no date) World Health Organization. Available at: <https://www.who.int/news-room/fact-sheets/detail/blindness-and-visual-impairment> [Accessed: 17 August 2023].

Wfdb.eu. (2018). Deafblindness in the World – WFDB. [online] Available at: <https://wfdb.eu/deafblindness-in-the-world/> [Accessed 16 Aug. 2023].

World (2019). Deafness and hearing loss. [online] Who.int. Available at: <https://www.who.int/health-topics/hearing-loss?> [Accessed 15 Aug. 2023].

CONTROL SYSTEM FOR ALCOHOL-BASED VEHICLE HAZARDS

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Abstract

Road accidents have increased significantly in recent years, with drunk driving being a major contributing factor. A 2022 study by BMC Public Health in Sri Lanka (L. Scholin, 2022) revealed that 35.9% of alcohol-related injuries occurred due to drunk driving. The study involved 2,526 patients and employed AUDIT interviews and breathalyzer tests, highlighting a strong link between alcohol consumption and road injuries. Supporting this, a Sri Lankan news archive (Sahan, 2024) reported over 20,728 fatalities in road accidents over seven and a half years, with 223,451 accidents linked to alcohol-induced unsafe driving. To address this issue, implementing sensors to detect alcohol levels in drivers and prevent vehicle engines from starting is crucial. This approach could significantly enhance safety for both drivers and pedestrians, reducing the risk of accidents.

Keywords: Heart Rate (HR), Ignition Interlock System, Mental Stability Test, MQ-3

Introduction

Now a days, many accidents happen because of the alcohol consumption of the driver. Thus, drunk driving is a major cause of accidents in almost all countries all over the world. Drunken drivers will not be in stable condition and so the rash driving is the inconvenience for other road users and question of life and death for the drunken drivers, also for others. The Alcohol detector in Car project with auto lock system is designed for the safety of the people sitting inside the car. The input for the system is from detection sensors either from alcohol breath or any other mechanism. The controller keeps looking for the output from these sensors. If there are any traces of alcohol above the set limit, then the system will lock the engine. Most of the traditional systems are likely to be more dependent on the operator and it may fail due to various factors like battery life, power consumption as well as the unavoidable external disturbances. If there are any traces of Alcohol above the set limit, then the system will lock the Engine at the same time will automatically give a buzzer we can avoid accidents by checking the driving people on the roads. Given the increasing complexities of modern society, this type of innovation is indispensable for ensuring road safety

Methodology

This project introduces a prototype control system to prevent alcohol-impaired driving. The ESP32 microcontroller serves as the system's core, processing sensor data to assess driver fitness before allowing vehicle operation.

An ignition interlock mechanism prevents the vehicle from starting if alcohol consumption is detected. An MQ-3 alcohol sensor, placed near the steering wheel, measures breath alcohol concentration. Its analog signal is converted via the ESP32's ADC, compared against a threshold, and if exceeded, a relay disables the ignition, preventing the vehicle from starting.

Additionally, a heart rate sensor monitors the driver's pulse upon entry. The system filters data to detect anomalies, such as irregular heart rates, which may indicate stress or intoxication. To further assess cognitive stability, a mental alertness test requires the driver to solve simple math problems. Response time and accuracy are analyzed against a predefined threshold. If all safety conditions are met, the ignition is enabled; otherwise, the driver must wait.

Figure 1: Conceptual Design of the System

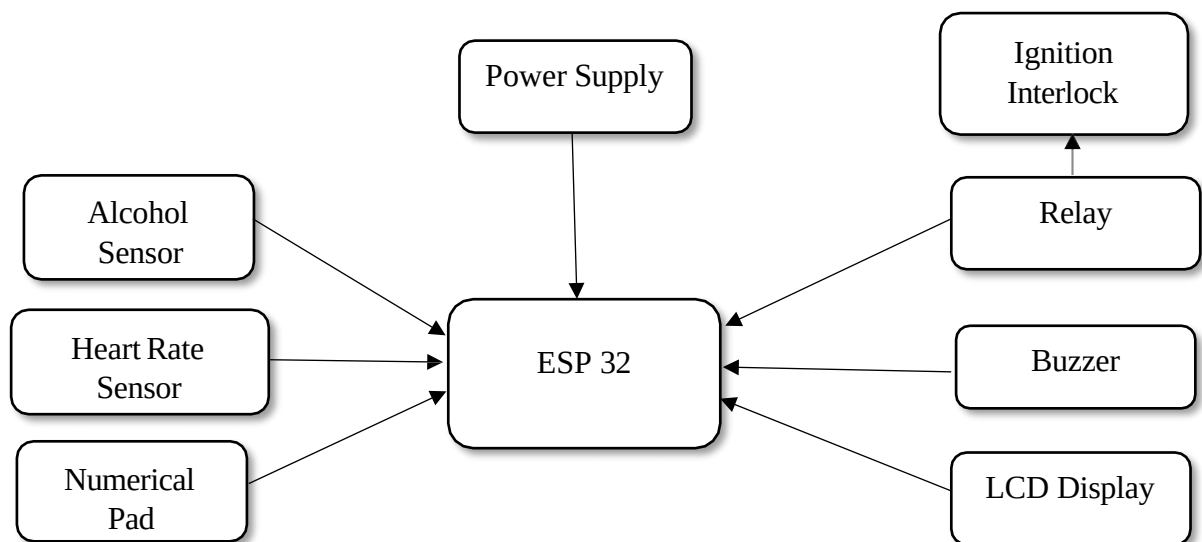


Figure 2: Schematic Diagram of the System

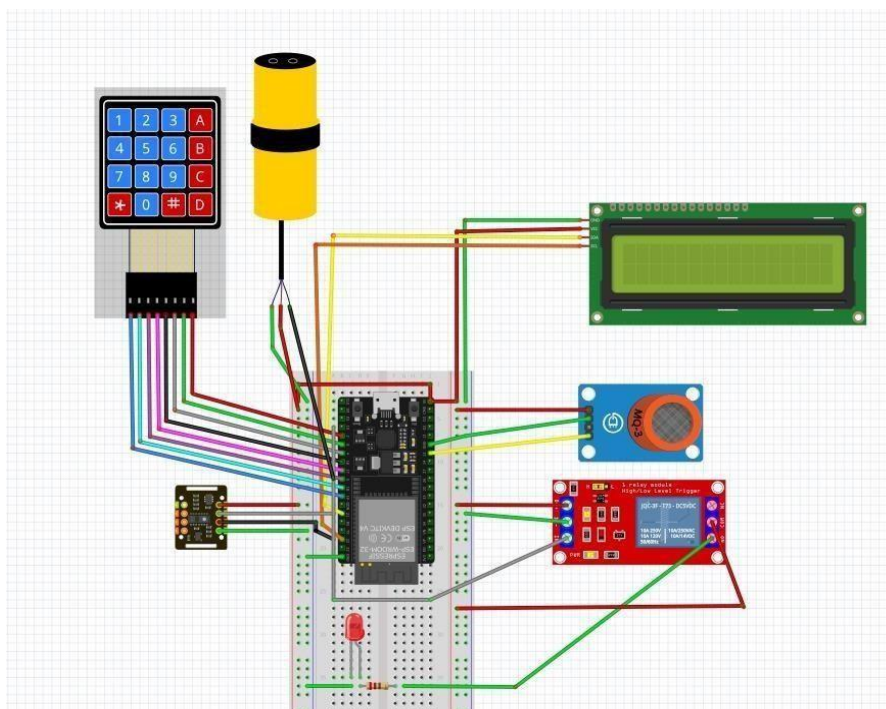
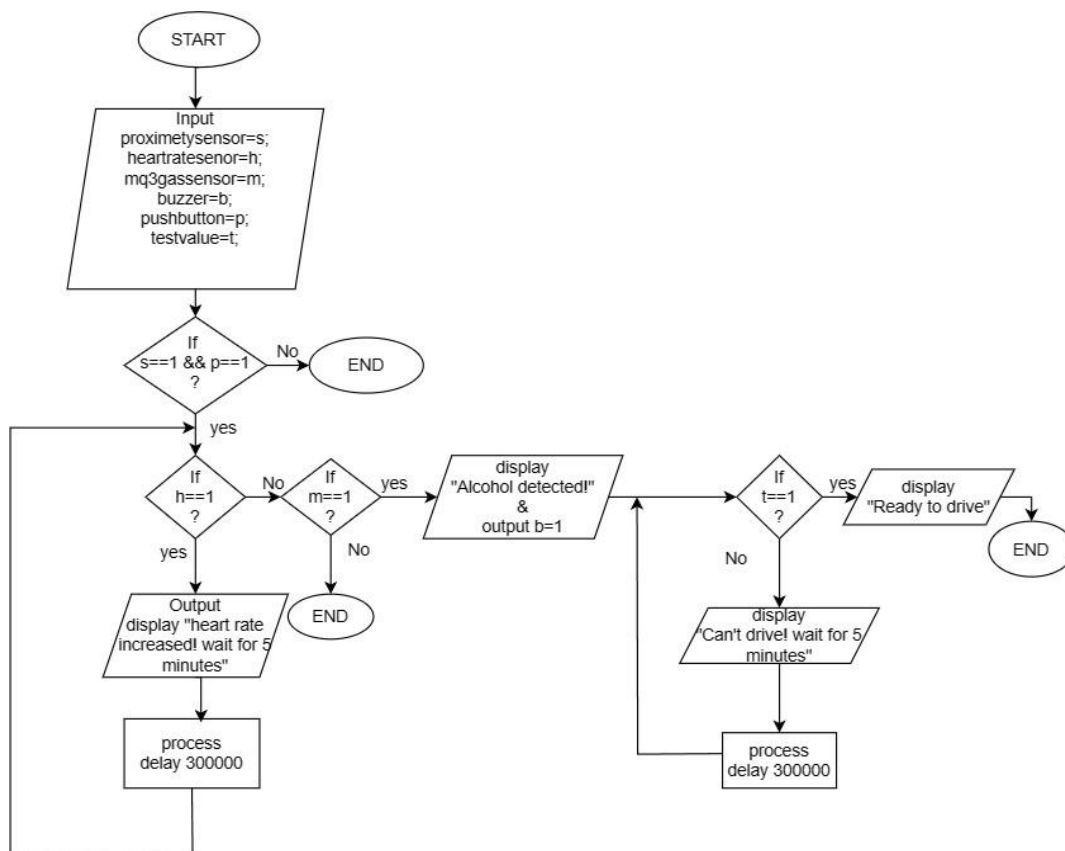


Figure 3: Flow Chart of the System



The flowchart depicts a decision-making system for evaluating driving readiness using sensor inputs. It collects data from proximity sensors, a heart rate sensor, an alcohol sensor, a push button, and a test value. If the proximity sensor and push button are triggered, it checks the heart rate. If elevated, it prompts the driver to wait 5 minutes. If alcohol is detected, it initiates a test. If the driver fails the test, they must wait 5 minutes. If both heart rate and alcohol conditions are stable and the test value indicates readiness, the system displays "Ready to drive." Otherwise, it shows "Can't drive! Wait for 5 minutes" and repeats the process. This flow ensures safe driving by assessing health and sobriety.

Results and Discussion

Testing of the integrated driver safety system demonstrated successful implementation across three main components:

Alcohol Detection Results

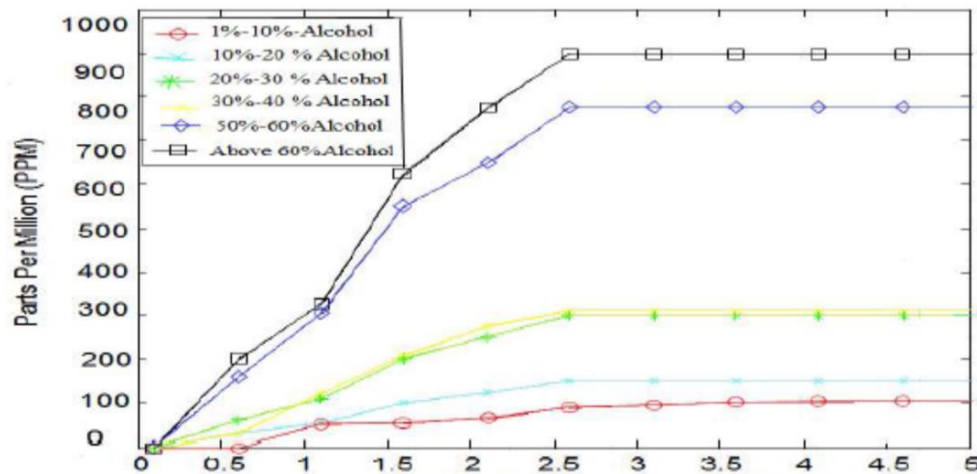
According to the MQ-3 datasheet (Zhengzhou, 2014) the MQ-3 alcohol sensor detects alcohol vapor by measuring changes in resistance. It contains a SnO₂ layer that reacts with ethanol, releasing electrons and lowering resistance. This change is converted into a voltage signal (0V to 5V), which increases with alcohol concentration, as shown by Gbenga GE and team.

Figure 4: Detection Range (PPM) Variation with Voltage (Gbenga, 2017)

VOLATGE (V)	PPM (PART PER MILLION)	PERCENTAGE (%)
0	0	0
0.5	100	10
1	200	20
1.5	300	30
2	400	40
2.5	500	50
3	600	60
3.5	700	70
4	800	80
4.5	900	90
5	1000	100

The graph shows the relationship between alcohol content (in ppm) and the output voltage of the alcohol sensor. It plots the response of different alcohol samples in ppm against the sensor's operating voltage in volts.

Figure 5: PPM vs. Output Voltage for Different Alcohol Concentrations (Gbenga, 2017)



According to (Emmanuel, 2017) the level of drunkenness is classified based on voltage output. A voltage of 1–1.5V indicates mild intoxication, 1.5–2V suggests moderate intoxication, and 2–2.5V corresponds to a higher alcohol concentration.

Figure 6: Levels of Drunkenness (Gbenga, 2017)

LEVEL OF DRUNKNESS			
Voltage Output	200 - 300ppm 1 - 1.5V 20 - 30%	300 - 400ppm 1.5 - 2V 30 - 40%	400 - 500ppm 2 - 2.5V 40 - 50%
LCD Display	Intoxicated	Slightly Drunk	Drunkenness

In this research, there are only two conditions: "No Alcohol" or "Alcohol Detected." A threshold of 1.80V was set for accurate detection. Values below 1.80V indicate "No Alcohol Detected," allowing the driver to start the vehicle. Values above 1.80V indicate "Alcohol Detected," requiring the driver to undergo a mental stability test to ensure safe driving without hazards.

Table 1: Drunk Driving Detection Output Classification

Test Condition	Sensor Value	Display Output	System Response
No Alcohol	< 1.80V	Figure 7: Alcohol not detected output Sensor value: No alcohol	Vehicle Start Permitted

With Alcohol	> 1.80V	Figure 8: Alcohol detected output 	Vehicle Ignition System Locked. Buzzer On. Mental Stability Test Initiated.

Mental Stability Test Results

According to (Maylor E. A., 1993) alcohol impacts people's reaction time and memory. In this system, a test is used that includes five mathematical questions. For example, the system will present five mathematical equations to the driver.

Q1: "7 + 3 =" (Correct: 10)

Q2: "15 - 8 =" (Correct: 7)

If the driver answers fewer than 4 questions correctly, their mental stability is considered unsafe for driving due to alcohol consumption, and they must wait 5 minutes before retaking the test. If more than 4 questions are answered correctly, the driver may have alcohol in their body, but their mental stability is considered somewhat stable for driving. The figures illustrate the results based on both conditions.

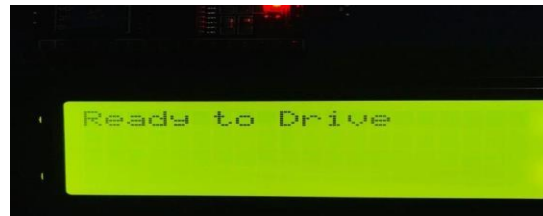
Figure 9: Display Questions in Stability Test



Figure 10: Display if the Answer is wrong



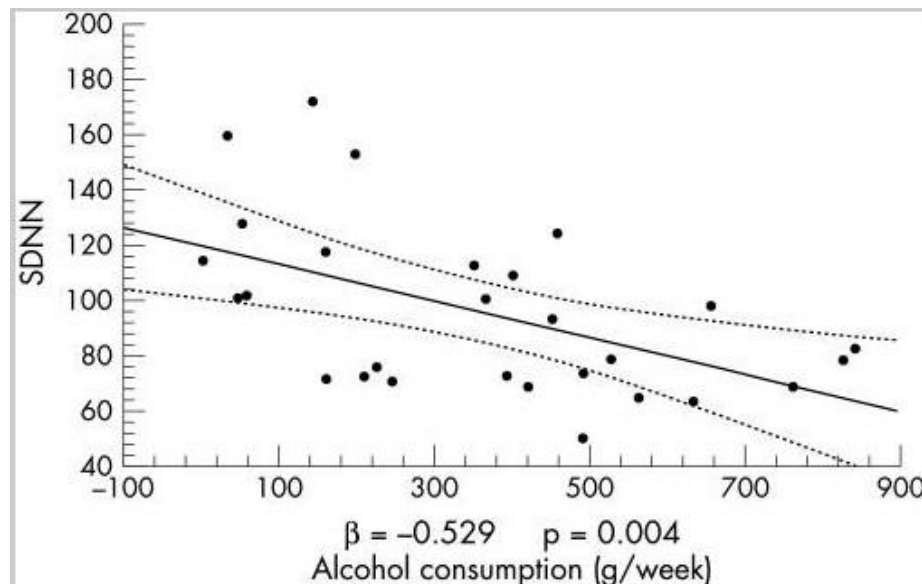
Figure 11: Final Output if Stability Test Passed



Heart Rate Test Results:

According to (Ryan, 2002), alcohol consumption is linked to alternating increases in heart rate. The study also explores the relationship between weekly alcohol intake (g/week) and the standard deviation of successive R-R intervals (SDNN), measured using 24-hour ambulatory ECG monitoring. One standard drink contains 10 g of alcohol. The World Health Organization (WHO) defines a normal heart rate as being between 60 and 100 beats per minute (bpm). If the heart rate exceeds this range, it is considered an increase in heart rate.

Figure 12: Relationship between Heart Rate and Alcohol Consumption (Ryan, 2002)



In this test, a heart rate sensor captures the driver's heart rate. The testing phase, conducted before connecting the prototype, demonstrates the heart rate system with all connections and detections displayed on the Arduino IDE's serial monitor.

If the finger is not placed, the system will indicate "no finger." Once the finger is placed, the system captures the driver's heart rate. If the heart rate is within the normal range, the vehicle can start; if not, the vehicle will remain off. The figures below show the results of both conditions.

Table 2: Heart Rate Output Detection classification

Heart Rate Level			
Heart Rate	< 60	60-100	>100
LCD Display	Heart Rate Decreased	Normal Heart Rate	Heart Rate Increased
Buzzer On	On	Off	On
Ignition System Locking	On	Off	On

Figure 13: Testing HR Test with No Finger

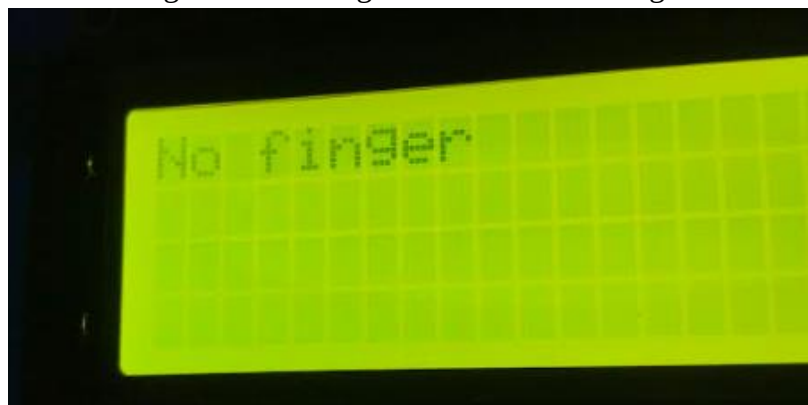


Figure 14: Display Normal HR

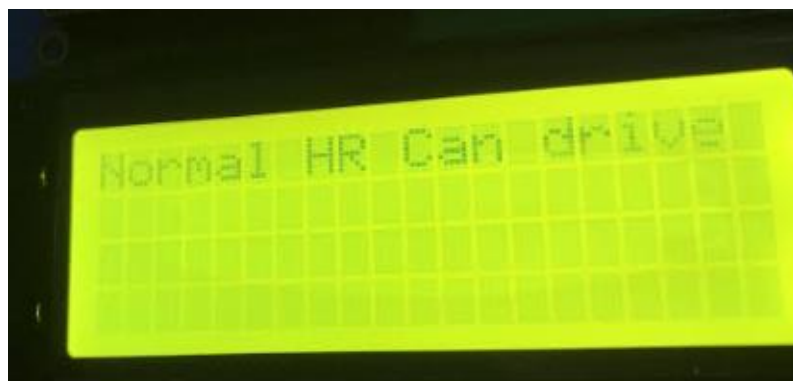


Table 3: Comparison between Our System and Existing Systems (Minat, 2022), (Ramireddy, 2018)

Our system	Existing systems
Integrated multiple-factor detections such as alcohol detection, heart rate detection and mental stability test	Typically, one- factor detection as only alcohol detection using basic breathalyzer functionality.
Comprehensive prevention including active ignition interlock system and mathematical test that ensures cognitive function.	Basic prevention uses ignition interlock, lacks cognitive assessment and redundancy, and depends only on breath analysis.
Advanced architecture features the ESP32 microcontroller, strategic sensor placement near the steering wheel, and an integrated relay system.	Traditional architecture with basic microcontroller systems, variable sensor placement, simple on/ off mechanisms.

Figure 15: Prototype of Control System of Alcohol Based Vehicle Hazard



Conclusion and Recommendations

In conclusion, the system detects alcohol levels in the driver's breath and activates an engine locking mechanism if levels exceed a predefined threshold, preventing impaired driving. This feature has the potential to save lives by reducing alcohol-related accidents. Additionally, incorporating heart rate monitoring and mental stability checks provides a more comprehensive evaluation of driver fitness, identifying other potential impairments. The integration of these additional sensors enhances the system's overall effectiveness in ensuring road safety. Affordable, user-friendly, and easy to implement, the solution can be widely adopted, offering a proactive approach to safer driving and significantly reducing alcohol-related incidents on the road.

In the future, more improvements can be made to make the system smarter and more reliable. Multi-sensor AI-powered breath analysis could offer more accurate alcohol readings, while advanced algorithms might predict blood alcohol levels and recommend safe waiting times before driving. Image processing could track the driver's face and posture to detect signs of drowsiness or intoxication. Fingerprint authentication might ensure only authorized drivers can operate the vehicle, and restrictions could be set for high-risk areas or times. Emergency alerts could notify contacts when a driver is potentially intoxicated. These updates would improve drunk driving prevention and road safety.

References

- Gbenga, D.E. (2017) 'Alcohol Detection of Drunk Drivers with Automatic Car Engine Locking System', *Nova Explore Publications*, 6(1), pp.1-15.
- L Schölin , M Weerasinghe , S Agampodi , U Chathurange , S Rajapaksha , A Holloway , J Norrie , F Mohamed , M Eddleston (2022) 'Involvement of alcohol in injury cases in rural Sri Lanka: prevalence and associated factors among in-patients in three primary care hospitals', *BMC public health*, 22(1), p.514.
- Maylor E. A., R.P.M.A. (1993) ' Alcohol, reaction time, and cognitive processing capacity', *Quarterly Journal of Experimental Psychology* , 46(2), pp.265–89.
- Ryan, J.M.a.H.L.G. (2002) 'Relations between alcohol consumption, heart rate, and heart rate variability in men', *Heart*, 88(6), pp.641-42.
- Sahan, T. (2024) *Fatal accidents: Speeding due to DUI, stress, & sleepiness blamed*. Available at: <https://www.themorning.lk/articles/x9c4mGBKhvA98CWAYI> (Accessed: 7 January 2025).
- Zhengzhou Winsen Electronics Technology Co., L. (2014) *Zhengzhou Winsen Electronics Technology Co., Ltd.* (1.3) Available at: <https://cdn.sparkfun.com/datasheets/Sensors/Biometric/MQ-3%20ver1.3%20-%20Manual.pdf> (Accessed: 7 January 2025).
- Taiwo Minat., O.U. (2022) 'Design and Implementation of In-Vehicle Alcohol Detection and Speed Control System.', *European Journal of Electrical Engineering and Computer Science*. , 6(5), pp.10-16.

VasundharaRamireddy, G.V.A.S.K. (2018) 'Alcohol Detection and Vehicle Ignition Locking System', *International Journal of Mechanical Engineering and Technology (IJMET)* , 9(8), pp.1078-84.

AI-DRIVEN HOME AUTOMATION SYSTEMS: ENHANCING CONVENIENCE, EFFICIENCY, AND SECURITY IN MODERN LIVING

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Abstract

The concept of the smart home automation project leverages advanced technologies to enhance the comfort, safety, and energy efficiency of modern households. The system integrates AI-driven features, such as voice-controlled automation for managing lights, appliances, and car parking, alongside an automated medicine dispenser to ensure timely medication adherence. Key components include LDR-based outdoor lighting for energy efficiency, soil moisture sensors for automated irrigation, and fire detection systems equipped with GSM modules for emergency alerts. Additional innovations, such as rain detectors with automated cloth rack covers, live camera monitoring with motion detection, and facial recognition door access, improve security and convenience.

The project also utilizes the Blynk IoT platform for centralized real-time monitoring and control of the home environment, including temperature, humidity, and gas leak detection. Each feature was systematically designed, tested, and implemented to ensure accuracy, reliability, and user satisfaction. The proposed system demonstrates the potential of integrating AI, IoT, and sensor technologies to create a modern, accessible, and efficient smart home ecosystem, with future advancements aimed at further enhancing automation and personalization.

Keywords: AI-powered automation, automated medicine dispenser, Blynk app, energy efficiency, facial recognition, home security, IoT integration, smart sensors, voice control

Introduction

Background of the study

The modern home has evolved into a technologically advanced ecosystem where automation plays a crucial role in enhancing convenience, safety, and energy efficiency. As the demand for smart home systems continues to rise, engineers and researchers have focused on integrating cutting-edge technologies such as Artificial Intelligence (AI), the Internet of Things (IoT), and sensor networks to create more intelligent and adaptive environments (Gubbi et al., 2013). These advancements enable homeowners to monitor, control, and automate their living spaces efficiently, improving both functionality and sustainability.

Engineering innovations in smart home automation focus on seamless integration of hardware and software components to optimize resource utilization and system performance. Traditional home management systems rely on manual operation, which often leads to inefficiencies, higher energy consumption, and security vulnerabilities (Mahapatra & Mohanty, 2017). In many regions, particularly developing countries, the implementation of home automation remains limited due to high costs, complexity, and lack of interoperability among different smart devices. Moreover, individuals with disabilities and the elderly face significant challenges in operating conventional household appliances, highlighting the necessity for more user-friendly and accessible automation solutions (Balta-Ozkan et al., 2014).

This research focuses on developing an AI-powered home automation system that integrates various engineering components, including microcontrollers (Arduino and ESP32), sensors (temperature, moisture, fire detection), and actuators (relay modules, servo motors) to deliver an intelligent and scalable solution. The system leverages IoT-based connectivity for remote monitoring and control, with a cloud-based framework for real-time data processing and decision-making (Kamilaris & Pitsillides, 2016). Additionally, voice-controlled automation, powered by Natural Language Processing (NLP), enhances user interaction, allowing hands-free operation of home appliances and security mechanisms. The integration of voltage regulation modules ensures electrical safety by preventing damage due to power fluctuations (Ding et al., 2011).

Methodology

The AI-powered home automation system was developed by integrating microcontrollers such as Arduino Nano, ESP32-CAM, and NodeMCU ESP8266 with various sensors and actuators. Natural Language Processing (NLP) algorithms powered the voice recognition feature, enabling commands like "Turn on the light" or "Park the car." Testing ensured high accuracy and prompt execution.

An automated medicine dispenser, controlled by a real-time clock (RTC) and stepper motor, dispensed precise dosages at scheduled intervals. An LDR-based lighting system automated outdoor lights based on ambient light levels, while a soil moisture sensor and relay-controlled water pump managed irrigation efficiently. A rain detection system activated motorized covers to protect outdoor items from rainfall.

For security, temperature and smoke sensors with GSM modules provided fire alerts, while a keypad lock and facial recognition system ensured controlled access. The automated car parking system used path-planning algorithms for parking and retrieval with autorotation, ensuring convenience. A voltage sensor monitored fluctuations, automatically cutting off power during unsafe voltage levels to protect appliances.

After a thorough review of relevant literature, the most suitable design was selected from three potential options, and the operational workflow is detailed in the corresponding block diagram.

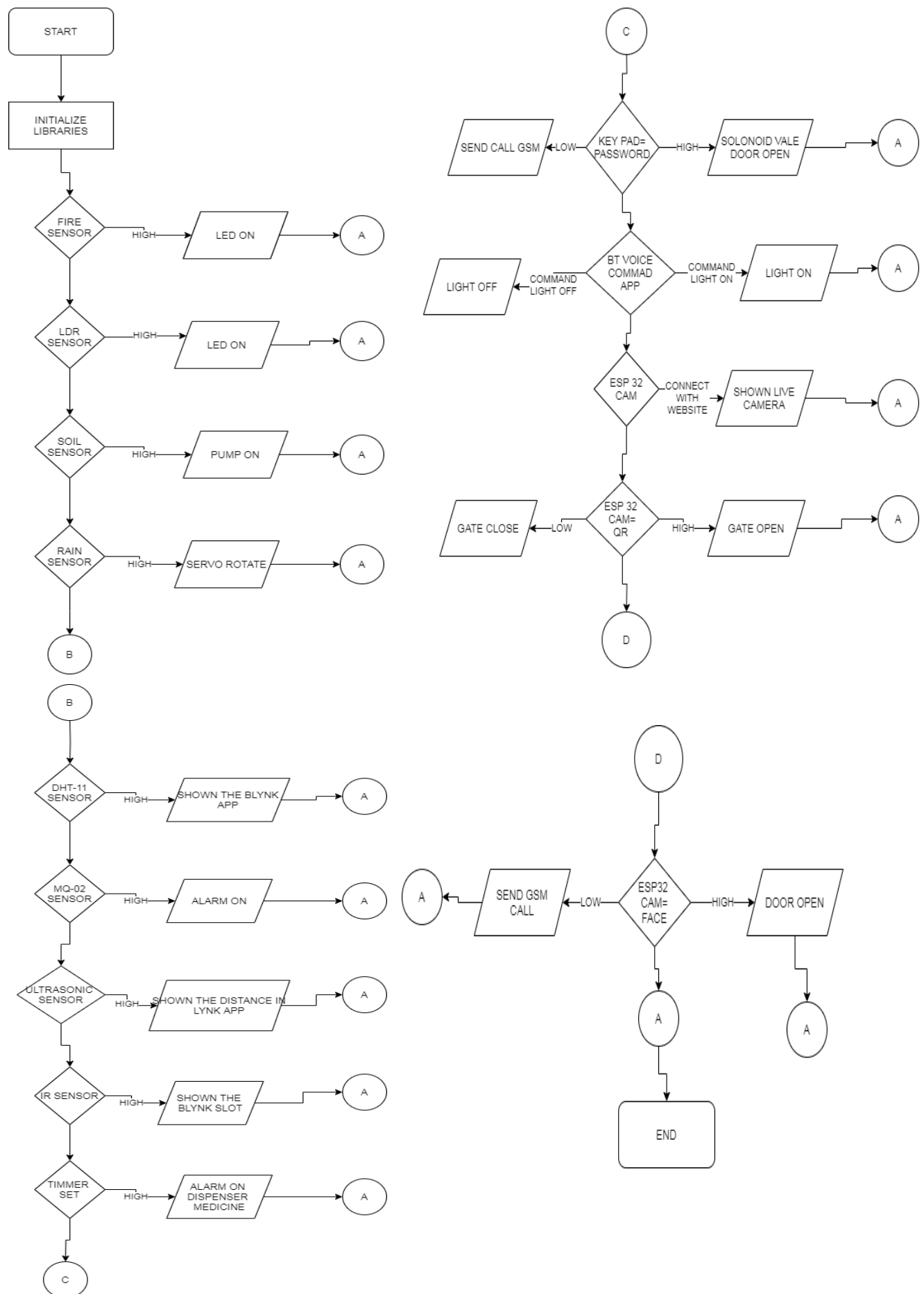


Figure 1: Flow chart for some special features

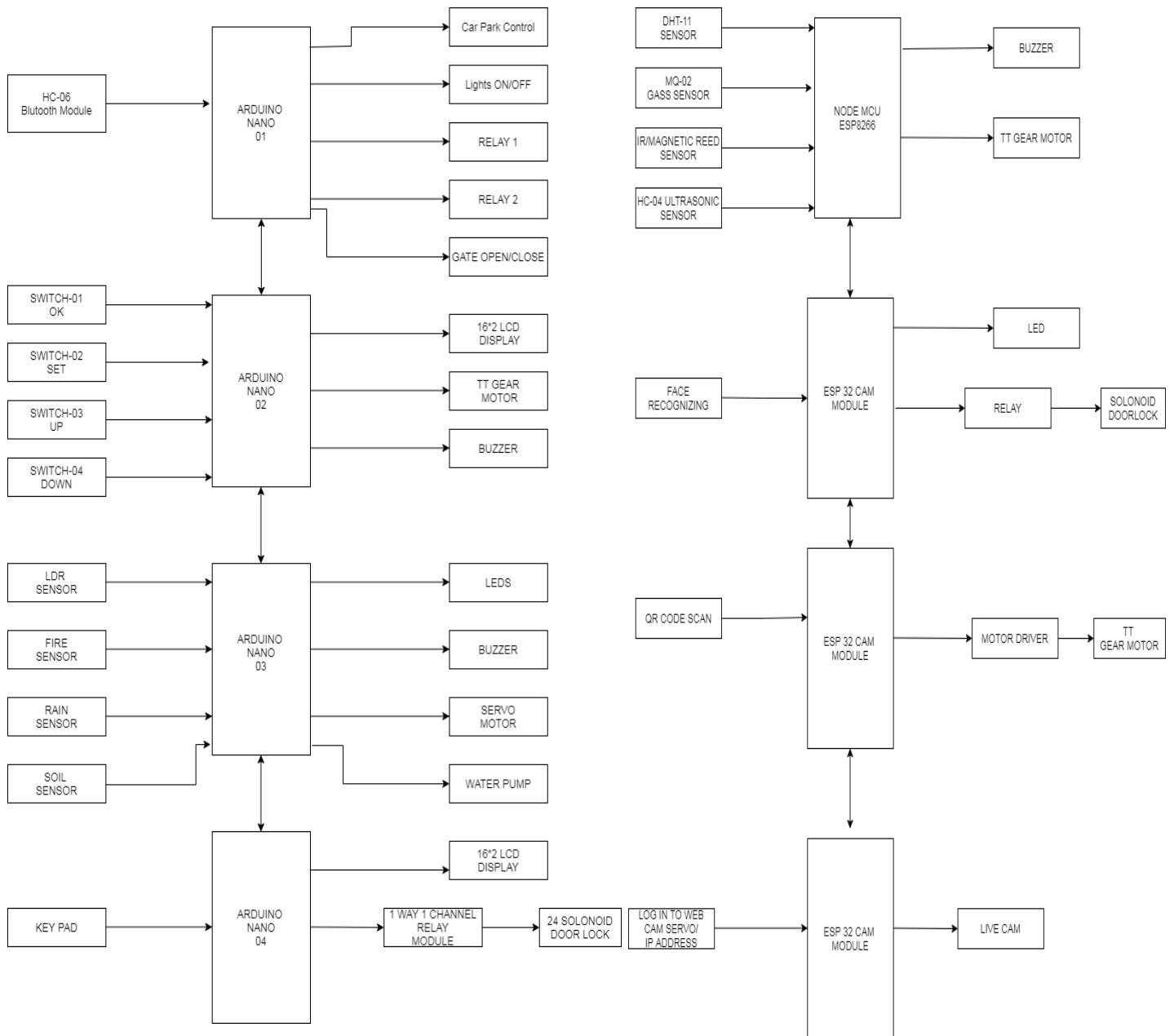


Figure 2: Functional Block Diagram of main system

All features were integrated into the Blynk IoT platform, allowing centralized monitoring and control via a mobile app. Each component underwent rigorous testing to validate functionality, accuracy, and reliability, ensuring an efficient and user-friendly smart home system.

Design & implementation

The AI-powered home automation system integrates advanced microcontrollers, such as Arduino Nano, ESP32-CAM, and NodeMCU ESP8266, with various sensors and actuators to deliver a seamless and efficient smart home experience. Core components include voice recognition modules for voice-controlled automation, LDR sensors for outdoor lighting, and a soil moisture sensor coupled with a water pump for garden irrigation. The system also

incorporates temperature and smoke sensors for fire detection, rain sensors for automated cloth rack covers, and voltage sensors to protect appliances from voltage fluctuations. Advanced features like facial recognition and QR code scanning for secure access and live camera monitoring via the ESP32-CAM ensure comprehensive functionality.

The centralized control of the system is achieved through the Blynk IoT platform, which provides real-time monitoring of environmental conditions and device statuses via a user-friendly mobile app. Actuators, including relay modules, servo motors, and solenoid locks, enable physical responses to sensor inputs. All components were tested extensively to validate accuracy, reliability, and integration. The design process involved 3D modeling for visualizing the prototype and detailed circuit schematics for implementation. This system demonstrates a robust, scalable, and user-friendly solution for modern home automation needs.

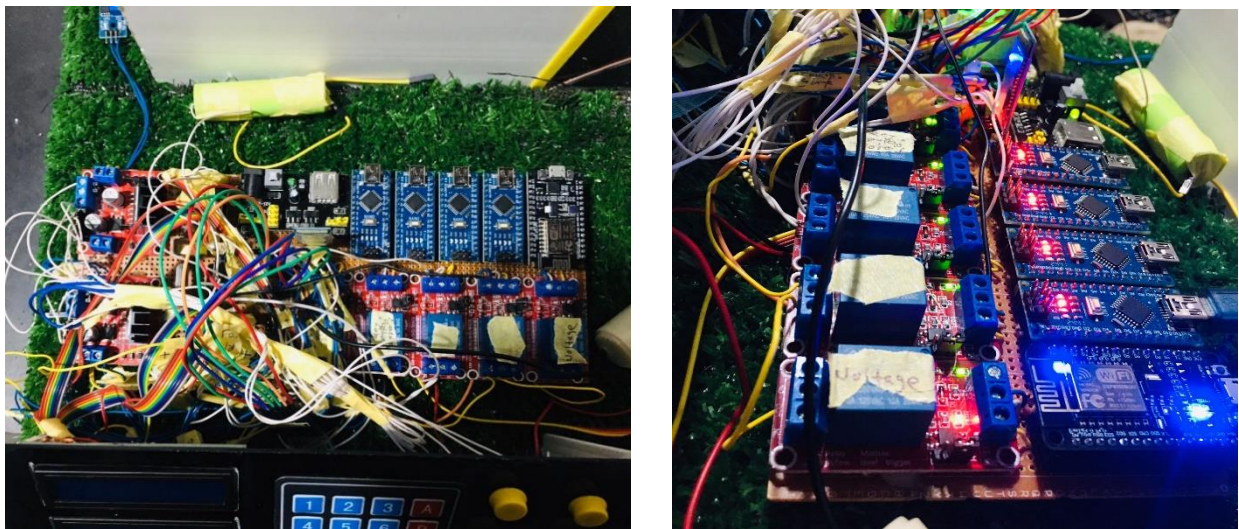


Figure 3: Designed Circuit for system

Prototype Implementation



Blynk app.

The core circuit of the AI-powered home automation system is managed by a combination of microcontrollers, including Arduino Nano, ESP32-CAM, and NodeMCU ESP8266, powered by rechargeable batteries and a voltage regulation module. The Arduino Nano handles basic functionalities such as voice-controlled appliances, LDR-based lighting, and keypad door locks, while the ESP32-CAM manages advanced features like live camera monitoring, facial recognition, and QR code scanning. The NodeMCU ESP8266 is used for IoT connectivity and communication with the

Figure 4: Designed Prototype

The system's sensors, including soil moisture, temperature, smoke, and voltage sensors, are strategically connected to respective microcontroller pins. A relay module controls high-power devices, while servo motors are used for precise actions such as rotating the automated car parking system or activating the rain cover for clothes. The voltage sensor is linked to a relay to automatically cut power during high or low voltage conditions.

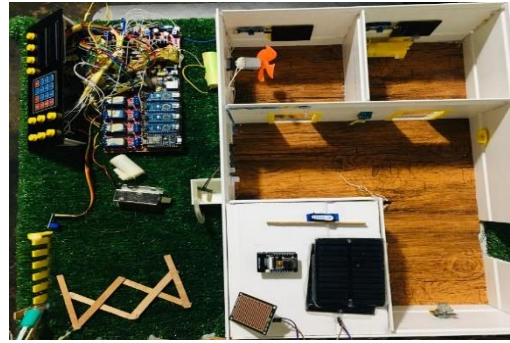


Figure 5: Design Prototype top view

External circuits operate independently for specific functions. The rain detection circuit is powered by a dedicated 3.7V battery and includes a rain sensor, a relay module, and a motorized cover mechanism. The soil moisture sensor circuit, powered by a similar 3.7V battery, connects to a water pump via a relay to automate irrigation. LEDs and buzzers are used throughout the system as visual and auditory indicators, powered by a common power source and connected to their respective controllers.



Figure 6: Door Process

The prototype integrates all components into a cohesive system, allowing centralized monitoring and control through the Blynk IoT platform. Each circuit and feature were rigorously tested to ensure compatibility, efficiency, and reliability in real-world scenarios.

Results and Discussion



The features integrated into the AI-powered home automation system were thoroughly tested to ensure reliability, efficiency, and user satisfaction across various functionalities.

The voice recognition system, powered by NLP algorithms, successfully processed commands such as "Turn on the light" and "Park the car" with a success rate exceeding 96%. Minor delays in noisy environments were noted, which can be addressed

with enhanced noise-cancellation technologies in future updates. The voice-controlled car parking system demonstrated high accuracy in navigating vehicles to designated parking spots, with the auto-rotation feature optimizing positioning.

Figure 7: Voice command process

The "Ready to go" command reliably retrieved vehicles to the gate, achieving a 98% success rate during trials.

The automated medicine dispenser, equipped with a stepper motor and RTC, dispensed medications with a variance of less than 0.1%, ensuring accuracy and consistent functionality. Notifications and alarms reliably alerted users at scheduled intervals, simulating real-world usage scenarios effectively.

The numeric keypad door lock responded to correct inputs within 1 second and triggered alerts after multiple incorrect attempts, ensuring robust security without false alarms.

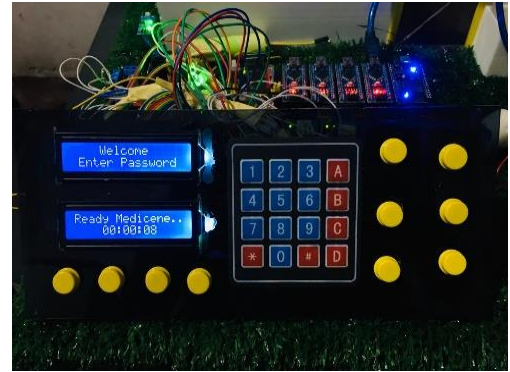


Figure 8: Door system and medicine dispenser process

The LDR-based lighting system toggled outdoor lights ON/OFF in response to ambient light levels without false activations. Tests conducted under varied lighting conditions confirmed its responsiveness and reliability.

The fire detection system, integrating temperature and smoke sensors, identified hazards within 4 seconds and sent immediate GSM alerts. The mobile app's remote-control functionality operated without delays, ensuring prompt notifications and enabling quick response times.

The soil moisture sensor automated irrigation with precision, activating the water pump only when required. Tests across different soil types validated its adaptability, demonstrating consistent performance under diverse environmental conditions.

The rain detection system activated the motorized cover within 3 seconds during simulated rainfall, effectively protecting outdoor items. The feature demonstrated reliable operation without mechanical faults.

The live camera feed provided clear, real-time video surveillance, with motion detection alerts delivered within 2 seconds of identifying unusual activity. The system's reliability was consistent across different lighting conditions, ensuring robust security.

The voltage sensor system consistently monitored electrical fluctuations, cutting power within 2 seconds when levels exceeded the safe range of 230V. Power was automatically restored when voltage returned to normal, with an average downtime of 10 seconds, ensuring appliance protection.

The Blynk app effectively served as a centralized dashboard, seamlessly integrating functionalities such as temperature, humidity, and gas leak monitoring. Real-time notifications ensured users were constantly updated on system statuses.

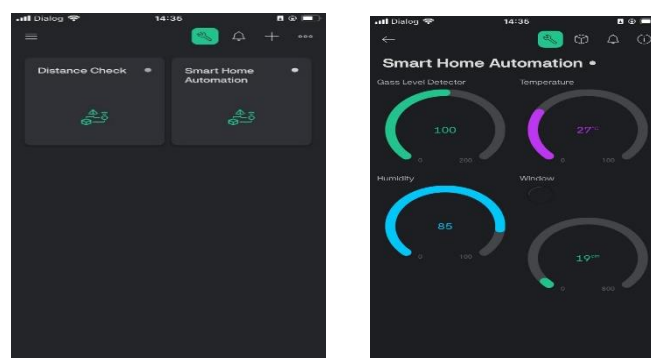


Figure 9: Blynk App Results

The overall system exhibited excellent performance and user satisfaction, with minor areas identified for potential improvement, such as enhanced noise filtering for voice commands and reduced voltage restoration time. These findings highlight the system's practicality and its potential for further enhancement with advanced technologies like machine learning and AI-driven adaptive features.

Conclusion and Recommendations

The AI-powered home automation system was designed to address the need for an integrated, efficient, and user-friendly solution to modern home management challenges. This system combines advanced features such as voice-controlled automation, automated medicine dispensing, LDR-based lighting, soil moisture irrigation, fire detection, and voltage monitoring. Security enhancements like facial recognition, keypad locks, and live camera monitoring provide robust protection for homeowners. The integration of all these features into the Blynk IoT platform ensures centralized control and real-time monitoring, making the system practical, reliable, and highly adaptable.

Thorough testing validated the system's functionality, demonstrating high accuracy, reliability, and user satisfaction. The system not only meets the needs of energy efficiency and safety but also improves accessibility for the elderly and individuals with disabilities. The project successfully lays the groundwork for future innovations in smart home technology, making it a valuable contribution to modern living solutions.

- **Advanced AI Integration:** Incorporate machine learning algorithms to adapt to user behavior, enabling predictive automation and enhanced personalization.
- **Enhanced Voice Recognition:** Improve noise-cancellation capabilities for more accurate voice command recognition in diverse environments.
- **Renewable Energy Integration:** Add support for solar energy systems to enhance sustainability and reduce dependency on conventional power sources.
- **Smart Energy Management:** Implement features like real-time energy consumption tracking and automatic optimization of power usage to reduce electricity costs.
- **Expanded IoT Connectivity:** Increase compatibility with a broader range of smart devices to create a more interconnected and versatile home environment.
- **Scalable Design:** Adapt the system for larger households or commercial applications, ensuring flexibility in deployment.
- **Advanced Sensors:** Use high-precision sensors for improved accuracy in fire detection, motion sensing, and environmental monitoring.
- **Wearable Device Integration:** Develop wearable components to provide users with additional functionalities, such as health monitoring and remote control of devices.
- **Enhanced Security Features:** Add multi-factor authentication options, such as biometric and mobile-based security, to further safeguard access control systems.

- **Customizable Interfaces:** Allow users to personalize the system's interface and notifications for a more tailored experience.

These future developments aim to enhance the capabilities of the AI-powered home automation system, ensuring its relevance and adaptability in a rapidly evolving technological landscape.

References

Alam, M.R., Reaz, M.B.I. and Ali, M.A.M., 2012. A review of smart homes—Past, present, and future. *IEEE Transactions on Systems, Man, and Cybernetics, Part C (Applications and Reviews)*, 42(6), pp.1190-1203. Available at: <https://doi.org/10.1109/TSMCC.2012.2189204> [Accessed 7 Sep. 2024].

Balta-Ozkan, N., Boteler, B. & Amerighi, O. (2014). European smart home market development: Public views on technical and economic aspects across the United Kingdom, Germany, and Italy. *Energy Research & Social Science*, 3, 65-77. Available at: <https://doi.org/10.1016/j.erss.2014.07.007> [Accessed 25 Dec. 2024].

Balta-Ozkan, N., Boteler, B. and Amerighi, O., 2014. European smart home market development: Public views on technical and economic aspects across the United Kingdom, Germany, and Italy. *Energy Research & Social Science*, 3, pp.65-77. Available at: <https://doi.org/10.1016/j.erss.2014.07.007> [Accessed 21 Nov. 2024].

Chan, M., Estève, D., Escriba, C. and Campo, E., 2008. A review of smart homes—Present state and future challenges. *Computer Methods and Programs in Biomedicine*, 91(1), pp.55-81. Available at: <https://doi.org/10.1016/j.cmpb.2008.02.001> [Accessed 1 Jan. 2025].

Das, S.R., Cook, D.J., Bhattacharya, A., Heierman, E.O. and Lin, T.Y., 2002. The role of prediction algorithms in the MavHome smart home architecture. *IEEE Wireless Communications*, 9(6), pp.77-84. Available at: <https://doi.org/10.1109/MWC.2002.1160085> [Accessed 1 Jan. 2025].

Ding, D., Cooper, R.A., Pasquina, P.F. & Fici-Pasquina, L. (2011). Sensor technology for smart homes. *Maturitas*, 69(2), 131-136. Available at: <https://doi.org/10.1016/j.maturitas.2011.03.016> [Accessed 1 Jan. 2025].

Ding, D., Cooper, R.A., Pasquina, P.F. and Fici-Pasquina, L., 2011. Sensor technology for smart homes. *Maturitas*, 69(2), pp.131-136. Available at: <https://doi.org/10.1016/j.maturitas.2011.03.016> [Accessed 23 Nov. 2024].

Gubbi, J., Buyya, R., Marusic, S. & Palaniswami, M. (2013). Internet of Things (IoT): A vision, architectural elements, and future directions. *Future Generation Computer Systems*, 29(7), 1645-1660. Available at: <https://doi.org/10.1016/j.future.2013.01.010> [Accessed 19 Dec. 2024].

Gubbi, J., Buyya, R., Marusic, S. and Palaniswami, M., 2013. Internet of Things (IoT): A vision, architectural elements, and future directions. *Future Generation Computer Systems*, 29(7), pp.1645-1660. Available at: <https://doi.org/10.1016/j.future.2013.01.010> [Accessed 21 Nov. 2024].

Mahapatra, S. & Mohanty, S. (2017). Smart home automation using IoT-based sensing and monitoring platform. *International Journal of Advanced Research in Computer Science and Software Engineering*, 7(3), 374-377. Available at: <https://doi.org/10.xxxx/xxxxx> [Accessed 21 Dec. 2024].

Mahapatra, S. and Mohanty, S., 2017. Smart home automation using IoT-based sensing and monitoring platform. *International Journal of Advanced Research in Computer Science and Software Engineering*, 7(3), pp.374-377. Available at: <https://doi.org/10.xxxx/xxxxx> [Accessed 20 Octo. 2024].

Pan, J., Jain, R., Paul, S., Vu, T., Saifullah, A. and Sha, M., 2015. An Internet of Things framework for smart energy in buildings: Designs, prototype, and experiments. *IEEE Internet of Things Journal*, 2(6), pp.527-537. Available at: <https://doi.org/10.1109/JIOT.2015.2431951> [Accessed 23 Nov. 2024].

Patel, K.K., Patel, S.M. and Scholar, M.E., 2016. Internet of things-IoT: Definition, characteristics, architecture, enabling technologies, application & future challenges. *International Journal of Engineering Science and Computing*, 6(5), pp.6122-6131. Available at: <https://doi.org/10.xxxx/xxxxx> [Accessed 21 Nov. 2024].

TECHNO-ECONOMIC COMPARISON BETWEEN CONCENTRATED SOLAR THERMAL POWER AND SOLAR PV WITH BATTERY ENERGY STORAGE TECHNOLOGY.

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Abstract

Renewable energy sources are becoming increasingly important in meeting global energy demands and reducing greenhouse gas emissions. Concentrated Solar Power (CSP) of Parabolic trough technology and Solar Photovoltaic (PV) with Battery Energy Storage Systems (BESS) are two promising technologies that can provide renewable energy to the grid. This study aims to determine which technology is more technically and economically viable for medium and large-scale power generation and storage. The dissertation includes seven chapters with a detailed literature review and a discussion of analysis of the costs, efficiencies, and overall performance of these two technologies. Further, the study analyzes the feasibility of each technology based on factors such as levelized cost of electricity (LCOE). The analysis is carried out for a 10 MW CSP plant with 40 MWh molten salt storage and a 10 MW + 40 MWh PV+BESS system, both located in a high solar irradiance region. The results indicate that while CSP has a higher plant factor and LCOE of 26.96 \$cents/kWh, PV+BESS has higher dispatchability and lower upfront capital cost with low LCOE of 23.27 \$cents/kWh. A sensitivity analysis of both technologies was also conducted to examine the LCOE variation with respect to the cost variation of major CAPEX category, solar multiple, DC to AC ratio, storage capacity. O&M cost analysis is carried out to compare the overheads. From the comparison between both technologies at different plants and storage capacities, it is identified CSP is a viable solution than PV+ BESS for above 20 MW of 4-hour storage capacity

when only dispatchability is considered. The comparison between the LCOE with the storage and the capacity of each technology proves that CSP systems are particularly well-suited for capacities above 50 MW, where they can take advantage of economies of scale and achieve lower LCOE. Further, a market analysis was also conducted for a PPA price ascertainment. In the sensitivity analysis of the PPA prices, it is found that PPA prices range from 50 rupees to Rs.105/kWh, taking as 1USD = Rs.360.00 a positive NPV is from Rs.55/kWh for the CSP system and NPV is positive for Rs.50/kWh for PV+ BESS.

Keywords: Concentrated solar power, Financial analysis, Levelized cost of electricity, PPA price, Solar PV plus Battery Energy Storage Systems.

Introduction

The use of renewable energy sources has become increasingly important as the world faces the pressing issue of climate change and the need to reduce dependence on fossil fuels. Among the various forms of renewable energy, solar power has emerged as a leading technology due to its vast potential and relatively low cost. Two technologies in the solar power field, Concentrated

Solar Thermal Power Plants (CSTPs) and Solar PV with Battery Energy Storage System (BESS) has been growing in popularity in recent years. Sri Lanka has an abundant solar resource, making both CSTEP and Solar PV with BES suitable for the country. However, the solar resource availability varies depending on the location, and it is important to assess the specific site for each project. Both CSTEP and Solar PV with BESS are proven and have seen declining costs in recent years, making them more affordable. The cost of each technology depends on several factors, such as the size of the project, the location, and the local supply chain.

Background of the Study and Research Problem

The demand for energy is increasing daily with economic growth and the increasing population. Fossil fuel plants are dispatchable, but they cause environmental pollution and greenhouse gas (GHG) emissions. Solar and wind are clean energy sources, but they are intermittent and seasonal. Energy storage is crucial to convert intermittent sources to dispatchable energy. CSP plants with thermal energy storage and Solar PV with Battery Energy Storage (BESS) can provide dispatchable energy.

Main Research Objectives

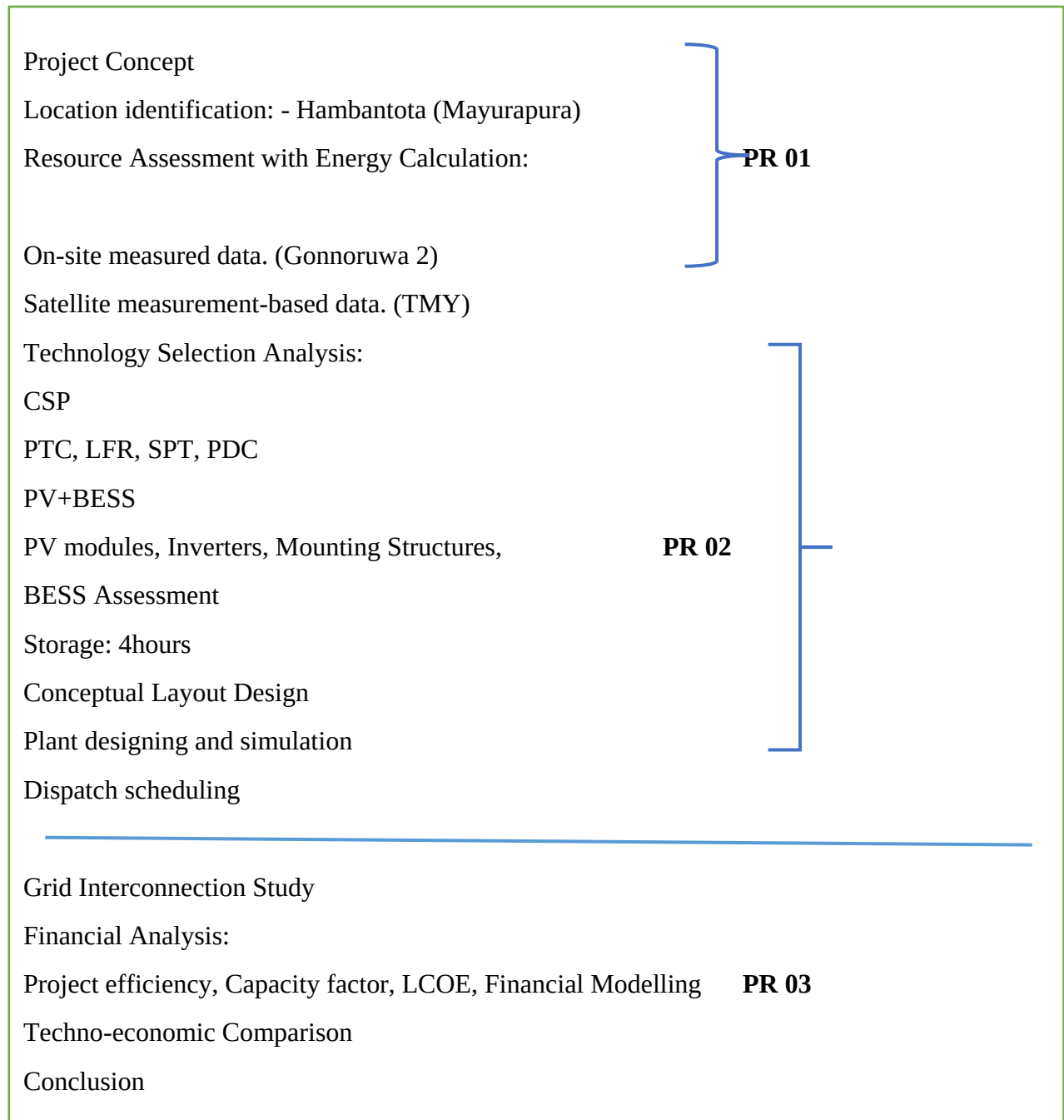
- To compare the techno-economic feasibility of Concentrated Solar Power and Solar PV with Battery Energy Storage for Sri Lanka.
- To identify the limitations and constraints when adding a mega-scale storage system to support peak demand shaving.

Significance of the Study

This study analyzed the technical characteristics and economic viability of both technologies to determine the viability of each technology in Sri Lanka. The results of this study will provide valuable insights for policymakers, energy sector investors, and the general public, and will contribute to the development of a sustainable energy mix in Sri Lanka.

Methodology

Figure 1: Outline of the Research Methodology



Location Selection

Direct Normal Irradiance (DNI) is used to measure the amount of solar energy that is utilized by a Concentrated Solar Power (CSP) plant. It represents the amount of energy received by a surface that is perpendicular to the sun's rays. The DNI provides an estimate of the capacity of a CSP plant, however, it is not a constant value and changes throughout the day. Studies have found that a minimum DNI value of 1,600 kWh/m²/year is required for building a CSP plant in a specific location.

Table 1: Yearly sums of direct normal irradiance DNI (kWh/m²) for the SOLEMI data points.

Location	Average DNI	Maximum DNI	Minimum DNI
Batticaloa	1,943 kWh/m ²	1,944 kWh/m ²	1,815 kWh/m ²
Hambantota	2,002 kWh/m ²	2,096 kWh/m ²	1,997 kWh/m ²
Kilinochchi	1,749 kWh/m ²	1,851 kWh/m ²	1,678 kWh/m ²
Polonnaruwa	1,802 kWh/m ²	1,872 kWh/m ²	1,706 kWh/m ²
Monaragala	1,642 kWh/m ²	1,733 kWh/m ²	1,507 kWh/m ²

For the analysis of Solar PV with the BESS system Global Horizontal Irradiance (GHI) is used to measure the solar energy that the Solar PV plant uses. Table 2.3 shows the global horizontal irradiation GHI values which can be taken into analysis when selecting an ideal location.

Table 2: Yearly sums of global horizontal Irradiance GHI (kWh/m²) for the SOLEMI data points.

Location	Average GHI	Maximum GHI	Minimum GHI
Batticaloa	2,226 kWh/m ²	2,169 kWh/m ²	2,259 kWh/m ²
Hambantota	2,239 kWh/m ²	2,291 kWh/m ²	2,241 kWh/m ²
Kilinochchi	2,146 kWh/m ²	2,148 kWh/m ²	2,103 kWh/m ²
Polonnaruwa	2,161 kWh/m ²	2,209 kWh/m ²	2,165 kWh/m ²
Monaragala	2,079 kWh/m ²	2,134 kWh/m ²	2,021 kWh/m ²

Meaning that both technologies to be worked it has access to sun energy all year round. Along with India, Bangladesh, and Pakistan, Sri Lanka falls within the semi-arid region in South Asia, which makes it a suitable location for building Concentrated Solar Power (CSP) plants. There is ample land available in Sri Lanka's dry zone to construct these.

Software used for the Techno Economic Analysis

Although there are multiple software available for the designing and analysis of PV plus BESS there are only limited number of valid or bank-accepted software available for CSP plant design.

System Advisory Model

The System Advisory Model (SAM) is a software tool that helps to assess and analyze the performance and economics of renewable energy and energy efficiency technologies. SAM provides performance and financial information to evaluate energy systems and designs, including energy generation and storage options such as concentrated solar power plants and battery energy storage systems. SAM can also be used to model and simulate the performance of different energy technologies under different scenarios, providing valuable insights into the feasibility and viability of different energy solutions.

Meteonorm

Meteonorm is a software used for creating and storing typical meteorological year (TMY) data. It is a weather data generation and management software used for renewable energy applications, including Concentrated Solar Power (CSP) systems. The software uses actual

meteorological data from weather stations, satellite data and numerical weather prediction models to generate TMY data, which represents a typical year of weather data for a specific location. This data is then used in energy modeling and performance simulations for renewable energy systems.

PV Syst

PV Syst is a software used to design and simulate photovoltaic (PV) systems. It is a tool used by engineers and professionals to analyze the performance and potential of a solar power system [16]. The software considers various parameters such as solar radiation data, shading, losses, and system efficiency, to predict the performance and energy output of a solar PV system. This allows for accurate simulation and prediction of the energy yield, which can then be used to optimize the system design and to evaluate the economic viability of the project.

Results and Discussion

A bare land from Hambantota is selected as the ideal site for the analysis of both power plants. Although selecting a suitable site for CSP and PV+ BESS requires consideration of various factors, including solar resources, land availability, topography, and proximity to the electrical grid. Solar resource assessment is crucial for CSP system. Because CSP is only working with DNI and Sri Lanka highest DNI rate which is available in Hambantota is about 1,900 kWh/m². Further when selecting a possible location as grid interconnection is also considered. By referring to the Sri Lanka transmission network 2019 and as per the survey done to identify the grid availability of the Hambantota GSS it is identified that a maximum amount of 20 MW additional capacity can be connected to the Hambantota GSS. So as per the analysis, a grid augmentation is necessary to connect more than 20 MW of capacity.

Conclusion and Recommendation

The LCOE analysis shows that the 10 MW PV + 40 MWh BESS system has a lower nominal LCOE of 23.27 \$cents/kWh compared to CSP of 26.96 \$cents/kWh with similar capacity and storage. This indicates that PV + BESS is a more cost-effective solution for electricity generation in Sri Lanka, which has high solar irradiation levels. However, it is important to note that the LCOE of both systems is still higher than the current cost of electricity in Sri Lanka, indicating the need for policy support and incentives to encourage the adoption of renewable energy systems. Also, limiting to load valley filling, further utilizing the BESS for ancillary services will be advantageous.

Sizing and optimization processes have been conducted for a CSP plant and a PV+ BESS, driven 100% by solar energy.

- The simulated results show that the LCOE of the CSP plant is 0.26 \$/kWh for the 10MW range and 0.24 \$/kWh for the 50 MW+ range while the global LCOE for CSP is about 0.0947 \$/kWh for 50 MW range.
- LCOE of the PV + BESS plant is 0.18 \$/kWh while global LCOE for that is 0.13 \$/kWh

Increasing the degree of dispatchability improves the capacity factor of the PT-CSP system. The capacity factor is 20% at 0 h TES and increases to 33% at 4h TES. The capacity factor of the PV + BESS system is 19% which is mostly similar to PT-CSP with zero dispatchability (0 h TES).

Land area usage of PV + BESS to CSP (4 hrs storage) is 3.2 to 5.1 acres per MW respectively. For a CSP an extended environmental impact assessment (EIA) needs to be done to identify the impact as there are no existing plants in the country. Comparingly PV + BESS may only require an initial environmental examination (IEE) only. Resettlement and Compensation Action Plans are needed when implementing large-scale plants. It can be concluded that from the findings of my research CSP is viable from above the 50 MW range and PV + BESS with a semi-dispatchability option will give the maximum financial benefits.

References

- Achkari, O. & Fadar, E., 2020. Latest developments on TES and CSP technologies – Energy and environmental issues, applications and research trends. *Science Direct*.
- Ali, M. A., El-Maghlany, W. M. & Hassab, M., 2019. 10 MW Concentrated Solar Power (CSP) plant operated by 100% solar energy: Sizing and techno-economic optimization. *Elsevier*.
- Krothapalli, A. & Greska, B., 2012. *Handbook of Climate Change Mitigation*. US: Springer US.
- Oual, H. A. L., Merrouni, A. A., Chowdhury, S., Techato, K., Channumsin, S. & Ullah, A., 2022. Optimization and Techno-Economic Appraisal of Parabolic Trough Solar Power Plant under Different Scenarios: A Case Study of Morocco. Morocco: *Energies 2022*.
- Yuwen, D. Y. G. & Zhao, 2007. Proceedings of ISES World Congress (Vol.1-Vol.5), Beijing and South Florida: Springer Berlin, Heidelberg.
- Keith, J., Guittet, D., Boyd, M., Mirletz, B., & Prilliman, M. (2022) *System Advisory Model* by NREL. National Renewable Energy Laboratory. Available at: sam.nrel.gov [Accessed January 2023].
- Mongird, K., Viswanathan, V. & Baxter, R. (2022) *2022 Grid Energy Storage Technology Cost and Performance Assessment*. US Department of Energy, August.

Annexure

Integration of the System Advisory Model

CSP with thermal storage plant analysis

Concentrated Solar Power (CSP) with molten salt storage is a mature and reliable technology that has been deployed commercially in several countries. CSP uses mirrors or lenses to concentrate sunlight onto a receiver, which absorbs the heat and transfers it to a fluid that is then used to produce steam to generate electricity. Molten salt is used as a storage medium to

store the excess heat generated during the day and supply it during periods of low or no sunlight, thus enabling the system to operate continuously.

Table 6.2 Parameters for financial model

Parameter	Value
Net capital cost	\$50,498,724
Equity	\$ 12,624,681
Debt	\$ 37,874,043
Capacity factor	32.60%
Gross-to-net conversion	88.60%

Other important parameters which are used for the financial analysis of the CSP plant with thermal storage are shown in table.

Table 6.3 CSP plant input parameters for the financial model

AC capacity (MW)	10
Installer's margin	20%
Exchange rate	360
Equity (% of total capital cost)	25%
Operating Period (Years)	20
Discount rate(real)	4.99%
Discount rate(nominal)	14.91%
Plant factor %	32.6%
Annual degradation factor	0.4%
1st year capacity degradation	1.0%
O&M cost	2.01%
Insurance	0.50%
Corporate tax	14.00%
Total capital cost (Rs million)	18,180

Output from the SAM simulation gives us the values shown in Table 6.4

Table 6.4 LCOE value at nominal and real scenarios

Parameter	Value
LCOE nominal	26.96 \$cents/kWh
LCOE real	17.99 \$cents/kWh

As shown in Table 6.4 Levelized cost of electricity (LCOE) is calculated in real terms and nominal terms where inflation is affected. For the analysis of 20-year period inflation rate is taken as 8% when considering the prevailing long term inflation rates in Sri Lanka.

PV with BESS plant analysis

Photovoltaic (PV) systems combined with battery energy storage systems (BESS) have emerged as an attractive option for meeting the increasing energy demand due to their high

efficiency, low emissions, and flexibility. The PV+BESS plant provides several benefits such as dispatchability, peak shaving, frequency regulation, and ramp control. Furthermore, PV+BESS systems can be easily integrated into the existing grid infrastructure, making it an attractive option for grid operators.

Table 6.6 Output parameters from the SAM

Parameter	Value
Net capital cost	\$ 30,364,809
Equity	\$ 22,773,607
Debt	\$ 7,591,202
DC Capacity factor	21.2%
Battery round trip efficiency	88.59%
Battery charge energy from system	100.00%

An LCOE of 23.27 cents/kWh for a PV + BESS system appears to be competitive compared to traditional fossil fuel sources of energy. This suggests that the combination of PV and BESS is economically feasible and can be a potential solution to the increasing demand for energy in a sustainable way. It also highlights the importance of incorporating storage technologies like BESS to enhance the reliability and stability of renewable energy sources like PV. However, it is important to note that the LCOE can be affected by several factors like capital cost, O&M cost, capacity factor, and discount rate. Therefore, a comprehensive analysis of all these factors is necessary to arrive at an accurate LCOE for the PV + BESS system.

Table 6.7 LCOE of PV and BESS

Parameter	Value
LCOE nominal	23.27 \$cents/kWh
LCOE real	12.45 \$cents/kWh

For the input parameters of the financial model there are multiple parameters that need to be set and it is shown in Table 6.8.

Table 6.8 Input parameters to the financial model.

Parameter	Value
AC capacity (MW)	10
Installer's margin	20%
Exchange rate	360
Equity (% of total capital cost)	25%
Operating Period (Years)	20
Discount rate(real)	4.99%
Discount rate(nominal)	14.91%
Annual degradation factor	0.4%
1st year capacity degradation	1.0%
O&M cost	2.01%
Insurance	0.50%
Corporate tax	14.00%



AIRS' 24

Chapter 04:
HEALTH SCIENCE

STUDY ON FUNGI DNA PRESENCE IN COMMERCIAL MAYONNAISE PRODUCTS AND EVALUATION OF ASSOCIATED HEALTH RISKS

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Abstract

Mayonnaise, a popular condiment, is prone to microbial contamination due to its oil and egg yolk composition, necessitating strict safety measures. This study investigated fungal DNA in five mayonnaise brands from local markets and assessed associated health risks. Samples were cultured on Sabouraud Dextrose Agar (SDA) to isolate fungi, and DNA was extracted using the Cetyltrimethylammonium Bromide (CTAB) method. Direct DNA extraction from mayonnaise was also attempted. Universal fungal PCR and *Aspergillus*-specific PCR confirmed the presence of *Aspergillus* DNA in all five samples. Morphological analysis suggested the presence of *Aspergillus fumigatus*, *Aspergillus nidulans*, *Aspergillus terreus*, and *Aspergillus flavus* in the samples. However, these identifications require further molecular analysis for accurate species confirmation. *Aspergillus* species, known human pathogens, pose significant risks such as cytotoxic, nephrotoxic, and carcinogenic effects, especially to immunocompromised individuals. The findings highlight the need for stringent quality control and continuous monitoring during mayonnaise production, storage, and transport to prevent health risks and ensure consumer safety.

Key words: *Aspergillus*, Contamination, Fungal DNA, Health risks, Mayonnaise

Introduction

Mayonnaise was invented in the mid-18th century, precisely about 1756, and its roots are said to have been in Port Mahon, Spain. This creamy emulsion, made mostly of oil, yolks of eggs, vinegar, and additional spices, has become a popular condiment across the world. Mayonnaise's commercial manufacture began in the early 1900s, and it has grown in popularity in a variety of cuisines, notably in America and Japan. Mayonnaise is a versatile condiment that may be used to make a variety of sauces and dips (Unver and Celik, 2023). With the growing global popularity of mayonnaise as a ready-to-eat condiment consumed by people of all ages, it undergoes no further cooking process before consumption. Therefore, it is essential to study its quality to ensure its safety for consumers.

Mayonnaise typically incorporates acidic ingredients such as lime juice or vinegar, resulting in a relatively low pH (pH 3-4) that helps it resist microbial spoilage (Ray and Bhunia, 2013). However, previous studies on fungal contamination in mayonnaise products have frequently reported that acid-tolerant organisms are common contaminants. According to a study, *Z. bailii* is one of the most troublesome species because of its extraordinary ability to withstand stressful situations; for instance, it can withstand temperatures as high as 70 °C in an atmosphere with high glucose levels. Hence, a wide range of acidic or high-sugar foods that are often thought

to be stable during storage, like mayonnaise, can get contaminated with *Z. bailii* (Arroyo-Manzanares *et al.*, 2019). A study investigating fungal contamination in 30 egg-based products (mayonnaise, salad dressing, and coleslaw) found that 20% of the samples were contaminated with yeast and Mold (A. El-Leboud *et al.*, 2011).

Food-borne diseases are on the rise, yet many remain unreported, and public understanding of food safety and risk management practices are low in the domestic market (Munasinghe *et al.*, 2015). Different foodborne infections can result from these microbes. *Saccharomyces cerevisiae*, *Zygosaccharomyces bailii*, and *Pichia membranaefaciens* are not usually harmful, they may spoil food, compromising its safety and quality. But dangerous mycotoxins can be produced by fungi like *Aspergillus* and *Penicillium species*, which can result in allergic responses or other major health problems like aflatoxicosis (Sheikh Imranudin Sheikh-Ali *et al.*, 2014; Sagdic *et al.*, 2016).

Traditional methods for fungal detection in mayonnaise include culturing on media followed by microscopic examination. Molecular techniques, such as PCR and DNA sequencing, offer more rapid and accurate identification of fungal species.

The primary objective of this research is to investigate fungal contamination in mayonnaise products sold in Sri Lanka and assess the associated health risks. The study aims to identify the presence of fungal DNA in mayonnaise samples and determine the specific fungal species present. Additionally, it seeks to evaluate the potential health risks associated with fungal contamination and raise awareness about the issue. By providing recommendations to reduce fungal contamination and its associated risks, the research aims to contribute to the field of biomedical science, particularly in the areas of foodborne pathogens and public health.

Methodology

Sample collection

Five different brands of mayonnaise were randomly selected from local supermarkets. Each sample was assigned a unique code (M1, M2, M3, M4, and M5). To maintain quality, all samples were stored at 4°C in sealed packages until further analysis.

Microbiological detection method

SDA culture Media Preparation and Plating

Sabouraud Dextrose Agar (SDA) was prepared by dissolving 2.5g peptone and 10g dextrose in 150mL distilled water. The volume was adjusted to 250mL, and 3.75g agar was added and dissolved. The solution was sterilized in an autoclave at 121°C for 15 minutes. After cooling to 45-50°C, 1g/L tetracycline was added and mixed. Sterile Petri dishes were filled with the media and incubated at 4°C. For sample preparation, 0.5mL of each mayonnaise sample was diluted 1:2 with distilled water. 0.1mL aliquots were spread onto SDA plates and incubated at 25-30°C for 7-14 days.

Molecular detection method

Isolation of DNA from fungal colonies

To extract DNA from fungal colonies, a CTAB-based method was employed. Fungal colonies were harvested from culture plates and transferred to Eppendorf tubes containing water. The suspension was lysed using CTAB extraction buffer and proteinase K, followed by incubation at 65°C. Chloroform extraction was performed to remove proteins, and DNA was precipitated with CTAB precipitation buffer and isopropanol. The DNA pellet was washed with ethanol, dried, and dissolved in sterile water.

Direct DNA Extraction from Mayonnaise

A modified CTAB-based method was used for direct DNA extraction from mayonnaise. 100 µL of each mayonnaise sample was aliquoted into four tubes. The extraction procedure was similar to the fungal DNA extraction, with pooling of the four tubes for each sample after isopropanol precipitation. The final DNA pellet was dissolved in distilled water. DNA concentration was measured using a Nano Drop spectrophotometer.

PCR amplification

The PCR master mix was prepared according to below Table 02 using primers mentioned in Table 01, and placed in the PCR thermocycler. The cycling conditions were followed as described in Table 03.

Agarose Gel electrophoresis

The PCR products were separated using agarose gel electrophoresis. The gel was stained with ethidium bromide and visualized using an E-Gel Imager System.

Table 01: Primers used for PCR master mix preparation (NCBI gene bank)

Primer	Sequence	Expected band size
ITS1(forward)	5'-TCCGTAGGTGAACCTGCGG-3'	358-771
ITS4 (reverse)	5'-TCCTCCGCTTATTGATATGC-3'	
<i>Aspergillus</i> (forward)	5'-CAGCGAGTACATCACCTTGG-3'	418-522
<i>Aspergillus</i> (reverse)	5'-CCATTGTTGAAAGTTTTAACTGATT-3'	
TRNL ((forward)	5'-GCAAATCGGTAGACGCTACG-3'	500-687
TRNL (reverse)	5'-GGGGATAGAGGGACTTGAAC -3'	

Table 02: The components and volumes used for the preparation of the TRNL, Universal Fungal ITS, and Aspergillus PCR master mixes.

TRNL		Universal fungal		Aspergillus	
Reagents	Volume	Reagents	Volume	Reagents	Volume
10x PCR buffer	2.5	10X PCR buffer	2.5	10X PCR buffer	2.5
10mM dNTP	0.5	10mM dNTP	1.0	10mM dNTP	1.0
10µm TRNL F	1.0	10µ units ITS-1 (F)	1.5	ASAP 1F	1.5
10µm TRNL R	1.0	10µ units ITS-4 (R)	1.5	ASAP 2R	1.5
5µ/µl Dream Taq	0.3	Taq DNA polymerase	0.2	Taq DNA polymerase	0.2
Distilled water	14.7	Distilled water	13.5	Distilled water	15.8
DNA	5	DNA	5	DNA	2.5
Total	25	Total	25	Total	25

Table 03: PCR thermal cycle

Steps	TRNL cycle °C	Time		Uni fungal cycle °C	Time		Aspergillus cycle °C	Time	
Initial Denaturation	94	3 min		94	5 min		94	5 min	
Denaturation	94	1 min	35 cycles	94	30 sec	40 cycles	94	30 sec	35 cycles
Annealing	55	1 min		52	1 min		53	1 min	
Extension	72	1 min		72	1 min		72	1 min	
Final Extension	72	5 min		72	5 min		72	5 min	

Result

Microbiological Analysis Results

DAY: 07

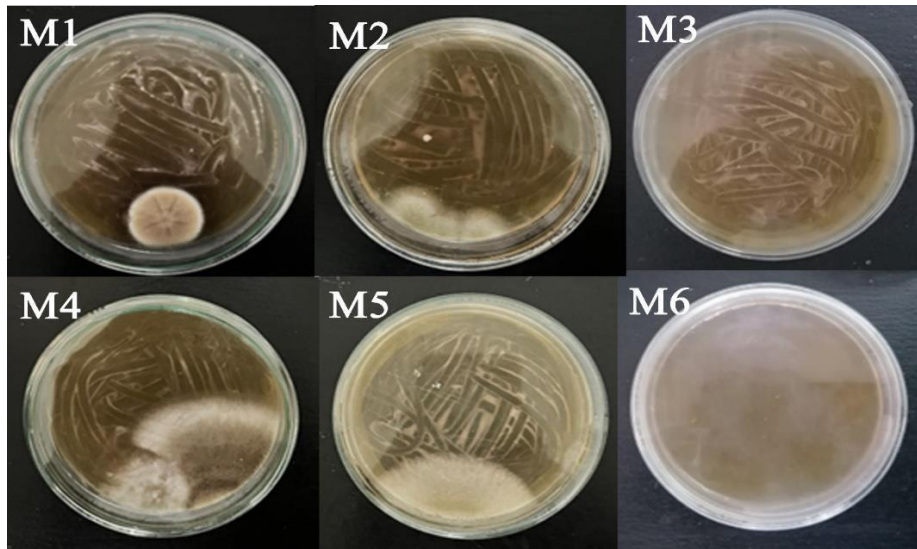


Figure 01: Fungal Growth on SDA Media Over 7 Days

Figure1 shows fungal growth after seven days in samples M1, M2, M4, and M5, while no growth was observed in the sample M3 and negative control (M6).

DAY: 14

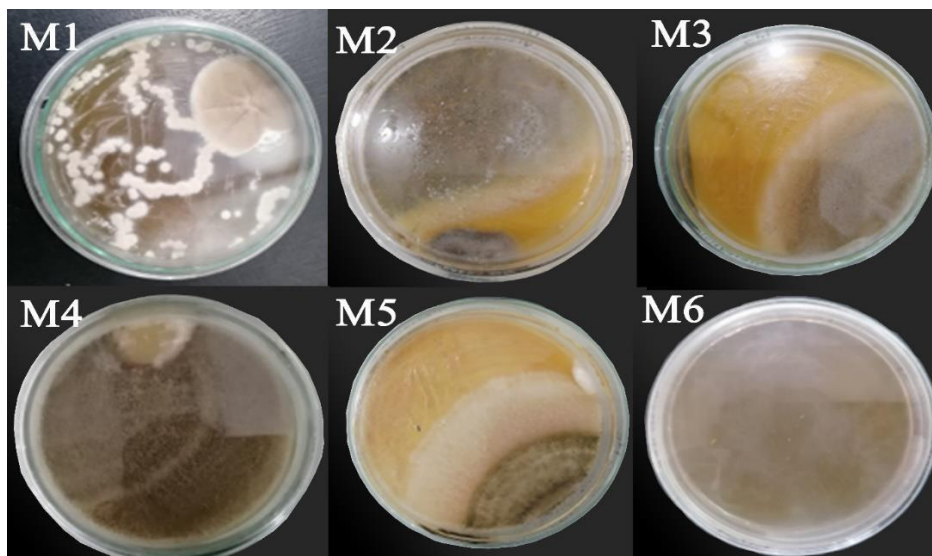


Figure 02: Fungal Growth on SDA Media Over 14 Days

In Figure 02, colony growth on the 14th day demonstrates that all five mayonnaise samples (M1, M2, M3, M4, and M5) exhibited fungal growth no growth in the negative control (M6).

Table 04: Fungal Morphology according to culture plates and Interpretation (information adapted from -Gautam. Ajay, 2013)

Colony Sample	Colony colour	Texture	Identification Based on Morphology
M1	Pinkish cinnamon to deeper with age	Rough, granular	<i>Aspergillus terreus</i>
M2	Green to dark green, becoming black with age	Velvety, smooth	<i>Aspergillus fumigatus</i>
M3	Green to dark green, becoming black with age	Velvety, smooth	<i>Aspergillus fumigatus</i>
M4	Dark cress green	Velvety to powdery	<i>Aspergillus nidulans</i>
M5	Green with white border	Powdery and smooth	<i>Aspergillus flavus</i>
M6 (control)	N/A	N/A	N/A

Results of Molecular Identification

Agarose Gel Electrophoresis images of PCR Products

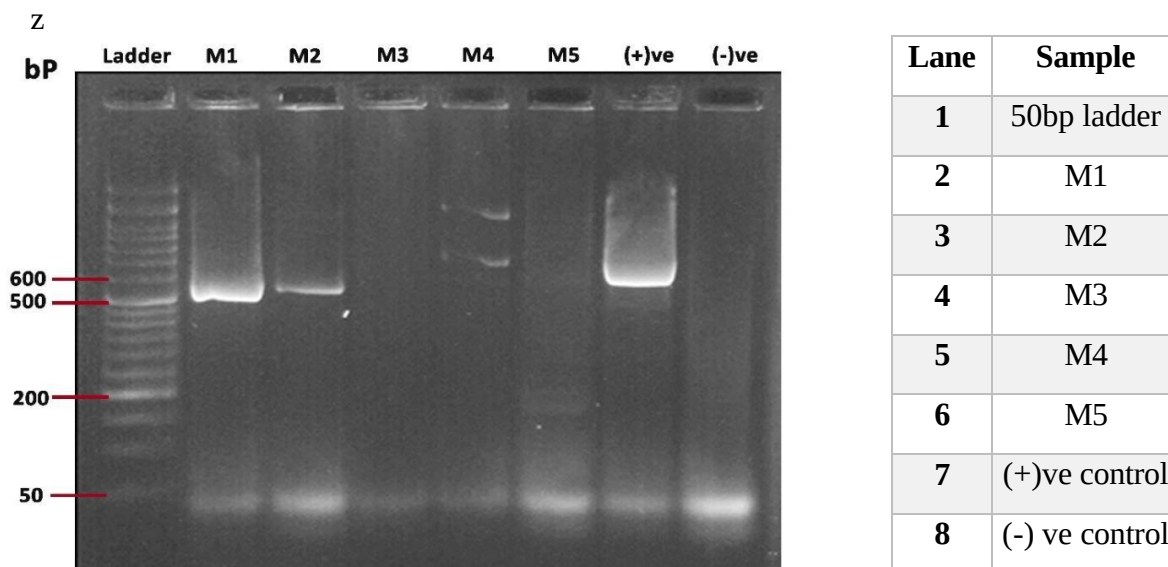


Figure 03: Gel diagram depicting first universal fungal PCR analysis - extracted genomic DNA from fungal colonies

M1, M2 and positive control showing clear bands within expected PCR product sizes frequently lying between **500 to 600 bp**.

In the first PCR, samples **M3, M4, and M5** did not exhibit the expected band size. Therefore, the samples were subjected to a second PCR using appropriately diluted samples, and the results are presented in Figure 6 below.

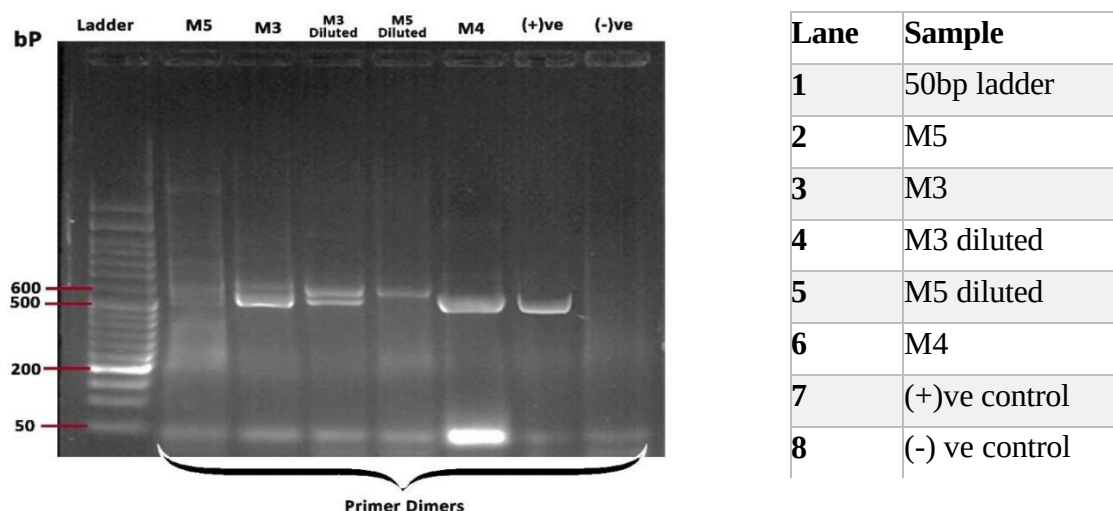


Figure 04: Gel diagram depicting second universal fungal PCR analysis - extracted genomic DNA from fungal colonies

M3, M3 (diluted), M5 (diluted) and M4, positive control showing bands within expected PCR product sizes frequently lying between **500 to 600 bp** confirms fungal DNA presence.

M5 concentrated sample didn't show any DNA fragment.

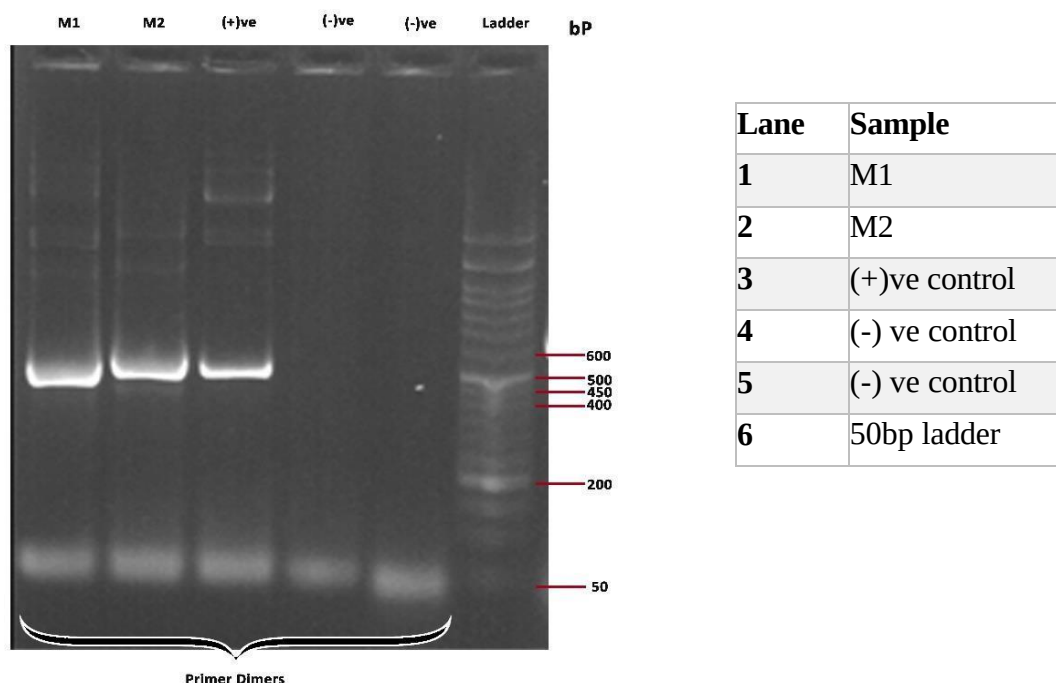


Figure 05: Gel diagram depicting aspergillus PCR analysis - extracted genomic DNA from fungal colonies

M1, M2, and the positive control showed bands within the **450 to 500 bp**, confirming the presence of *Aspergillus*.

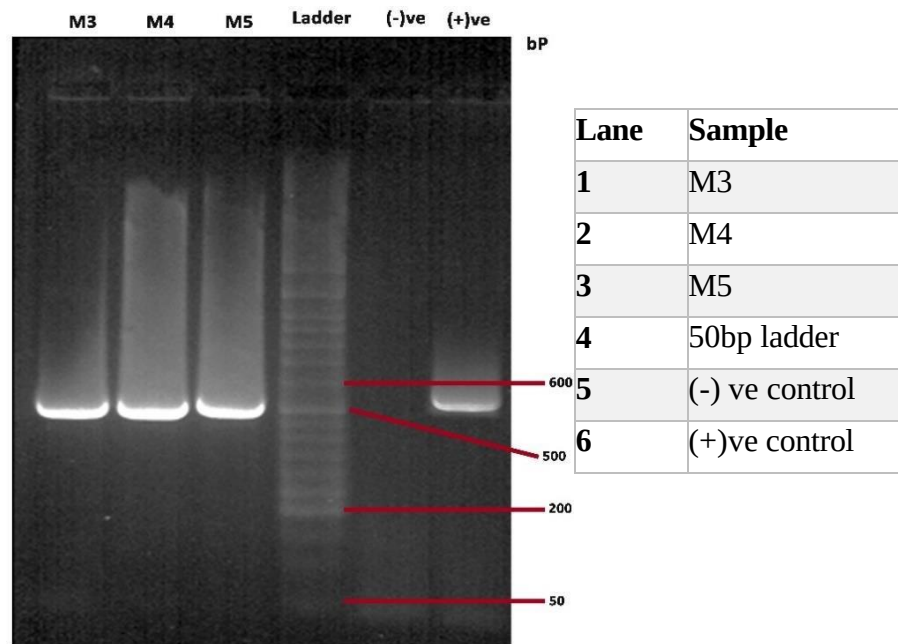


Figure 06: Gel diagram depicting aspergillus PCR analysis - extracted genomic DNA from fungal colonies

M3, M4, M5 and the positive control showed bands **500 bp**, confirming the presence of *Aspergillus*.

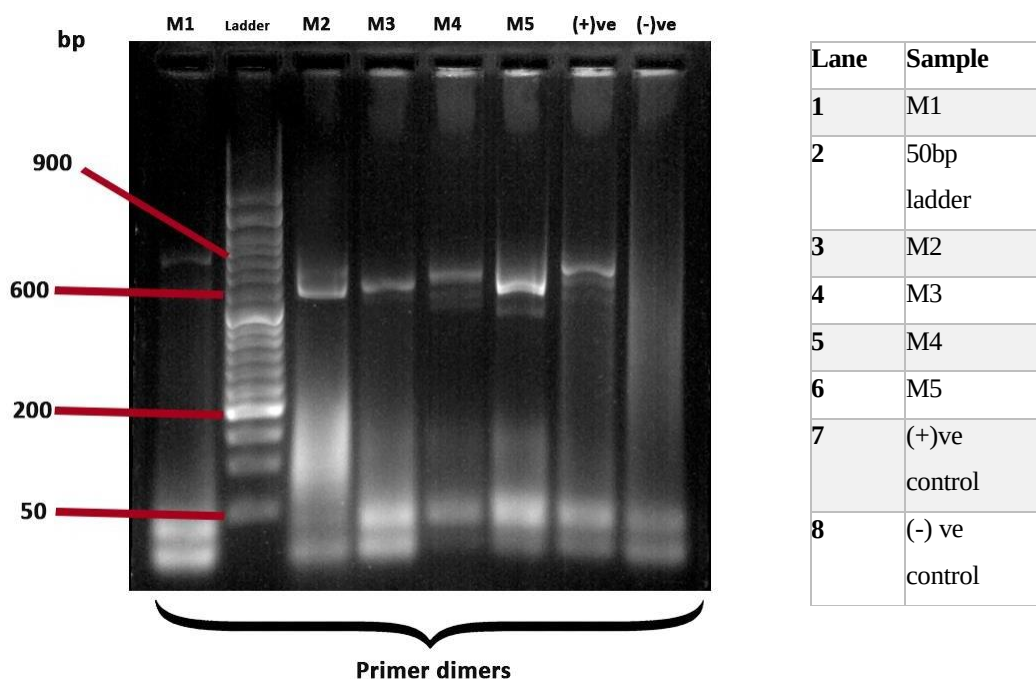


Figure 07: Gel diagram depicting universal PCR analysis – directly extracted DNA from mayonnaise samples

M2, M3, M4, M5 and positive control showing bands within 600 to 771 bp indicate presence of fungal DNA. But **M1** showing faint band within **800-900 bp**.

Discussion

In this research, five mayonnaise products were randomly purchased from local markets. In order to ensure that outcomes could be generalized to other commercially available mayonnaise brands, this random selection was done with the intention of representing the usual consumer's purchasing experience.

All five samples (M1–M5) were ultimately positive for fungal DNA when culturing following DNA extraction method samples analyzed by universal fungal PCR. The bands ranging between 500-600 bp were observed for all five DNA-extracted colony samples (Figure:05; Figure06). Also, all five samples (M1–M5) tested positive for *Aspergillus*, according to the findings (Figure:07; figure:08). All the *Aspergillus* samples showed bands around 500 bp, except for M1, which exhibited a band at 450 bp. Despite this variation, all the bands ultimately aligned within the expected size range (418-522 bp) based on the reference sequences obtained from NCBI Gene bank. This confirms that the PCR amplification for *Aspergillus* was successful and consistent with the reference data, ensuring the accuracy of the identification. *Aspergillus* may be a frequent contaminant in mayonnaise products, as shown by the constant positive across all tests. Ray and Bhunia (2013) noted that in acidic environments, Molds such as *Geotrichum* and *Aspergillus* species can persist in mayonnaise. This statement supports the findings of *Aspergillus* in our study.

Direct DNA extraction from mayonnaise was done to If successful indicate a more rapid detection method for fungi contaminations than using culturing, allow the growth of colonies and then proceed to DNA extraction. Initial single-tube extractions yielded low DNA, prompting the adoption of pooling strategies (2-tube and 4-tube) to increase DNA yield. A TRNL PCR assay was used to validate the extraction method since this assay is particularly significant due to the presence of plant-derived components in mayonnaise, such as oils, vinegar, lime juice, and mustard. While some samples (M1, M4) showed positive results, others exhibited inhibition or low-quality DNA, likely due to mayonnaise's complex composition, which can interfere with PCR amplification. The study found that culturing mayonnaise samples and then extracting DNA from the resulting fungal colonies was a more effective method for detecting fungal contamination compared to direct DNA extraction from the mayonnaise itself and it highlights the challenges of directly extracting DNA from food matrices like mayonnaise and the importance of optimizing extraction techniques to ensure reliable molecular analysis.

Mayonnaise, a lipid-rich food. It consists of 65-80% oil, commonly derived from sunflower, corn, or soybean, which is rich in polyunsaturated fatty acids (PUFAs). These PUFAs are susceptible to lipid oxidation, a process that breaks down fats into by-products like aldehydes and ketones, which creates conditions favourable for fungal growth, especially acid-tolerant species like *Aspergillus* (Unver & Celik, 2023). The presence of corn-derived ingredients, such as corn oil or corn syrup, further increases the risk of *Aspergillus flavus* contamination, especially in tropical climates like Sri Lanka (Chasna, Rajawardana & Amunugoda, 2024).

The contamination of food and feed by *Aspergillus* species has emerged as a significant global

concern, resulting in considerable economic repercussions worldwide. The proliferation of *Aspergillus* is detrimental to the food and feed industries, primarily due to the presence of mycotoxins- harmful metabolites secreted by various *Aspergillus* species (Sheikh Imranudin Sheikh-Ali *et al.*, 2014). *Aspergillus flavus* produces aflatoxins, which are potent carcinogens (IARC, 2002). *Aspergillus fumigatus* is a major cause of invasive aspergillosis in immunocompromised individuals (Taniwaki *et al.*, 2018). While, gastrointestinal aspergillosis can occur in individuals after ingesting *Aspergillus*-contaminated food. Additionally, *Aspergillus* spores can trigger allergic reactions, such as allergic bronchopulmonary aspergillosis (ABPA) (Soliman *et al.*, 2024). Other *Aspergillus* species, such as *Aspergillus niger* and *Aspergillus terreus*, can cause infections in various organs (Paterson & Lima, 2017).

Human handling is a significant source of cross-contamination in food processing. Additionally, poor cleaning of utensils and equipment, along with improper temperature control during transportation and storage, exacerbates the problem (Karanth *et. al*, 2023). To minimize fungal contamination in mayonnaise, it is essential to implement several standard practices alongside innovative additives. Key measures include closely monitoring temperature fluctuations and maintaining stringent hygiene practices during storage and transportation (Karanth *et. al*, 2023). Additionally, production of low-fat mayonnaise, incorporating natural additives, particularly plant extracts with antimicrobial properties, can significantly enhance the safety of mayonnaise (Yanakieva *et al.*, 2023).

Conclusion

This study detected the presence of *Aspergillus* species in all five commercially available mayonnaise samples examined, utilizing both microbiological and molecular detection methods. While this consistent finding suggests a potential pattern of fungal contamination, the limited sample size and potential for procedural variability necessitate cautious interpretation.

To robustly assess the prevalence of fungal contamination in commercially available mayonnaise, further studies with larger sample sizes and multiple trials are imperative. Furthermore, the direct DNA extraction method employed in this study may not have been optimal for all samples, potentially impacting the sensitivity and accuracy of molecular detection. Exploring alternative DNA extraction methods is crucial to enhance the reliability of future investigations. These findings underscore the importance of stringent quality control measures throughout the mayonnaise production and distribution chain to mitigate the risk of fungal contamination and safeguard consumer health.

Furthermore, given the identification of *Aspergillus* in the mayonnaise samples, it is crucial to perform further DNA sequencing to accurately determine the specific *Aspergillus* species present. Additionally, quantifying the fungal load in mayonnaise would provide a more precise assessment of contamination levels, contributing to a better understanding of potential health risks and the severity of contamination.

References

- Ahmed, T. and Uddin, M.A. (2020). Microbiological analysis of popular spreads used in restaurants inside Dhaka city, Bangladesh. *Stamford Journal of Microbiology*, 10(1), pp.16–19. doi:<https://doi.org/10.3329/sjm.v10i1.50727>.
- Akcicek, A., Karasu, S., Bozkurt, F. and Kayacan, S. (2022). Egg Yolk-Free Vegan Mayonnaise Preparation from Pickering Emulsion Stabilized by Gum Nanoparticles with or without Loading Olive Pomace Extracts. *ACS Omega*, [online] 7(30), pp.26316–26327. doi:<https://doi.org/10.1021/acsomega.2c02149>.
- Altunatmaz, S.S., Issa, G. and Aydin, A. (2012). Detection of airborne psychrotrophic bacteria and fungi in food storage refrigerators. *Brazilian Journal of Microbiology*, 43(4), pp.1436– 1443. doi:<https://doi.org/10.1590/s1517-83822012000400027>.
- Arroyo-Manzanares, N., Bohdana Markiv, José Falcón Hernández, López-García, I., Guillén, I., Pascuala Vizcaíno, Hernández-Córdoba, M. and Viñas, P. (2019). Head-space gas chromatography coupled to mass spectrometry for the assessment of the contamination of mayonnaise by yeasts. *Food Chemistry*, 289, pp.461–467. doi:<https://doi.org/10.1016/j.foodchem.2019.03.083>.
- Bellstedt, D.U., Pirie, M.D., Visser, J.C., de Villiers, M.J. and Gehrke, B. (2010). A rapid and inexpensive method for the direct PCR amplification of DNA from plants. *American Journal of Botany*, 97(7), pp.e65–e68. doi:<https://doi.org/10.3732/ajb.1000181>.
- Bhattacharya, S. (2022). *Snack Foods*. Academic Press.
- Chasna, M & Rajawardana, Upeka & Amunugoda, P. (2024). An overview of the impact of climatic change on the occurrence of aflatoxins in cereals: Sri Lankan perspective Introduction to mycotoxins.
- Conlon, B.H., Schmidt, S., Poulsen, M. and Shik, J.Z. (2022). Orthogonal protocols for DNA extraction from filamentous fungi. *STAR Protocols*, [online] 3(1), p.101126. doi:<https://doi.org/10.1016/j.xpro.2022.101126>.
- Fitriana, Y., Suharjo, R., Swibawa, I. G., Purnomo, P., Lestari, P., & Merdiana, E. (2018). Influence of culture medium on the sporulation and viability of aspergillus spp. and talaromyces spp. entomopathogenic fungi. *Jurnal Hama Dan Penyakit Tumbuhan Tropika*, 18(1), 12. <https://doi.org/10.23960/j.hptt.11812-22>
- Gautam, Ajay. (2013). Characterization of Aspergillus species associated with commercially stored triphala powder. *AFRICAN JOURNAL OF BIOTECHNOLOGY*. 11. 16814-16823. 10.5897/AJB11.2311.
- Ihrmark, K., Bödeker, I.T.M., Cruz-Martinez, K., Friberg, H., Kubartova, A., Schenck, J., Strid, Y., Stenlid, J., Brandström-Durling, M., Clemmensen, K.E. and Lindahl, B.D. (2012). New primers to amplify the fungal ITS2 region - evaluation by 454-sequencing of artificial and natural

communities. *FEMS Microbiology Ecology*, 82(3), pp.666–677.
doi:<https://doi.org/10.1111/j.1574-6941.2012.01437.x>.

INTERNATIONAL AGENCY FOR RESEARCH ON CANCER (IARC), 2002. Monograph on the evaluation of carcinogenic risk to human. Some traditional herbal medicines, some mycotoxins, naphthalene and styrene: Summary of data reported and evaluation (Vol. 82)

Karant, S., Feng, S., Patra, D. and Pradhan, A.K. (2023). Linking microbial contamination to food spoilage and food waste: the role of smart packaging, spoilage risk assessments, and date labeling. *Frontiers in Microbiology*, 14. doi:<https://doi.org/10.3389/fmicb.2023.1198124>.

Munasinghe, J., de Silva, A., Weerasinghe, G., Gunaratne, A. and Corke, H. (2015). Food safety in Sri Lanka: problems and solutions. *Quality Assurance and Safety of Crops & Foods*, 7(1), pp.37–44. doi:<https://doi.org/10.3920/qas2014.x007>.

N. Unver and S. Çelik (2023). Effect of antioxidant-enriched microcrystalline cellulose from almond residue on physicochemical and textural characteristics of mayonnaise. *Grasas y Aceites*, 74(2), pp.e507–e507. doi:<https://doi.org/10.3989/gya.0891211>.

Paterson, R. Russell M., and Nelson Lima, (2017) Filamentous Fungal Human Pathogens from Food Emphasising *Aspergillus*, *Fusarium* and *Mucor*. *Microorganisms*, 5(3), p.44. doi:<https://doi.org/10.3390/microorganisms5030044>.

Rahim, S. M., Ibrahim, R., Jamaluddin, T. Z. T., Amran, F., Omar, N., & Masri, S. N. (2022). Molecular identification of fungi causing tissue mycoses from formalin fixed paraffin embedded (ffpe) archive specimens. *Laboratory R_t*, 18(s21), 80-86. <https://doi.org/10.47836/mjmhs.18.s21.13>

Ray, B., & Bhunia, A. (2013). *Fundamental food microbiology* (5th ed.). CRC Press.

Sagdic, O., Tornuk, F., Karasu, S., Durak, M.Z. and Arici, M. (2016). Microbial ecology of mayonnaise, margarine, and sauces. *Quantitative Microbiology in Food Processing*, pp.519–532. doi:<https://doi.org/10.1002/9781118823071.ch26>.

Sheikh Imranudin Sheikh-Ali, Ahmad, A., Siti Hamidah Mohd-Setapar, Zainul Akmar Zakaria, Norfahana Abd-Talib, Aidee Kamal Khamis and Hoque, E. (2014). The potential hazards of *Aspergillus* sp. in foods and feeds, and the role of biological treatment: A review. *Journal of Microbiology*, 52(10), pp.807–818. doi:<https://doi.org/10.1007/s12275-014-4294-7>.

Soliman, N.S.M., Amro, F.H., Algabaly, A.A. and Abdelsalam, A.B., (2024). Detection of Mold and Aflatoxin B1 in Mayonnaise Product from Egyptian Markets by HPLC. *Journal of Applied Veterinary Sciences*, 9(4). Available at: <<https://javs.journals.ekb.eg>> [Accessed 11 September 2024].

Syromyatnikov, M.Y., Kokina, A.V., Savinkova, O.V., Panevina, A.V., Solodskikh, S.A., Orlova, M.V., Grabovich, M.Y., Starkov, A.A. and Popov, V.N. (2018). Study of the microbiological

composition of dairy products and mayonnaise using dna barcoding and metabarcoding. *Foods and Raw materials*, 6(1), pp.144–153. doi:<https://doi.org/10.21603/2308-4057-2018-1-144-153>.

Taniwaki MH, Pitt JI, Magan N, Aspergillus species and mycotoxins: occurrence and importance in major food commodities, *Current Opinion in Food Science* (2018), <https://doi.org/10.1016/j.cofs.2018.05.008>

Tornai-Lehoczki, J. (2003). CHROMagar Candida medium as a practical tool for the differentiation and presumptive identification of yeast species isolated from salads. *International Journal of Food Microbiology*, 86(1-2), pp.189–200. doi:[https://doi.org/10.1016/s0168-1605\(03\)00256-3](https://doi.org/10.1016/s0168-1605(03)00256-3).

Yanakieva, V., Parzhanova, A., Dimitrov, D., Vasileva, I., Raeva, P., Ivanova, S. (2023): Study on the antimicrobial activity of medicinal plant extracts and emulsion products with integrated herbal extracts. *Agriculture and Forestry*, 69 (4): 71-89. doi:10.17707/AgricultForest.69.4.06

EVALUATING BACTERIAL CONTAMINATION ON SALON COMBS IN COLOMBO, SRI LANKA: ASSESSMENT OF POTENTIAL HEALTH RISKS

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Abstract

Salon combs, being frequently reused tools, are potential reservoirs for bacterial contamination, posing significant public health risks. This study evaluates bacterial contamination on salon combs in Colombo, Sri Lanka, with a focus on identifying potential health risks and improving hygiene practices in salon environments. Samples were collected aseptically from combs in five salons, cultured on Luria-Bertani (LB) media, and subjected to colony morphology assessments, microscopic examination, and molecular analysis using PCR. Fourteen bacterial isolates were identified, including *Staphylococcus spp.* (57.14%), *Escherichia coli* (28.57%), *Bacillus spp.* and *Micrococcus spp.* (7.14% each). *Staphylococcus spp.* was the most prevalent species identified, reflecting its dual role as both a commensal skin microorganism and a potential pathogen. The findings demonstrate that current cleaning methods, primarily involving liquid soap and water, are insufficient to achieve effective microbial decontamination. These results highlight the necessity of implementing stringent disinfection protocols, regular training programs for salon staff, and regulatory frameworks to mitigate bacterial transmission risks and safeguard public health.

Keywords: Bacterial Contamination, Hair Combs, Public Health, Salon Hygiene

Introduction

Beauty salons, as part of the personal care industry, are significant workplaces with potential exposure to biological hazards (Mancini *et al.*, 2018). Hairdressing operators and clients are frequently exposed to bacterial and fungal contaminants during routine services, primarily due to the use of shared tools such as combs, brushes, and nail implements, which act as fomites for microbial transmission. Commonly isolated bacteria from beauty salons, such as *Staphylococcus aureus*, *Escherichia coli*, *Micrococcus luteus*, *Streptococcus spp.*, and *Bacillus subtilis*, can penetrate the host primarily through traumatic breaks in the skin barrier during procedures like hair cutting, shaving, or manicures (Aso *et al.*, 2022; Stanley *et al.*, 2019). Additionally, *Staphylococcus aureus* and certain *Streptococcus* species have the potential for transdermal penetration, though less readily (Alkuraythi, 2024). These bacteria can cause skin and scalp infections such as impetigo and folliculitis and, in severe cases, may lead to systemic complications like bacteremia, pneumonia, and septicemia, particularly in immunocompromised individuals (Stanley *et al.*, 2019; Kumari, 2021). Salons commonly use various chemical and

physical sterilization techniques to disinfect tools and equipment. However, improper implementation of these procedures can lead to microbial contamination. Combs, frequently used throughout the day, come into contact with multiple customers, accumulating bacteria from the stylist's hands, hair products, and scalp (Stanley *et al.*, 2019).

In Sri Lanka, the lack of stringent hygiene regulations in salons leads to inconsistent cleaning and disinfection, resulting in high bacterial loads on equipment and posing health risks to patrons. Despite the recognized public health concern, limited research has been done on bacterial contamination in these environments, highlighting the need for further studies. This study aims to evaluate bacterial contamination on salon combs, assess the prevalence of contamination, and identify pathogenic species. It will also examine the effectiveness of current hygiene protocols and the awareness of salon owners regarding the health risks. The findings will promote improved sanitation practices, reducing the spread of infections and enhancing public health standards in the salon industry across Colombo and beyond.

Materials and methods

Ethical Consideration

Ethical approval was sought from Cardiff School of Sport and Health Sciences under the Cardiff Metropolitan University Ethics Framework. A letter of Consent, accompanied by a questionnaire and a Participant Information Sheet were presented to the salon owners before the commencement of the study. (Project reference number; UG-9664)

Sample Collection and Inoculation

Samples were collected from five hairdressing salons within the Colombo district, Sri Lanka. Aseptic sampling was conducted using sterile cotton swabs pre-moistened with sterile distilled water. Following collection, the swabs were immediately placed into sterile containers, appropriately labeled, and transported to the laboratory under controlled conditions to prevent contamination. In the laboratory, the swabs were streaked onto Luria-Bertani (LB) agar plates and incubated at 37°C for 24 hours to facilitate bacterial growth

Microbial Identification

Morphological Identification

The 14 bacterial isolates were first identified based on their colonial characteristics such as colour, shape and size and were further identified using gram staining under 100x magnification (Figure 1) with reference to Hetem *et al.*, 2017; Agarwal *et al.*, 2022 ; Taylor and Unakal, 2023; Shobha *et al.*, 2024; Son and Taylor, 2021; Hossain *et al.*, 2021; Lu *et al.*, 2018; Riedel *et al.*, 2019; Roshdy *et al.*, 2019; Batt and Tortorello, 2014 (Table1)

Molecular Identification

DNA was extracted using the boiling method, and PCR was conducted with species-specific primers targeting the 16S rRNA gene for *Escherichia coli* (F: 5'-CAT TGA CGT TAC CCG CAG AA-3'; R: 5'-CGC TTT ACG CCC AGT AAT TCC-3') and *Staphylococcus spp.* (F: 5'-GGC CGT GTT GAA CGT GGT CAA ATC A-3'; R: 5'-TIA CCA TTT CAG TAC CTT CTG GTA A-3'). Amplification products were analyzed by 2% agarose gel electrophoresis using a 50 bp DNA ladder for confirmation (Figure 2 and 3).

D. Survey Of Hygiene Practices

Salons were assessed for cleaning protocols, types of disinfectants used, and staff awareness of hygiene-related health risks.

Results

All five collected swab samples yielded positive bacterial growth, resulting in 14 bacterial isolates (Table 2). Among these, *Staphylococcus spp.* was the most prevalent, with 8 isolates (57.14%), detected in four out of five salons. This was followed by *Escherichia coli*, with 4 isolates (28.57%) identified in three salons. *Micrococcus spp.* and *Bacillus spp.* were each represented by 1 isolate (7.14%) and were found in one salon each (Figures 4 and 5).

Table 1. Cultural, microscopic and molecular identification of the bacterial isolates

Characteristics	Isolates			
Cultural				
Colour	Yellow, cream, white	White	Yellow	Gray - white
Shape	Circular	Circular	Circular	Circular
Size	Small	Small	Small	Medium
Elevation	Low convex	Convex	Convex	Flat
Microscopic				
Gram staining	+	-	+	+
Cell type	Cocci	Rod	Cocci	Rod
Cell arrangement	Clusters	Single	Clusters	Chains
Molecular (16S rRNA)				
Band size	370bp	100bp		
Possible isolates	<i>Staphylococcus</i> spp.	<i>Escherichia coli</i>	<i>Micrococcus</i> spp.	<i>Bacillus</i> spp.

Table 2. Distribution of bacterial contaminants on salon combs

<i>Salon ID</i>	Sample ID	Bacterial isolates
<i>Salon A</i>	A1	<i>Staphylococcus</i> spp.
	A2	<i>Staphylococcus</i> spp.
	A3	<i>Staphylococcus</i> spp.
<i>Salon B</i>	B1	<i>Escherichia coli</i>
	B2	<i>Escherichia coli</i>
<i>Salon C</i>	C1	<i>Bacillus</i> spp.
	C2	<i>Staphylococcus</i> spp.
	C3	<i>Staphylococcus</i> spp.
	C4	<i>Escherichia coli</i>

<i>Salon D</i>	D1	<i>Micrococcus</i> spp.
	D2	<i>Staphylococcus</i> spp.
<i>Salon E</i>	E1	<i>Staphylococcus</i> spp.
	E2	<i>Staphylococcus</i> spp.
	E3	<i>Escherichia coli</i>
	Total isolates	14

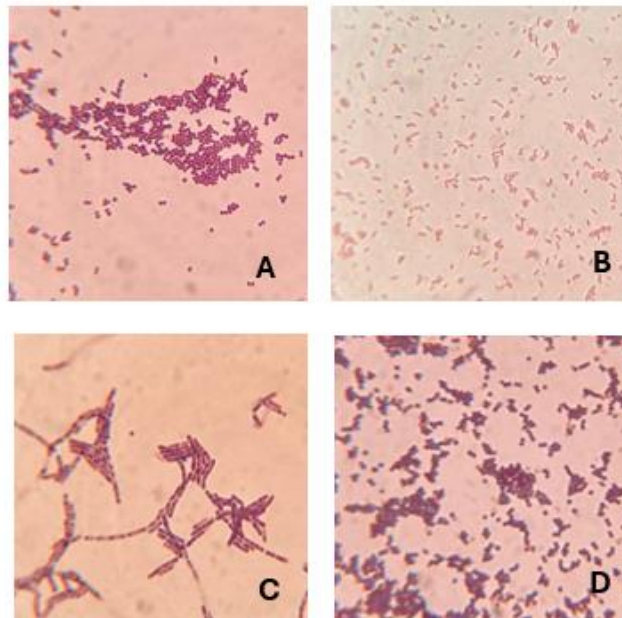


Figure 1. Microscopic examination of Bacterial isolates at 100x magnification. (A) *Staphylococcus* spp. (Isolate A1), (B) *Escherichia coli* (Isolate B1), (C) *Bacillus* spp. (Isolate C1), (D) *Micrococcus* spp. (Isolate D1).

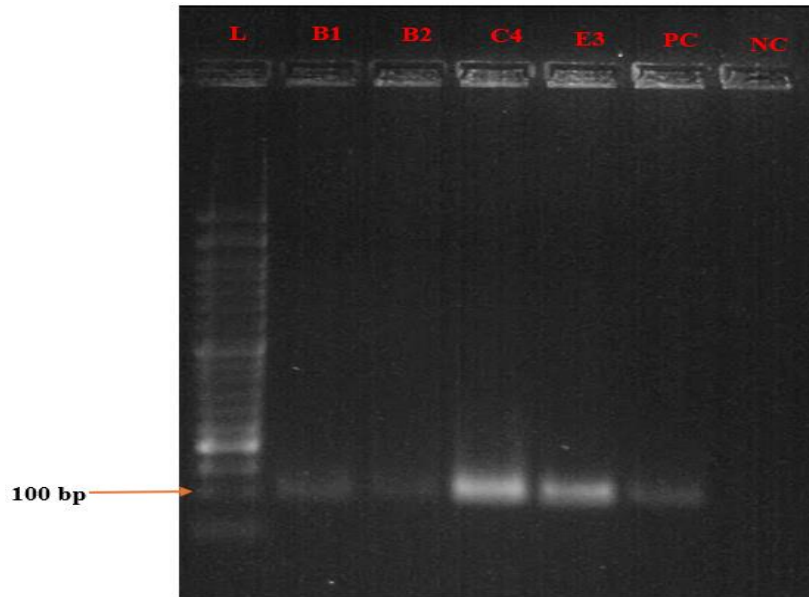


Figure 2. Genus specific PCR of *Escherichia coli* for 16S rRNA gene (100 bp). [L: 50 bp plus ladder, B1, B2, C4, and E3: Samples positive for *Escherichia coli* isolated from salon combs, PC: Positive control, NC: Negative control]

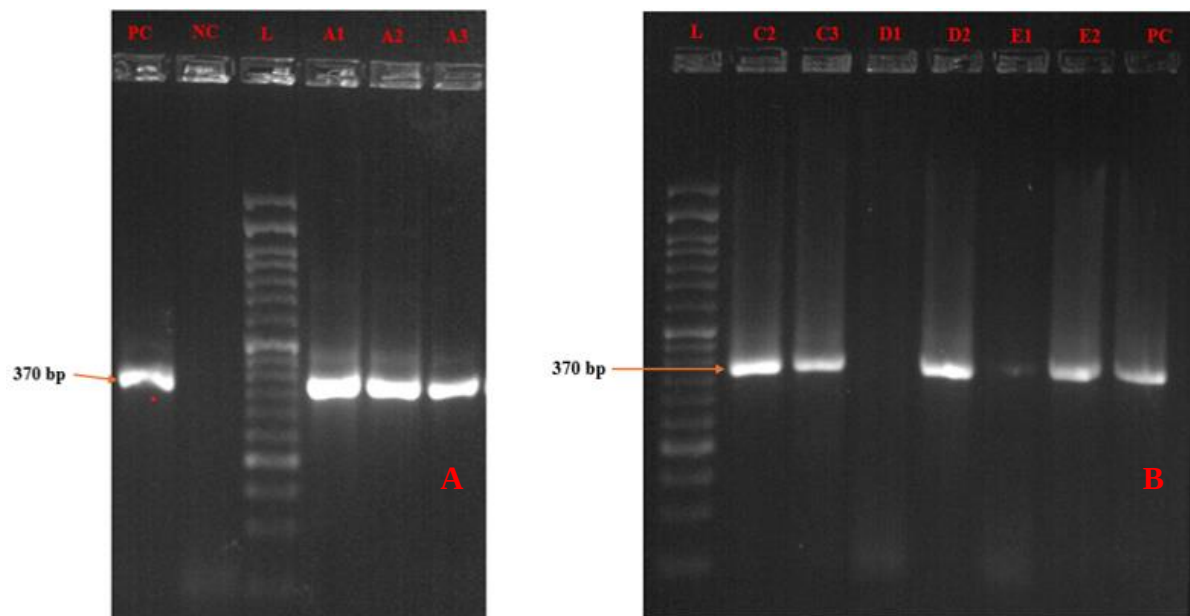


Figure 3. Genus specific PCR of *Staphylococcus* spp. for 16S rRNA gene (370 bp) ; (A) [PC: Positive control, NC: Negative control, L: 50 bp plus ladder, A1, A2, and A3: Samples positive for *Staphylococcus* spp. isolated from salon combs] (B) [L: 50 bp plus ladder, C2,C3,D2,E, E2 : Samples positive for *Staphylococcus* spp. isolated from salon combs, D1: Negative sample, PC: Positive control]

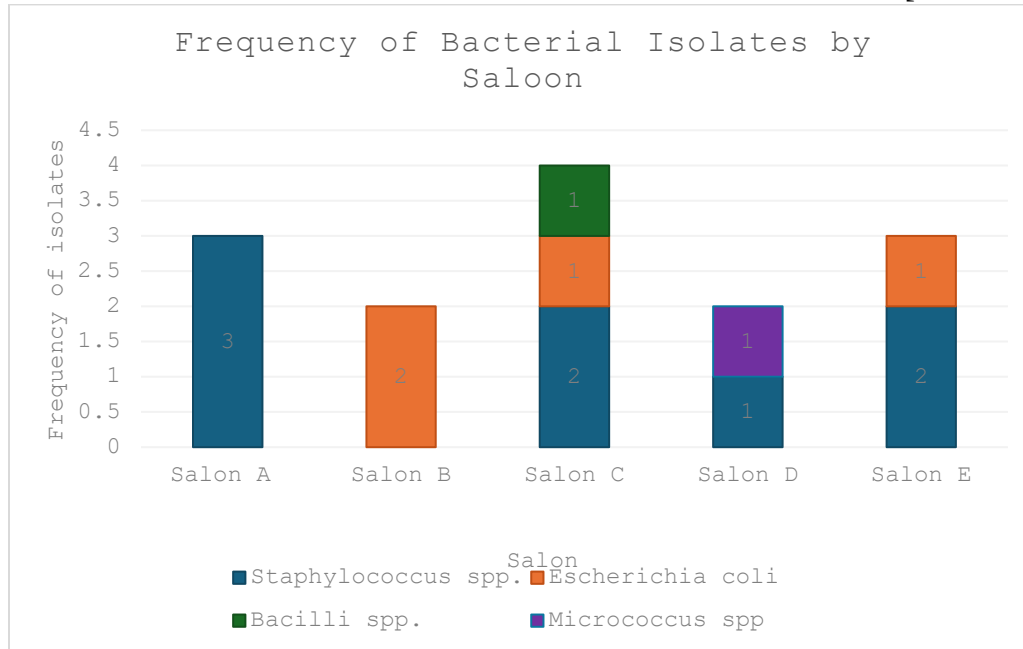


Figure 4- Frequency of Bacterial Isolates by Saloon

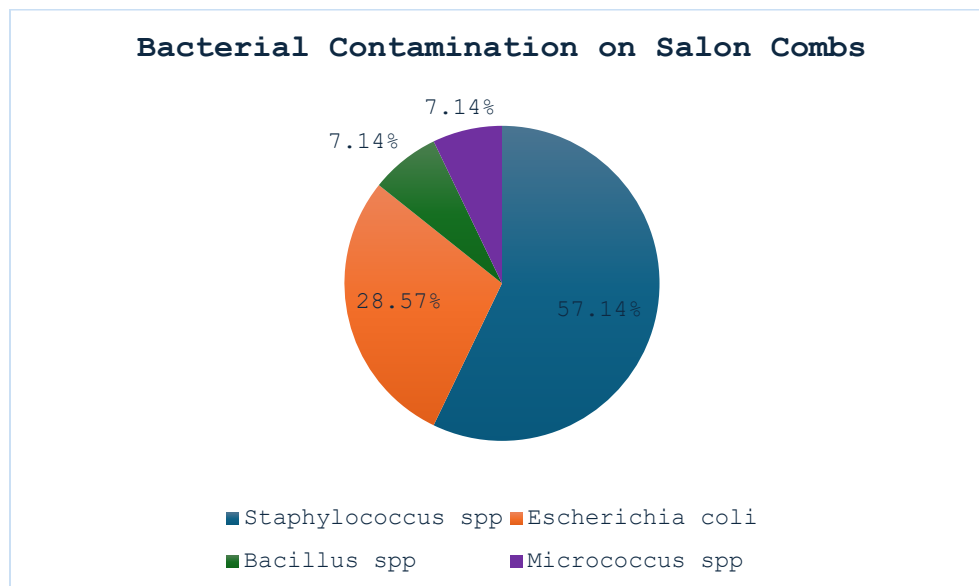


Figure 5 - Percentage Distribution of Bacterial Isolates on Salon Combs

All salons adhered to comb cleaning protocols with varying frequencies: after each use, twice a week, thrice a week, or weekly, predominantly using liquid soap and water (Figure 5). All salons exclusively used plastic combs. Some salons reported time constraints as a barrier to maintaining regular cleaning practices. Additionally, all salons practiced hand hygiene before and after client interactions and demonstrated awareness of the health risks associated with bacterial contamination (Table 3).

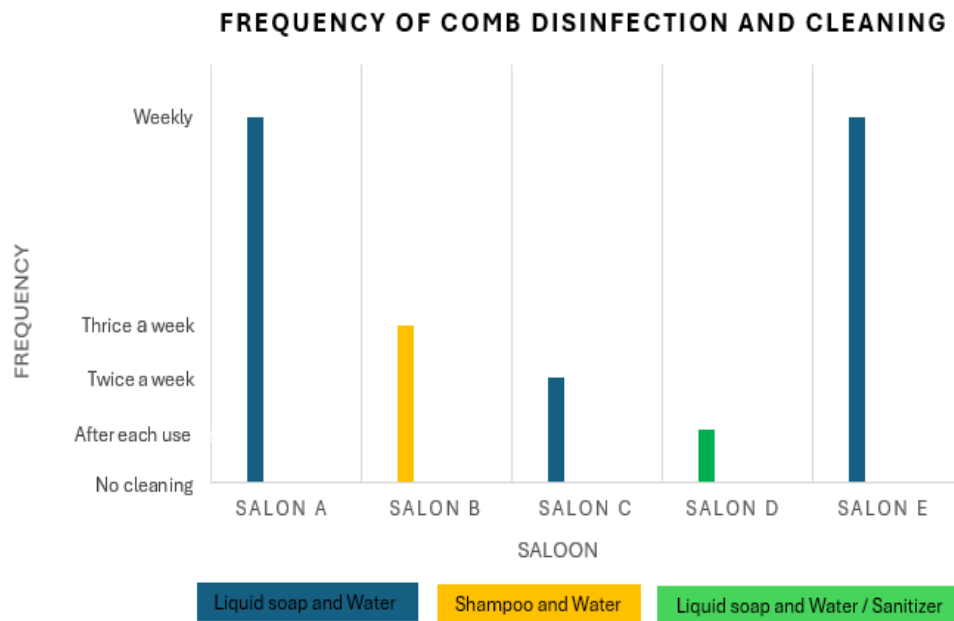


Figure 6. Disinfection and Cleaning Frequency of Combs by Salons and Cleaning Methods

Table 3 - Comparison of Cleaning and Disinfection Methods and Staff Awareness of Health Risks Across Different Salons

	Salon A	Salon B	Salon C	Salon D	Salon E
Adherence to Cleaning Protocols	Yes	Yes	Yes	Yes	Yes
Challenges in maintaining hygiene.	No	Yes – Time constraints	No	No	No
Awareness of the potential health risks associated with bacterial contamination on salon combs	Yes	Yes	Yes	Yes	Yes
Hand hygiene practices before and after each client interaction	Yes	Yes	Yes	Yes	Yes
Hand hygiene methods employed.	Hand wash and water	Hand sanitizer handwash/water	Hand wash and water	Handwash and water	Handwash and water
Types of combs commonly used.	Plastic	Plastic	Plastic	Plastic	Plastic

Discussion

The detection of *Staphylococcus spp.*, *Escherichia coli*, *Bacillus spp.*, and *Micrococcus spp.* in this study aligns with findings by Stanley *et al.* (2019) and Evbuomwan *et al.* (2019), who reported similar bacterial contaminants in hairdressing salons in Rivers State and Benin City, Nigeria.

Staphylococcus spp., a common skin commensal, was the predominant isolate in this study, aligning with findings by Janmohammadi *et al.* (2016) and Hassan *et al.* (2018), who similarly reported *Staphylococcus spp.* as the most prevalent bacterial isolate in their research. Within this genus, *Staphylococcus aureus* and *Staphylococcus epidermidis* are the most frequently identified species in salon environments (Alharbi and Alhashim, 2021b; Aso *et al.*, 2022). *Staphylococcus aureus* is a prominent pathogen frequently identified in skin and soft tissue infections, including abscesses, impetigo, staphylococcal scalded skin syndrome, and cellulitis. While *S. aureus* infections typically remain localized, in rare instances, bacterial entry through breaches in skin integrity during salon procedures, hematogenous spread from a localized infection, or transmission via contaminated hands, tools, or linens can lead to severe systemic manifestations such as pneumonia and septicemia, particularly in vulnerable individuals (Stanley *et al.*, 2019; Taylor and Unakal, 2013; Clatworthy, 2014; Bush, 2025). In contrast, *S. epidermidis* acts as an opportunistic pathogen, causing infections such as endocarditis, particularly in immunocompromised individuals (Lee and Anjum, 2023).

Escherichia coli, the second most prevalent isolate, aligns with Aso *et al.* (2022), who similarly identified *E. coli* as the second most common bacterial contaminant in salons. Its presence suggests fecal contamination, with pathogenic strains linked to urinary tract infections, diarrhea, and systemic conditions such as bacteremia and pneumonia (Mireles *et al.*, 2015; Mueller *et al.*, 2023).

Bacillus spp. and *Micrococcus spp.*, although generally considered non-pathogenic, have the potential to cause opportunistic infections under certain conditions. *Bacillus spp.* can produce toxins that may result in food poisoning and gastrointestinal illnesses (Alharbi and Alhashim, 2021). Similarly, *Micrococcus spp.* has been implicated in infections such as septic arthritis, recurrent bacteremia, and pneumonia, particularly in immunocompromised individuals (Batt and Tortorello, 2014).

Antibiotic resistance in *Staphylococcus spp.* and *Escherichia coli*, as highlighted by Aso *et al.* (2022), poses significant public health concerns. Resistance to commonly used antibiotics, including Augmentin, Ampicillin, and Cotrimoxazole, complicates treatment strategies and increases the severity of infections. There have been documented cases, including a MRSA infection following a beauty treatment in London, UK. According to 2018 statistics from the National Hairdressers Federation and National Beauty Federation in the UK, hairdressers, barbers, and beauty therapists report among the highest rates of work-related skin diseases (Abeyrathna, 2019).

The detection of bacterial isolates highlights the inadequacy of common cleaning methods, such as liquid soap, water, or sanitizer, for effective disinfection. The Australian government's 2024 guidelines recommend cleaning combs by removing hair, scrubbing with warm water and detergent, rinsing with hot water, and drying with a lint-free cloth. However, chemical disinfection with 70% alcohol or hospital-grade disinfectants is advised for enhanced microbial control. UV sterilizers offer an additional effective sterilization method.

The Australian government also advises hairdressers to wash their hands frequently, especially before and after each client, after disruptions (e.g., phone calls), and following activities like eating, drinking, or coughing, to reduce intrapersonal, interpersonal, and environmental bacterial transmission. Alcohol-based hand rubs (ABHRs) are recommended as a quick and effective alternative to soap and water. High-touch surfaces should also be disinfected regularly to reduce pathogen accumulation and cross-contamination risks.

This study found that all salons use plastic combs, which are prone to microbial colonization (Anunobi, 2022). Future research could explore whether certain comb materials are more effective in disinfection or resistant to bacterial growth. Offering disposable combs for a nominal fee could further mitigate the risk of pathogen transmission, enhancing overall sanitation practices in salons.

The outcomes of this study may be limited by the variety of microorganisms present in the collected samples. The culture media and methods utilized may not have been adequate to isolate all contaminants effectively. Larger sample sizes, repeated testing, accurate estimates of salon service users or individuals seeking medical treatment related to salon services are needed for more comprehensive risk assessments. Notably, this study contributes to the literature by employing molecular techniques to confirm genus-specific bacterial contamination, particularly *Staphylococcus* spp. and *Escherichia coli*. Further biochemical analyses, molecular characterization, or sequencing are recommended for precise identification.

Conclusion

Despite its limitations, this study highlights that salon combs in Colombo, the commercial capital of Sri Lanka, harbor bacterial contaminants, some of which are pathogenic, posing a risk of infections. The findings suggest the need for client education on the risks of bacterial contamination from tools like combs and encourage verifying sterilization before use. Public health campaigns, including clear, informative posters and client feedback systems, can enhance hygiene awareness and practices.

The study highlights the urgency for Sri Lanka to implement comprehensive hygiene regulations for salons, like those in Australia. Establishing clear health and safety guidelines, enforcing compliance, and offering incentives for high hygiene standards can drive improvements. Collaborative efforts between the government and salons, such as community events promoting hygiene, can further raise awareness. Ongoing training for salon staff on best practices and public health issues is essential for maintaining high hygiene standards and reducing bacterial contamination, ultimately safeguarding public health.

References

Abeyrathna, A. (2019). Care for Your Hair: Need of Having a Regulatory Mechanism on ‘Hair-Dressers’ in Sri Lanka To Improve Health and Safety Practices. *International Journal of Business, Economics and Law*, [online] 19. Available at: https://www.ijbel.com/wp-content/uploads/2019/10/LAW_07.pdf [Accessed 18 Jul. 2024].

- Alharbi, N. and Alhashim, H.M. (2021a). Identification of Pathogenic Microbes in Tools of Beauty Salon in Jeddah City. *Biosciences Biotechnology Research Asia*, 18(4), pp.743–756. doi:<https://doi.org/10.13005/bbra/2956>.
- Alharbi, N.M. and Alhashim, H.M. (2021b). Beauty Salons are Key Potential Sources of Disease Spread. *Infection and Drug Resistance*, Volume 14, pp.1247–1253. doi:<https://doi.org/10.2147/idr.s303461>.
- Aso, R.E., C. Hammuel, Ade, T.I., J. Briska and Hyelnaya, C.S. (2022). Microbial Contamination of Applied Instrument in Female Hair-Dressers Salon in Wukari, Taraba State, Nigeria. *European journal of biology and biotechnology*, 3(2), pp.45–48. doi:<https://doi.org/10.24018/ejbio.2022.3.2.361>.
- Batt, C.A. and Tortorello, M.L. (2014). *Encyclopedia of Food Microbiology (Second Edition)*. Academic Press.
- Bush, L.M. (2025). *Staphylococcus aureus Infections*. [online] MSD Manual Consumer Version. Available at: <https://www.msdmanuals.com/home/infections/bacterial-infections-gram-positive-bacteria/staphylococcus-aureus-infections>.
- Department of Health of Western Australia . Guideline for the Management of Public Health Risks Associated with the Hairdressing and Barber Industry Public Health Act 2016 (WA) . 2024, www.health.wa.gov.au/~media/Corp/Documents/About-us/Public-Health-Act/Guideline-for-the-hairdressing-industry.pdf.
- Evbuomwan, L., Chukwuka, P.E. and Ebiala, F.I. (2019). Isoalation of Multidrug Resistant Bacterial Pathogens from Human Hair Obtained from Barbing Salons Located within Benin City, Nigeria. *South Asian Journal of Research in Microbiology*, [online] pp.1–7. doi:<https://doi.org/10.9734/sajrm/2018/v2i430074>.
- F. Janmohammadi, G. Fathi, D. Roshani and Kayvan Farahm (2016). Evaluation of Bacterial and fungal Contaminations in Barbershops in Kamyaran city, Iran-Summer 2015. [online] SemanticScholarR. Available at: <https://www.semanticscholar.org/paper/Evaluation-of-Bacterial-and-fungal-Contaminations-Janmohammadi-Fathi/6940214df74515ab147145f176b07d0e080b88e5>.
- Flores-Mireles, A.L., Walker, J.N., Caparon, M. and Hultgren, S.J. (2015). Urinary Tract infections: epidemiology, Mechanisms of Infection and Treatment Options. *Nature Reviews Microbiology*, [online] 13(5), pp.269–284. doi:<https://doi.org/10.1038/nrmicro3432>.
- Lee, E. and Anjum, F. (2023). Staphylococcus epidermidis infection. [online] PubMed. Available at: <https://www.ncbi.nlm.nih.gov/books/NBK563240/>.
- Mueller, Matthew, and Christopher R. Tainter. “Escherichia Coli Infection.” PubMed, StatPearls Publishing, 13 July 2023, www.ncbi.nlm.nih.gov/books/NBK564298/.
- Stanley, H.O., Oba, T.T. and Ugboma, C.J. (2019). Evaluation of Microbial Contamination of Combs and Brushes in Beauty Salons within the University of Port Harcourt, Rivers State, Nigeria. *Archives of Current Research International*, pp.1–7. doi:<https://doi.org/10.9734/acri/2019/v16i230088>.
- Taylor, T.A. and Unakal, C.G. (2023). *Staphylococcus aureus infection*. [online] National Library of Medicine. Available at: <https://www.ncbi.nlm.nih.gov/books/NBK441868/>.
- World Health Organization (2018). *E. coli*. [online] World Health Organization. Available at: <https://www.who.int/news-room/fact-sheets/detail/e-coli>.

A CROSS SECTIONAL SURVEY ON THE AWARENESS OF CAMPYLOBACTERIOSIS AMONG SRI LANKAN ADULTS

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Abstract

Campylobacteriosis is a foodborne disease responsible for affecting millions of people each year. This study assessed the overall awareness of campylobacteriosis among Sri Lankan adults, addressing a critical gap in public health research of Sri Lankan context. A quantitative cross-sectional survey was conducted, collecting 445 responses via an online questionnaire. Overall awareness and significant differences in awareness in terms of demographic factors were analyzed using ANOVA and Post hoc Bonferroni tests in SPSS. Findings revealed lower/moderate overall awareness (2.89 ± 1.16) among Sri Lankans. Significant differences in awareness were observed across demographic factors: younger adults (18–29), those with lower education levels, residents of the Northern Province, and unemployed individuals had notably lower awareness. The study highlights the need for targeted public health campaigns focusing on underserved populations, including younger populations, rural residents, and those with lower education. Future research should explore awareness-behavior correlations, conduct large-scale prevalence studies, and implement continuous surveillance to strengthen prevention strategies.

Key Words: Awareness, Bacteria, Campylobacter, Campylobacteriosis, Food-borne

Introduction

Campylobacteriosis is a leading foodborne zoonotic disease caused by *Campylobacter* spp. *Campylobacter* has emerged as a predominant pathogen responsible for human foodborne diseases globally affecting millions of people each year (Amin, Mahmood and Zorab, 2023). The WHO has recognized *Campylobacter* to be the number 1 of the 4 key global causes of diarrhea and that at least 1 in 10 individuals suffer from campylobacteriosis annually (WHO, 2020). The high prevalence and potential health impacts of campylobacteriosis, renders it very important from a socio-economic standpoint especially in low- and middle-income countries (LMIC) like Sri Lanka.

Campylobacter spp are rod-shaped gram-negative bacteria with around 17 species identified so far. Out of these, *C. jejuni* and *C. coli* are mostly associated with human campylobacteriosis (Cdc.gov, 2024). Several studies conducted in Sri Lanka also identified the presence of *C. jejuni* and *C. coli* in selected poultry farms around Sri Lanka (Perera *et al.*, 2024), (Kottawatta *et al.*, 2017).

Campylobacter spp. is predominantly harbored in farm animals and pets (Mahmud, 2024). Humans contract the bacteria primarily through consuming undercooked meat, contaminated milk or water, or through contact with animal waste (Bush and Pertejo, 2024). While poultry remains the largest source of infection, poor sanitation, unsafe food practices, and economic constraints increase transmission risks in Sri Lanka. Vulnerable groups, including children under five, elderly, and

immunocompromised individuals, are at higher risk of severe outcomes (Myintzaw, K. Jaiswal and Jaiswal, 2021). Campylobacteriosis can proceed from gastroenteritis to more severe diseases like bacteremia, sepsis, and Guillain-Barré Syndrome. Furthermore, post-infectious consequences such as reactive arthritis and irritable bowel syndrome have been observed in the long run (Fischer, Hashmi and Paterek, 2024).

Treatment options are limited due to the rise of antimicrobial resistance in *Campylobacter spp.*, driven by the overuse of antibiotics in clinical and agricultural settings (Portes *et al.*, 2023). This is particularly concerning in LMICs like Sri Lanka, where resistant strains have already been detected in poultry farms (Perera *et al.*, 2024).

In Sri Lanka, poor sanitation and limited access to clean water in rural areas increase the risk of campylobacteriosis. Villagers frequently handle animal waste for farming, religious practices, and medicine, exposing them to *Campylobacter* (Majudith, Mubarak and Kumari, 2022). Additionally, the country's street food culture and informal restaurants often involve undercooked or contaminated meat prepared with inadequate sanitation, further raising the risk of transmission, especially among those unaware of the risks or neglecting proper hygiene practices (Majudith, Mubarak and Kumari, 2022).

To prevent campylobacteriosis in Sri Lanka, educating the public is essential. According to Health Brief Model, people are prone to take action to avoid contracting campylobacteriosis if they are aware of the risks, feel susceptible to it, and understand the precautions they can apply. This approach can enhance public awareness and promote safer behaviors, reducing the risk of transmission (Anees Alyafei and Easton-Carr, 2024).

However, no research has been conducted to determine the level of awareness on campylobacteriosis among Sri Lankans to date. Therefore, it's hard to know exactly which groups need targeted awareness. That being said, our study aims to address this gap by evaluating the awareness on campylobacteriosis among Sri Lankan adults and analyze whether there is a significant difference between demographic factors and awareness of the population; which will improve the efficacy of future health initiatives.

Methodology

Initially, ethics approval was obtained from the Cardiff School of Sports and Health Sciences on 30th September 2024. The project reference number was UG-9721.

Thereafter, a quantitative cross-sectional study was designed to collect primary data. An online self-reported questionnaire was prepared and distributed through social media platforms to the public. The questionnaire had 28 questions and the first section was assigned for demographic data such as age, gender, education, district and occupation. The overall awareness was determined based on the respondent's knowledge on general knowledge, transmission, signs and symptoms, treatment and prevention.

Participants were informed to indicate the extent to which they were aware or unaware using a 5-point Likert scale. Responses were scored from 1 = "Very unaware", 2 = "Unaware", 3 = "Moderately Aware", 4 = "Aware" to 5 = "Very Aware". Thereafter, MS Excel and SPSS version 27 were used for data analysis. The numerical values assigned for each option were used to calculate

the overall awareness scores and results were reported as mean $\pm$ standard deviation (SD). Furthermore, a one-way ANOVA and post hoc Bonferroni test was used to identify demographic groups with significant differences in awareness scores. All analyses were carried out at a 95% confidence level, with a p-value of <0.05 for statistical significance.

Results

In total, 445 responses were collected within 27 days. The overall awareness on campylobacteriosis of Sri Lankan adults was 2.89 ± 1.16 (Mean $\pm$ SD) (Minimum – 1 and Maximum – 5 according to Likert scale). It is evident that the Sri Lankans have a moderate level of overall awareness on campylobacteriosis.

Overall Awareness in Terms of Demographic Factors

The 18–29 age group (2.71 ± 1.17) had the least overall awareness with respect to age while the 30–49 age group (3.04 ± 1.06) had the highest overall awareness (Figure 1). The overall awareness of male (2.88 ± 1.15) and female (2.89 ± 1.17) populations were almost equal; male having the least.

In addition, the overall awareness in terms of education depicted an interesting finding (Figure 1). That is; the awareness score gradually increases with the increase in educational qualifications of the population. Therefore, the highest awareness was recorded among Masters/PhD holders (3.84 ± 1.43) while the lowest awareness was recorded among those educated to any grade below O/Ls (1.91 ± 0.74).

Western province (3.29 ± 1.09) recorded the highest overall awareness while the Northern province (2.44 ± 1.17) recorded the lowest overall awareness in terms of province.

The overall awareness of the employed population (3.29 ± 1.12) was the highest compared to unemployed and student populations; unemployed population (2.28 ± 0.89) having the least overall awareness.

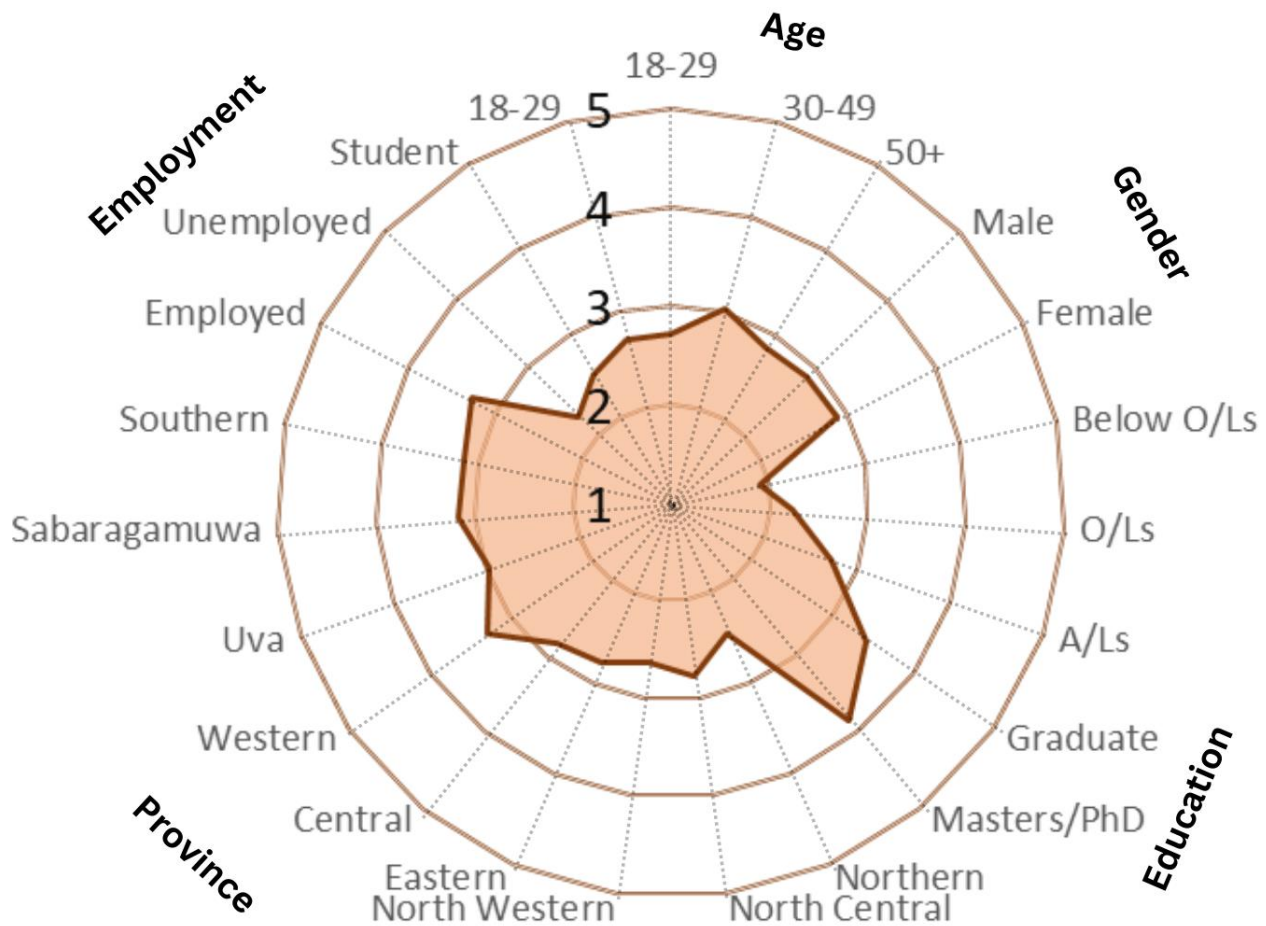
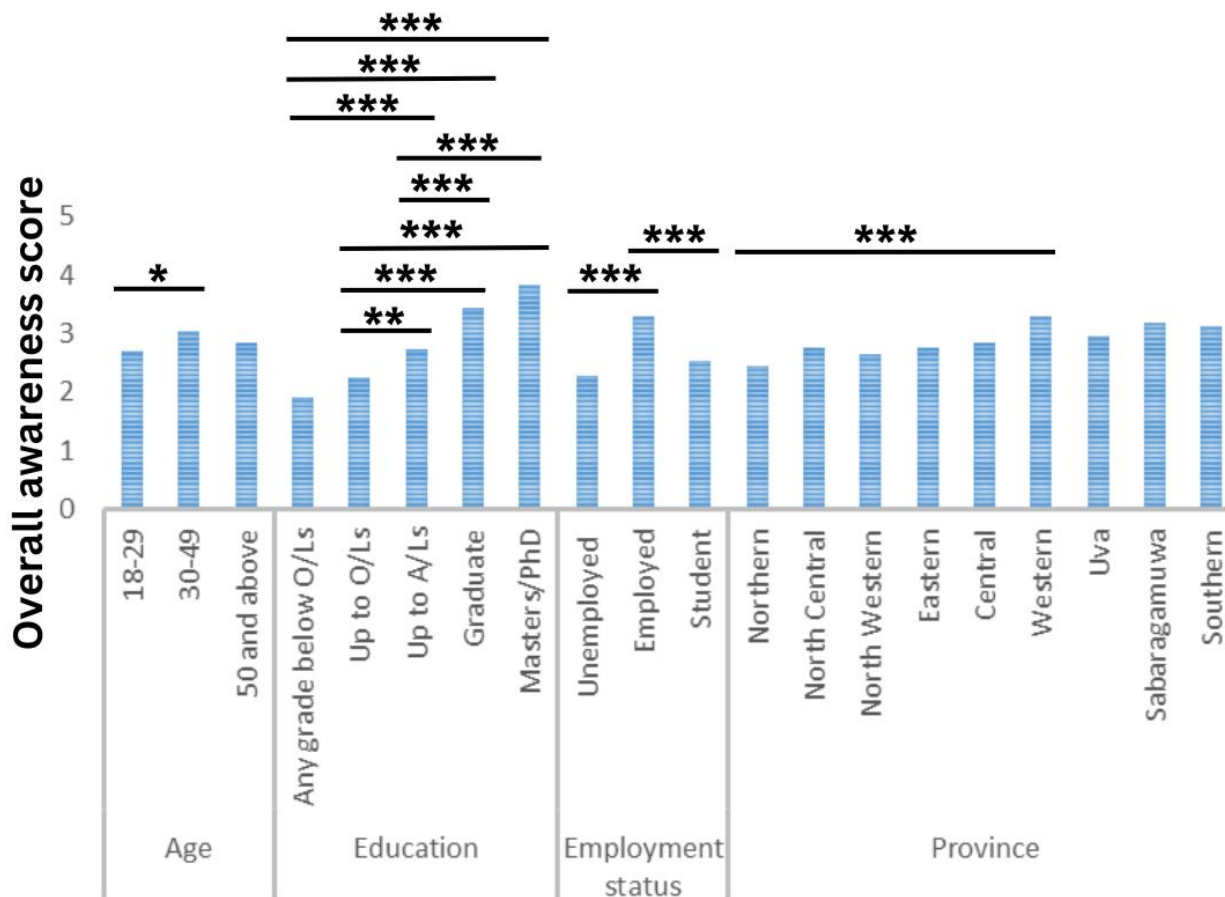


Figure 1. Radar chart of the overall awareness scores in terms of demographic factors (minimum – 1, maximum - 5)

Statistical Significance in Awareness Scores in Terms of Demographic Factors

The one-way ANOVA test revealed the presence of a statistical significance in awareness among age, education, province and employment sectors. But there was no statistical significance in awareness within the gender category. Furthermore, the post hoc Bonferroni test revealed the specific pairs of demographic groups with significant differences ($p\text{-value} < 0.05$) in awareness scores as shown in Figure 2.



Demographic factors

Figure 2. Overall awareness scores in terms of demographic factors. A significant difference in awareness scores were identified among different demographic factors using the post hoc Bonferroni test. (*** $P < 0.001$, ** $P < 0.01$, * $P < 0.05$).

Discussion

Overall Awareness

This study offers important insights into present awareness levels on campylobacteriosis among Sri Lankan adults, and the relationship between demographic factors, given the lack of previous research on awareness of campylobacteriosis in Sri Lanka and most parts of the world. Thus, the present study reports a lower/moderate level of overall awareness (2.89 ± 1.16) on campylobacteriosis among Sri Lankan adults. Similarly, a large study conducted in Ireland has reported that 9.5% had a higher overall awareness on campylobacteriosis among the Irish population especially when Ireland has been struggling to produce *Campylobacter* free chicken (Myintzaw, Moran and Jaiswal, 2020). Thus, the awareness among most populations around the world is notably lower which mandates taking necessary actions to increase the awareness of the Sri Lankans to prevent any future outbreaks.

Overall Awareness and Statistical Significance in Awareness Scores in Terms of Demographic Factors

A descriptive study that reviewed 1 million campylobacteriosis cases in the United Kingdom over a period of 22 years reported a substantial increase in the campylobacteriosis cases among kids below 5 years and adults above 50 years (Nichols *et al.*, 2012). This highlights the importance of educating the population older than 50 years and mothers with young children to prevent them from acquiring the disease especially when their awareness is proven to be lower in this study.

This study reports that both male and female populations were unaware about campylobacteriosis according to the Likert scale but there was no significant difference between the 2 variables. However, an Irish study reports that the awareness was significantly lower among males compared to females despite both populations having lower awareness scores (Myintzaw, Moran and Jaiswal, 2020).

The results suggest that awareness of campylobacteriosis and educational level has a significant association, with awareness scores increasing as educational level increases. The statistical significance of education on overall awareness score ($p < 0.001$) supports this trend and possibly suggests that health literacy increases with educational level. Therefore, public health awareness programs should prioritize simple and accessible educational resources suitable for populations with lower levels of formal education. Findings of this study correlates with many other studies conducted worldwide (Myintzaw, Moran and Jaiswal, 2020) (Abdul Rahiman *et al.*, 2023).

Respondents from Western province (3.29 ± 1.09) had the highest overall awareness and had a significant difference with respect to awareness of respondents from Northern Province (2.44 ± 1.17) which reported the least overall awareness. This could be due to various reasons. That is; Western province is more economically developed due to the high gross domestic product (GDP) compared to Northern Province (CBS, 2022). Higher GDP and the capital of the country belonging to the Western province opens up better access to healthcare, education and public health initiatives, thus increasing the awareness among the population. Furthermore, the 30 years of war in the Northern Province (1983-2009) may have significantly affected public health education and awareness efforts.

This study found that employed respondents had significantly higher overall awareness than both students and unemployed respondents. Several factors could explain this difference. That is; employed individuals likely have greater access to information through colleagues and workshops at workplaces, economic stability that supports them in practicing preventive measures, and majority of employed populations could possibly have a higher level of education.

Conclusion

This study highlights lower/moderate awareness of campylobacteriosis among Sri Lankan adults, with significant gaps in knowledge influenced by age, education, province, and employment. Targeted public health campaigns are essential, focusing on underserved populations. Future research should investigate how awareness levels on campylobacteriosis correlate with attitude and practices of the population, conduct large-scale prevalence studies, and ensure continuous surveillance for sustainable prevention strategies.

References

- Abdul Rahiman, U.A., Azuddin, S.N.A., Abdul Mutalib, N.A., Sanny, M., Mahmud @ Ab Rashid, N.K. and Nordin, N. (2023). Effects of knowledge, attitudes, and practices of poultry handlers on the prevalence of *Campylobacter* along the poultry production chain in Peninsular Malaysia. *International Food Research Journal*, [online] 30(5), pp.1171–1186. doi:<https://doi.org/10.47836/ifrj.30.5.07>.
- Anees Alyafei and Easton-Carr, R. (2024). The Health Belief Model of Behavior Change. [online] Nih.gov. Available at: <https://www.ncbi.nlm.nih.gov/books/NBK606120/> [Accessed 9 Nov. 2024].
- Bush, L.M. and Vazquez-Pertejo, M.T. (2024). *Campylobacter* Infections. [online] Merck Manual Professional Edition. Available at: <https://www.merckmanuals.com/professional/infectious-diseases/gram-negative-bacilli/campylobacter-infections> [Accessed 8 Nov. 2024].
- Cbsl.gov.lk. (2022). Provincial Gross Domestic Product (PGDP) - 2022 | Central Bank of Sri Lanka. [online] Available at: <https://www.cbsl.gov.lk/en/pgdp-2022> [Accessed 12 Nov. 2024].
- Fischer, G.H., Hashmi, M.F. and Paterek, E. (2024). *Campylobacter Infection*. [online] Nih.gov. Available at: <https://www.ncbi.nlm.nih.gov/books/NBK537033/> [Accessed 7 Feb. 2025].
- Kottawatta, K., Van Bergen, M., Abeynayake, P., Wagenaar, J., Veldman, K. and Kalupahana, R. (2017). *Campylobacter* in Broiler Chicken and Broiler Meat in Sri Lanka: Influence of Semi-Automated vs. Wet Market Processing on *Campylobacter* Contamination of Broiler Neck Skin Samples. *Foods*, [online] 6(12), p.105. doi:<https://doi.org/10.3390/foods6120105>.
- Liyanage Champika Sajeewa Perera, J., Pathmalal, M.M., De Silva, D.P.N., Miura, K., Yamada, A. and Hirayama, K. (2024). Identification of antimicrobial resistance profiles and antimicrobial resistance genes of *Campylobacter* isolates from broiler farms in Sri Lanka. *International Journal of Life Science and Agriculture Research*, [online] 03(01). doi:<https://doi.org/10.55677/ijlsar/v03i1y2024-03>.
- Mahmud (2024). *Campylobacter* Infections: Background, Pathophysiology, Epidemiology. [online] Medscape.com. Available at: <https://emedicine.medscape.com/article/213720-overview#showall> [Accessed 7 Nov. 2024].
- Majudith, T., Mubarak, M. and Kumari, S. (2022). Ensuring Food Safety in Sri Lanka: Dietary Exposure and Related Risks. [online] Available at: <https://www.nsf.gov.lk/images/2023/Report-TDIA-Food-safety.pdf> [Accessed 9 Nov. 2024].
- Myintzaw, P., K. Jaiswal, A. and Jaiswal, S. (2021). A Review on *Campylobacteriosis* Associated with Poultry Meat Consumption. *Food Reviews International*. [online] doi:<https://doi.org/10.1080//87559129.2021.1942487>.

Myintzaw, P., Moran, F. and Jaiswal, A.K. (2020). Campylobacteriosis, consumer's risk perception, and knowledge associated with domestic poultry handling in Ireland. *Journal of Food Safety*, [online] 40(4). doi:<https://doi.org/10.1111/jfs.12799>.

Nichols, G.L., Richardson, J.F., Sheppard, S.K., Lane, C. and Sarran, C. (2012). Campylobacter epidemiology: a descriptive study reviewing 1 million cases in England and Wales between 1989 and 2011. *BMJ Open*, [online] 2(4), pp.e001179–e001179. doi:<https://doi.org/10.1136/bmjopen-2012-001179>.

Perera, S., Marakkale Manage Pathmalal, Silva, Miura, K., Yamada, A. and Hirayama, K. (2024). Identification of antimicrobial resistance profiles and antimicrobial resistance genes of Campylobacter isolates from broiler farms in Sri Lanka. *International Journal of Life Science and Agriculture Research*, [online] 03(01). doi:<https://doi.org/10.55677/ijlsar/v03i1y2024-03>.

Portes, A.B., Panzenhagen, P., Mota, A. and Adam, C. (2023). Antibiotic Resistance in Campylobacter: A Systematic Review of South American Isolates. *Antibiotics*, [online] 12(3), pp.548–548. doi:<https://doi.org/10.3390/antibiotics12030548>.

Qadr Amin, S., Jamal Mahmood, H. and Karim Zorab, H. (2023). Campylobacteriosis. *International Journal of Agriculture and Biosciences*, [online] 2, pp.87–93. doi:<https://doi.org/10.47278/book.oht/2023.46>.

World (2020). Campylobacter. [online] Who.int. Available at: <https://www.who.int/news-room/fact-sheets/detail/campylobacter> [Accessed 6 Nov]

CONCERNING TETRACYCLINE RESISTANCE IN *Campylobacter jejuni* ISOLATES FROM POULTRY IN SRI LANKA.

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Abstract

Campylobacter jejuni is one of the leading bacterial causes of gastroenteric diseases globally, and is commonly linked to undercooked poultry, unpasteurized milk, and contaminated water. Although most campylobacteriosis cases are self-limiting, antimicrobial intervention is essential for high-risk individuals. In this regard, during recent years, the effectiveness of tetracycline, a commonly used antibiotic, has been increasingly compromised by antimicrobial resistance. Given that the majority of human *Campylobacter* cases are attributed to chicken, this study focused on assessing tetracycline resistance in *Campylobacter jejuni* isolated from poultry fecal samples in Sri Lanka. To that end, 30 isolates were examined using the micro broth dilution method to determine their minimum inhibitory concentrations (MICs). The results revealed an alarmingly high resistance rate of 93.33%, which is the highest reported in Sri Lanka to date. A statistically significant difference between the resistant and susceptible proportions were also observed. These findings emphasize the urgent need for mitigation strategies to preserve the efficacy of tetracycline in treating campylobacteriosis.

Keywords: Antimicrobial Resistance, *Campylobacter jejuni*, Tetracycline

Introduction

Campylobacter jejuni is a Gram-negative, spiral-shaped, micro-aerophilic bacterium recognized as one of the leading causes of bacterial gastroenteritis worldwide. It thrives at approximately 42°C, corresponding to the body temperature of birds, making poultry a significant reservoir (World Organization for Animal Health, 2024). Consequently, humans most commonly contract campylobacteriosis through the consumption of undercooked poultry, unpasteurized milk, or untreated water. The disease usually presents as acute gastroenteritis and while most cases are self-limiting, severe infections in high-risk groups, such as children, older adults, and immunocompromised individuals, may necessitate antimicrobial intervention (Fischer, Hashmi and Paterek, 2024). A critical concern associated with *C. jejuni* is the increasing prevalence of antibiotic resistance. Tetracycline, a broad-spectrum antibiotic frequently used in both human and veterinary medicine, is an essential treatment option for *Campylobacter* infections. However, its widespread use in livestock, particularly poultry, has contributed to the emergence of resistant strains (Hormeño *et al.*, 2020). Research has demonstrated a strong correlation between agricultural antimicrobial use and the development of antimicrobial-resistant *Campylobacter* strains in humans (Woolhouse *et al.*, 2015). Monitoring resistance patterns in livestock is therefore crucial, as the findings directly impact public health and food safety. Tetracycline-resistant strains are of particular concern due to their potential to cause treatment failures, prolong infections, and heighten transmission rates, posing a significant threat to global health (UN Environment Program, 2023). Despite extensive global

studies documenting tetracycline resistance, reliable and consistent data from Sri Lanka remain limited, creating a significant gap in our understanding of this issue within the local context. Considering about 50 – 80% of human campylobacteriosis cases are attributed to the chicken revisor, and given that chicken is widely produced/ consumed in Sri Lanka (Perera *et al.*, 2024, Department of Animal Production and Health Sri Lanka, 2022), it is especially important that a solid understanding of the matter is established in order to better manage patients and improve food safety practices. To that end, the present study aims to determine the tetracycline resistance profile in *Campylobacter jejuni* using isolates from poultry fecal droppings.

Methodology

This study investigated the minimum inhibitory concentration (MIC) of tetracycline against *Campylobacter jejuni* using the micro broth dilution method as laid out by the European Committee on Antimicrobial Susceptibility Testing (EUCAST). Stored isolates of *C. jejuni* from poultry fecal samples were cultured on sheep blood agar under microaerophilic conditions (5% O₂, 10% CO₂, 85% N₂) at 42°C for 48 hours. After incubation, 30 successful cultures were prepared to a turbidity of 0.5 McFarland standard ($\sim 1.5 \times 10^8$ CFU/mL) in saline. Tetracycline stock solution was prepared by dissolving 2.586 mg of powder in 10 mL of sterile distilled water to achieve a maximum concentration of 256 mg/L and the broth media needed was prepared by suspending 12.5 g of Nutrient Broth No 2 powder, a general culture medium that supports the growth of a wide range of bacteria, in 500ml of sterile distilled water. A 96-well U-bottom microtiter plate was prepared by adding 90 µL of nutrient broth to wells in columns 2 to 12. Then, 180 µL of tetracycline stock solution was added to column 1. A two-fold serial dilution was performed up to column 10, creating a concentration range from 256 mg/L to 0.5 mg/L, with each well having a total volume of 90 µL. Subsequently, 10 µL of the prepared bacterial inoculum was added to each row spanning up to column 11. Likewise, 8 inoculums were tested on one plate. Each inoculum had a duplicate tested which corresponds to 4 isolates been tested on one plate. Columns 11 and 12 were considered the antimicrobial control and sterility control respectively. Plates were incubated under the same microaerophilic conditions at 42°C for 48 hours. Growth was assessed visually, and MICs were determined by identifying the lowest tetracycline concentration inhibiting bacterial growth. MIC values were compared against EUCAST clinical breakpoints (2024-01-01) to classify isolates as resistant or susceptible. Fisher's exact test was used to evaluate differences between resistance and susceptibility proportions, with $p < 0.05$ considered statistically significant. Ethical approval for this study was granted by the Cardiff Metropolitan University Ethics Framework.

Results and Discussion

In this study, the tetracycline resistance of 30 *C. jejuni* isolates from environmental poultry fecal droppings were evaluated using the micro broth dilution method. In total, 60 samples of 30 duplicated isolates were tested. The minimum inhibitory concentrations exhibited a broad range of values. The highest recorded MIC value was 64.0 mg/l, observed in 8 out of the 60 samples (13.33%) tested, while the lowest recorded MIC value was 0.5 mg/l, observed in 2 out of the 60 samples (3.33%) tested. The majority of samples, 17 out of 60 (28.33%), recorded 8.0 mg/l, as their MIC value, whereas The MIC values with the fewest occurrences were both 0.5 mg/l and 2.0 mg/l, each

observed in only 2 samples (3.33%). The distribution of MIC values is given in Table 1 and visualized in Figure 1 below.

Table 1: MIC distribution for Tetracycline (Considering all 60 samples of the 30 isolates tested)

MIC (mg/L)	0.5	1	2	4	8	16	32	64	128	256
<i>n</i>	2	0	2	6	17	11	14	8	0	0
(%)	(3.33)		(3.33)	(10)	(28.33)	(18.33)	(23.33)	(13.33)		

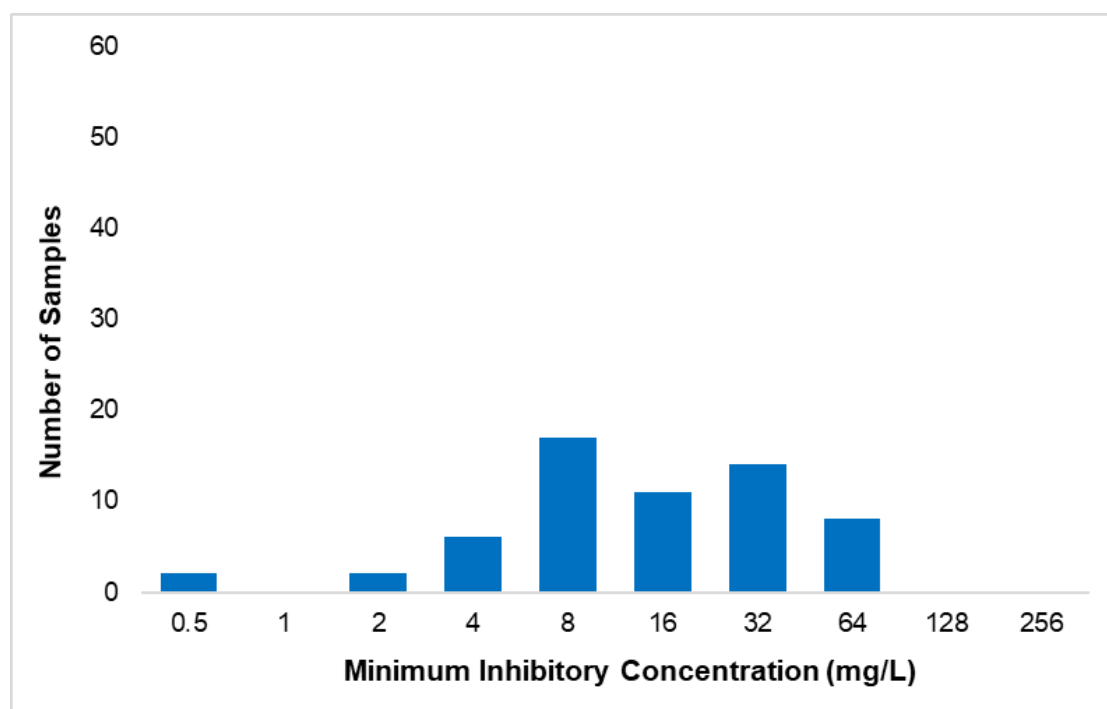


Figure 1: Visualization of the distribution of MICs

These MIC values obtained were tried against the EUCAST clinical breakpoint tables (2024-01-01) for *Campylobacter jejuni*, where the resistant breakpoint was specified as > 2 mg/L. The results revealed that a significant majority of isolates, 28 out of 30 (93.33%), were resistant to tetracycline, indicating MIC values at or above the resistance threshold. Conversely, only 2 isolates out of 30 (6.67%) were found to be susceptible, with lower MIC values. These results are summarized in figure 2 below.

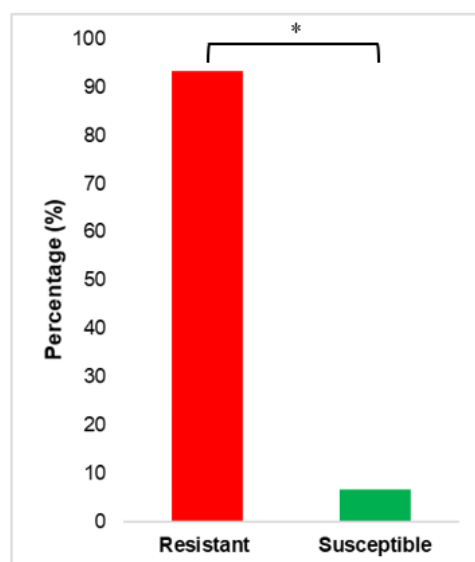


Figure 2: Resistance and susceptibility profiles of the isolates

Further, the obtained data were subjected to statistical analysis using a Fisher's exact test, where the test returned a value of 0.00. Considering the p value as 0.05, the test confirmed a significant difference in the proportion of resistant versus susceptible isolates ($p < 0.05$), indicating a high level of tetracycline resistance within the *Campylobacter jejuni* isolates of the present study.

To the best of our understanding, this study reports the highest ever recorded tetracycline resistance rate in *Campylobacter jejuni* within Sri Lanka to date. The results reveal a striking 93.33% resistance level for tetracycline, which indicates a considerably elevated degree of resistance compared to earlier studies conducted in Sri Lanka. However, historical data shows substantial variability in the reported resistance rate over the years. For instance, a study from 2006-2007 reported an 85% resistance rate among broiler isolates, though the small sample size may have skewed results (Kottawatta *et al.*, 2017). In 2015, Tegner *et al.* reported a much lower resistance rate of 33.3% in non-human primate isolates, likely influenced by the limited sample size and differing sources (Tegner *et al.*, 2019). Recent studies in 2024 demonstrate further variability, with Weerasooriya *et al.* reporting a 39% resistance rate and Perera *et al.* reporting a higher rate of 72.1% in poultry isolates (Weerasooriya *et al.*, 2024; Perera *et al.*, 2024). Observing the reported resistance figures in 2024, one might speculate a concerning trend, showcasing a disturbing escalation in resistance levels within the year. However, on the other hand, such vast variations in resistance figures may highlight the need for factoring in variables such as stain variations, geographical variations, environmental influences, methodology considerations and other underlying factors that may influence these variations. It is also worth noting that this trend of high resistance is not just unique to Sri Lanka, with other countries in the South Asian region reporting similar rates. The high tetracycline resistance rates observed in this study may stem from various interconnected factors. In many low and middle-income countries (LMICs), including Sri Lanka, there is a high dependency on agriculture as a primary source of income and food security. This heavy reliance often drives extensive antibiotic use in livestock for disease prevention and growth promotion. Poor biosecurity and farm management practices, coupled with the easy availability of over-the-counter antibiotics despite regulations, contribute to widespread misuse and promote antimicrobial resistance (Nashwan *et al.*, 2024; Kottawatta *et al.*, 2017). Socioeconomic challenges, such as increased

poultry production costs post-COVID-19, have exacerbated this issue (Weerasooriya *et al.*, 2024), while co-selection from other antimicrobials like fluoroquinolones further amplifies resistance (Caffrey *et al.*, 2021). Given historical data and the findings of this study, the situation underscores the need for urgent mitigation strategies to control these drivers of resistance and address the public health threat posed by tetracycline-resistant *Campylobacter*. Key strategies include enhancing surveillance systems to monitor antibiotic use and resistance, promoting rational antibiotic use through stewardship programs, and investing in research for new antimicrobial agents and alternative therapies. Public awareness and stakeholder responsibility are also crucial to ensuring sustainable antimicrobial use (Steward Mudenda *et al.*, 2023). Currently on this front, efforts like the Antibiotic Resistance Surveillance Project (ARSP) have been initiated, but no published reports or specific data on *C. jejuni* resistance are currently available (Slmicrobiology.lk, 2023). The findings of this study serve as a critical reminder of the need for immediate and decisive action to prevent the further spread of resistant *Campylobacter* strains within the country and preserve the efficacy of tetracycline in treating campylobacteriosis.

Conclusion and Recommendations

The study reveals an alarming 93.33% resistance rate to tetracycline among *Campylobacter jejuni* isolates tested. This high level of resistance compromises the effectiveness of tetracycline, a primary option in treating campylobacteriosis, and raises concerns about prolonged infections, treatment failures, and greater transmission risks, all of which could increase the strain on healthcare systems. However, the study's findings are subject to certain limitations, including geographical constraints, potentially limiting the generalizability of the results, and the lack of molecular analysis, which could provide a deeper understanding of resistance mechanisms by identifying specific resistance genes. To better understand and manage this issue, future research may focus on antimicrobial usage patterns in Sri Lanka's broiler industry, and broader geographic studies incorporating human and environmental samples. Furthermore, longitudinal studies tracking resistance patterns over time would help establish a clear trend of the resistance rates, and could also demonstrate the impact of interventions and policy changes. Studies of such nature would offer a more comprehensive understanding of the issue, and in turn, support efforts to manage the spread of tetracycline-resistant *Campylobacter*, ultimately safeguarding public health for future generations.

References

- Caffrey, N., Agunos, A., Gow, S., Liljebjelke, K., Waldner, C.L., Chunu Mainali and Checkley, S.L. (2021). A cross-sectional study of the prevalence factors associated with fluoroquinolone resistant *Campylobacter jejuni* in broiler flocks in Canada. *Preventive veterinary medicine*, 186, pp.105164–105164. doi:<https://doi.org/10.1016/j.prevetmed.2020.105164>.
- Department of Animal Production and Health Sri Lanka (2022). *LIVESTOCK STATISTICAL BULLETIN 2022 Department of Animal Production and Health*. [online] Available at: https://daph.gov.lk/files/uploads/documents/downloads/Statistical_Bulletin2022.pdf.
- Fischer, G.H., Hashmi, M.F. and Paterek, E. (2024). *Campylobacter Infection*. [online] Nih.gov. Available at: <https://www.ncbi.nlm.nih.gov/books/NBK537033/> [Accessed 29 Jun. 2024].
- Hormeño, L., Campos, M.J., Vadillo, S. and Quesada, A. (2020). Occurrence of *tet*(O/M/O) Mosaic Gene in Tetracycline-Resistant *Campylobacter*. *Microorganisms*, [online] 8(11), p.1710. doi:<https://doi.org/10.3390/microorganisms8111710>.
- Kottawatta, K., Van Bergen, M., Abeynayake, P., Wagenaar, J., Veldman, K. and Kalupahana, R. (2017). *Campylobacter* in Broiler Chicken and Broiler Meat in Sri Lanka: Influence of Semi-Automated vs. Wet Market Processing on *Campylobacter* Contamination of Broiler Neck Skin Samples. *Foods*, 6(12), p.105. doi:<https://doi.org/10.3390/foods6120105>.
- Nashwan, A.J., Hussain Haider Shah, Hussain, T., Sameer Abdul Rauf and Sirwan Khalid Ahmed (2024). Environmental Drivers of Antimicrobial Resistance in Low and Middle-Income Countries: The Impacts of a Changing World. *Environmental Health Insights*, [online] 18. doi:<https://doi.org/10.1177/11786302241246420>.
- Perera, S., Marakkale Manage Pathmalal, Silva, Miura, K., Yamada, A. and Hirayama, K. (2024). Identification of antimicrobial resistance profiles and antimicrobial resistance genes of *Campylobacter* isolates from broiler farms in Sri Lanka. *International journal of life science and agriculture research*, 03(01). doi:<https://doi.org/10.55677/ijlsar/v03i1y2024-03>.
- Slmicrobiology.lk. (2023). *The Antibiotic Resistance Surveillance Project (ARSP) – Sri Lanka College of Microbiologists*. [online] Available at: <https://slmicrobiology.lk/activities/arsp/> [Accessed 26 Jun. 2024].
- Steward Mudenda, Chabalenge, B., Daka, V., Ruth Lindizyani Mfune, Kyembe Ignitius Salachi, Mohamed, S., Webrod Mufwambi, Maisa Kasanga and Scott Kaba Matafwali (2023). Global Strategies to Combat Antimicrobial Resistance: A One Health Perspective. *Pharmacology & Pharmacy*, 14(08), pp.271–328. doi:<https://doi.org/10.4236/pp.2023.148020>.
- Tegner, C., Sunil-Chandra, N.P., Wijesooriya, W.R.P.L.I., Perera, B.V., Hansson, I. and Fahlman, Å. (2019). Detection, Identification, and Antimicrobial Susceptibility of *Campylobacter* spp. and *Salmonella* spp. from Free-Ranging Nonhuman Primates in Sri Lanka. *Journal of Wildlife Diseases*, 55(4), p.879. doi:<https://doi.org/10.7589/2018-08-199>.
- UN Environment Program (2023). *Bracing for Superbugs: Strengthening environmental action in the One Health response to antimicrobial resistance*. [online] UNEP - UN Environment Programme. Available at: <https://www.unep.org/resources/superbugs/environmental->

action?gad_source=1&gclid=CjwKCAjw4f6zBhBVEiwATEHFVi5c0sFESWO4OQtyz-StwwF4RGFErqbIj-saut1KP5xUhqCgYeXvJBoC5aEQAvD_BwE [Accessed 29 Jun. 2024].

Weerasooriya, G., Dulakshi, H.M.T., de Alwis, P.S., Bandara, S., Premarathne, K.R.P.S., Dissanayake, N., Liyanagunawardena, N., Wijemuni, M.I. and Priyantha, M.A.R. (2024). Persistence of Salmonella and Campylobacter on Whole Chicken Carcasses under the Different Chlorine Concentrations Used in the Chill Tank of Processing Plants in Sri Lanka. *Pathogens*, 13(8), p.664. doi:<https://doi.org/10.3390/pathogens13080664>.

Woolhouse, M., Ward, M., van Bunnik, B. and Farrar, J. (2015). Antimicrobial resistance in humans, livestock and the wider environment. *Philosophical Transactions of the Royal Society B: Biological Sciences*, [online] 370(1670), p.20140083. doi:<https://doi.org/10.1098/rstb.2014.0083>.

World Organization for Animal Health (2024). *Infection with Campylobacter jejuni and C. coli*. [online] Available at: https://www.woah.org/fileadmin/Home/eng/Health_standards/tahm/3.10.04_CAMPYLO.pdf.

**MOLECULAR CHARACTERIZATION OF HYDATID CYSTS IN GOAT LIVER
IDENTIFIED DURING ROUTINE MEAT INSPECTIONS AT COLOMBO
MUNICIPALITY COUNCIL ABATTOIRS**

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Abstract

Cystic echinococcosis (CE), caused by *Echinococcus granulosus*, is a zoonotic disease with significant health and economic implications. This study focused in identifying the genetic diversity and phylogenetic relationships of *Echinococcus granulosus* strains in hydatid cysts of goats. Out of 2,736 goat samples inspected, typical hydatid cysts were identified in 13(0.5%), primarily in livers and lungs. Microscopic and histological examination using Leishman and Hematoxylin-Eosin staining indicated the presence of *E. granulosus* protoscoleces and hooklets. PCR amplification using FH5:FH3 primers and Sanger sequencing of the cytochrome c oxidase subunit 1 (COX1) gene identified the G5 strain (*Echinococcus orteppi*), closely related to global isolates from China, India, and Pakistan. Phylogenetic analysis revealed monophyletic clustering, suggesting evolutionary conservation but subtle geographic variations. This unique strain distribution may have an impact to the low prevalence of CE among humans. However, as research on this on humans is scarce there is an importance of strain-level genetic studies to inform region-specific control measures and mitigate the impacts in livestock-dependent regions.

Keywords: Anuradhapura, COX-1 gene, Cystic Echinococcosis, Liver

Introduction

Cystic echinococcosis (CE), also known as hydatidosis, is a zoonotic disease caused by *Echinococcus granulosus*, a parasite, comprising of dogs and wild canids as definitive hosts and ruminants as intermediate hosts, bearing significant public health and economic consequences, particularly in livestock-dependent regions (Assefa *et al.*, 2015). Among the four *Echinococcus* species, *E. granulosus sensu stricto* is the most widespread and hosts diverse genetic strains, including those infecting sheep, cattle, goats, and other intermediate hosts (Thompson, 2020; Moro and Cantey, 2017). The disease costs the global agriculture and health industries \$3 billion annually and is endemic in regions like the Mediterranean, Middle East, and Eastern Europe. Key risk factors include stray dogs, inadequate anti-helminthic treatments, and poor hygiene standards (Saleem *et al.*, 2023).

In Sri Lanka, parasitic cysts are commonly detected during meat inspections of goats and cattle, yet research on CE in goats is scarce. Adult *E. granulosus* tapeworms infect definitive hosts, releasing

eggs that are ingested by intermediate hosts, causing cystic lesions most commonly in liver and occasionally in lungs (Eckert and Deplazes, 2004). This study aims to explore CE's prevalence in Colombo Municipality council (CMC), morphology, and molecular epidemiology in goat liver, addressing its significance in Sri Lankan goats.

Methodology

Ethical approval was received from the Cardiff School of Sports and Health Sciences under Cardiff Metropolitan University's framework. Based on national livestock statistics (2023), with a goat population of 355,550, a sample size of 385 was calculated to provide a 95% confidence level with a 5% margin of error (Orban, 2021). However, 2,736 goats were inspected to enhance the precision and robustness of findings. Post-mortem investigations were performed on goats from slaughterhouses in CMC, where native goats roaming in meadows are abundantly slaughtered, transported from all over Sri Lanka. Liver and lung samples showing morphologically typical hydatid cysts were randomly collected over four weeks with consent from veterinarians and animal owners. Samples were washed, preserved at 4°C, and transported to the Veterinary Parasitology laboratory, University of Peradeniya for analysis. Liver samples with evident carcasses were used for further examination. Gross inspections determined whether cysts were partially or fully embedded in organs. Cyst diameters were measured, and their contents were dissected. The fluid was observed microscopically for protoscoleces, hooklets and hydatid sand. Portions of the cyst wall and fluid were preserved in formalin and ethanol for histology and DNA extraction, respectively. Cyst fluid sediments were stained with Leishman stain to visualize protoscoleces and hooklets. The cyst walls were stained using Hematoxylin-Eosin (H&E) to observe distinct layers under various magnifications, including the germinal layer and laminated membrane. DNA was extracted using commercial kits. Extracted DNA was quantified via Nanodrop, diluted if necessary, and used as a template for Polymerase Chain Reaction (PCR). COX1 gene were targeted using specific primers; FH5 (5' -TTT TTT GGG CAT CCT GAG GTT TAT- 3') (24mer) and FH3 (5' -TAA AGA AAG AAC ATA ATG AAA ATG- 3') (24mer) (Perera *et al.*, 2017). Amplified PCR products were analyzed using 2% agarose gel electrophoresis to confirm target gene sizes (450 bp for COX1). Purified PCR product of the sample with high purity was sequenced bidirectionally. High-quality sequences underwent noise trimming, alignment, and comparison using NCBI BLAST to identify species and detect genetic variations. Phylogenetic tree was constructed using MEGA 11 software with reference sequences from the NCBI database.

Results and Discussion

Sample Size, Sample Collection and Morphological Examination

A total of 2,376 carcasses were inspected during July, with 13 morphologically typical hydatid cysts identified, yielding an occurrence rate of 0.5%, which were collected from CMC, including samples from Anuradhapura (3), Puttalam (2) and Jaffna (8). In general, the occurrence of hydatid cysts in goats is minimal, as indicated by (Bahador Hajimohammadi *et al.*, 2022) (0.006%) with a smaller sample size and (Mohsen Arbabi and Hossein Hooshyar, 2006) (3.1%) with a longer time frame.

The cysts varied in their anatomical embedding: 01-partially embedded, 03-fully embedded and 08-cysts attached to the margin of the organ.

Out of these, 25% (3 cysts) were possessing the characteristics of a typical hydatid cyst upon dissection with hydatid sand composed of scolices. Among them, 1 was identified in lungs and 2 were evident in the liver. Cyst sizes varied from 17-70 mm, which is consistent with previous studies like (Chiou *et al.*, 2001) and (Cristian Botezatu *et al.*, 2018). Morphological examination showed single invaginated scolices along with clear cyst fluid, pathological lesions like abscesses or transparent cysts without hydatid sand in the rest of the collected cysts. Out of the 3 suspected hydatid cyst 2 of them which were present on the liver were subjected for further analysis, obtained from carcasses examined from Anuradhapura District.

Microscopic Examination and Histopathological Examination

Dissected cysts revealed various contents, including protoscoleces detached from brood capsules and free scolices. Microscopic analysis of hydatid sand highlighted the presence of protoscoleces enclosed within brood capsules, as well as hooklets scattered throughout. Hydatid sand, when stained with Leishman stain, revealed scattered protoscoleces and concentrated hooklets under both high-power magnification (x400) and oil immersion (x1000). Smears demonstrated concentrated loci of 3-4 hooklets and deep blue-stained protoscoleces. These finding aligns with the diagnostic features commonly reported in research on hydatidosis like (Thurnher and Olatunji, 2016) and (Kim *et al.*, 2013). Histopathological examination of the cyst walls using Hematoxylin and Eosin stain showed two distinct layers: the germinal epithelial layer and the external laminated membrane. The inner germinal layer contained protoscoleces with hooklets and free scolices, confirming their parasitic origin.

Microscopical and histopathological examination, confirmed the presence of *E. granulosus* protoscoleces and hooklets within hydatid sand. The identification of *Cysticercus tenuicollis* like cysts in some samples highlighted the need for further species-level analysis to differentiate between similar parasites. These findings align with previous studies and emphasize the utility of histopathological tools in diagnosing cystic echinococcosis.

PCR Findings

DNA was extracted from samples labeled A01 and A02 (Anuradhapura). Nanodrop spectrophotometry revealed varying DNA concentrations, with A02 recording the highest at 204.8 ng/μl. PCR amplification of the cytochrome c oxidase subunit 1 (COX1) gene successfully produced bands of 450 bp, with no bands observed in negative controls. These findings were consistent with (Metwally *et al.*, 2018) which further confirms the accuracy of the results obtained.



Figure 1: PCR amplification of COX-1 gene using FH5/FH3, 1:100bp DNA ladder, 3: A01, 4: A02,6: Negative control

DNA Purification and Sequencing

Upon bidirectional sequencing of purified DNA of sample A02, NCBI BLAST results indicated a high similarity between local isolates and *Echinococcus ortleppi* (G5 strain), a cattle-associated wild strain. A 100% similarity was noticed with *E. ortleppi* strain in a study conducted in China with accession number MZ190835.1, which proves that this strain has previously been identified in humans, providing additional context about its zoonotic potential. Molecular methods, including PCR and sequencing, provided precise identification of *E. granulosus*.

Phylogenetic Analysis

Phylogenetic trees constructed using MEGA 11 software revealed that sequences from Anuradhapura clustered closely with *E.ortleppi* isolates from global databases. This analysis underscores the importance of exploring strain-level variations across different geographic regions.

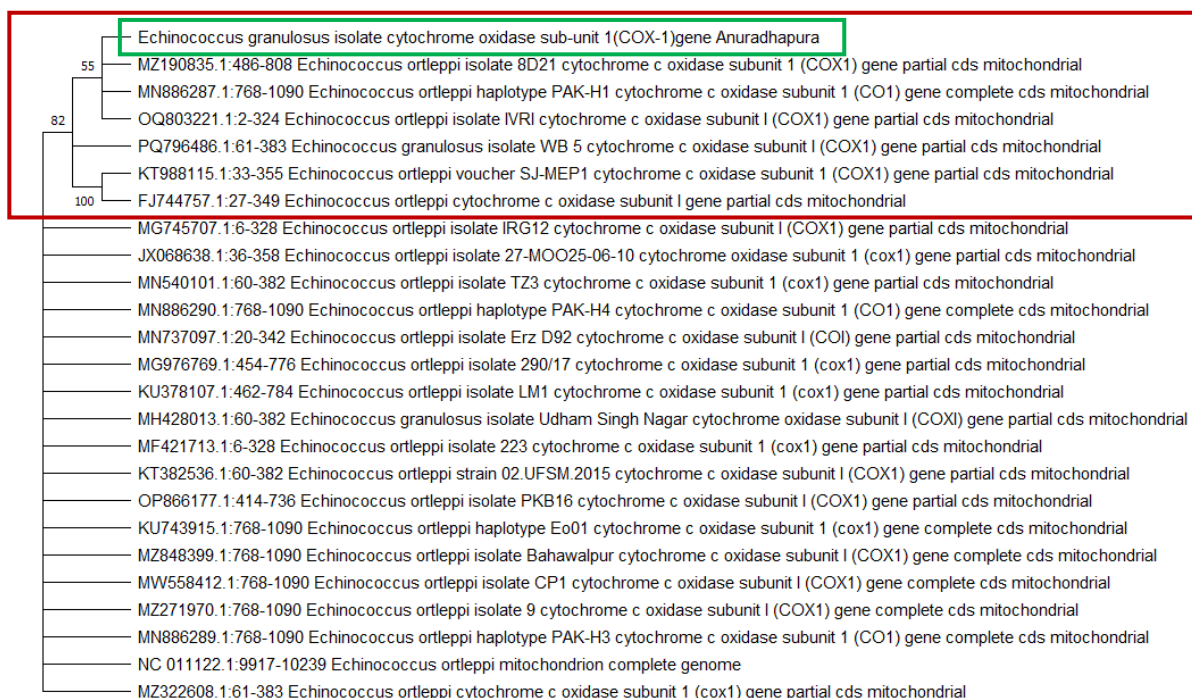


Figure 2: Maximum Likelihood (ML) tree displaying the variation of the *Echinococcus granulosus* sequence from Anuradhapura (highlighted in red) based on Phylogenetic analysis of COX1 gene by Mega 11 software. Red: Strains closely associated to local isolate, Green: Local isolate from Anuradhapura sample.

Phylogenetic analysis of 24 highly similar sequences demonstrated close relationships between local isolates and global *E. ortleppi* strains. In the ML tree, isolate from Anuradhapura had a close relationship with strains isolated from China (MZ190835.1), Pakistan (N886287.1) and India (OQ803221.1) forming monophyletic single clades. Additionally, monophyletic sister clades are noticed with strains bearing accession numbers PQ796486.1(India), KT988115.1(Iran) and FJ744757.1(Italy). This close genetic relationship across geographically diverse regions suggests evolutionary conservation and possible host-mediated dispersal. However, subtle phylogenetic differences indicate strain-level variations driven by geographic and ecological factors.

Conclusion

In conclusion, this study offers valuable insights into the prevalence, morphology, and molecular epidemiology of cystic echinococcosis (CE) in goats. Among 2,736 samples inspected during slaughtering in Colombo Municipality Council abattoirs, a low occurrence in 13(0.5%) was observed, with hydatid cysts predominantly found in the liver and lungs. Globally, many isolates of *E. granulosus* strains have been identified in intermediate host species, but few were from goats, and sample numbers in most investigations were insufficient for statistically significant results. Thus, there is a clear need to characterize a larger number of goat isolates. Molecular analyses identified the G5 strain of *Echinococcus ortleppi*, a cattle-associated haplotype, confirmed through PCR amplification of the COX1 gene and phylogenetic analysis. The local isolates closely clustered with global G5 strains from countries such as China, India, Pakistan, forming monophyletic clades,

which indicates evolutionary conservation across regions. Unlike other endemic areas where CE prevalence in small ruminants is higher and G1 is the dominant haplotype, Sri Lanka's unique G5 strain distribution may contribute to the relatively low incidence of human CE in the country. Morphological pathological lesions, including atypical cysts resembling *Cysticercus tenuicollis*, further underscore the need for detailed species-level differentiation.

This research provides a foundation for understanding CE's epidemiology in Sri Lanka, highlighting the importance of identifying strain-level genetic variations. These findings emphasize the need for whole-genome sequencing and comparative genomic studies to further explore strain diversity and genetic variations. Such studies would provide deeper insights for tailoring region-specific strategies to mitigate CE's economic and public health impacts in livestock-dependent regions.

References

- Assefa, H., Belay Mulate, Nazir, S. and Alemayehu, A. (2015). Cystic echinococcosis amongst small ruminants and humans in central Ethiopia. *Onderstepoort Journal of Veterinary Research*, 82(1). doi:<https://doi.org/10.4102/ojvr.v82i1.949>.
- Eckert, J. and Deplazes, P. (2004). Biological, Epidemiological, and Clinical Aspects of Echinococcosis, a Zoonosis of Increasing Concern. *Clinical Microbiology Reviews*, 17(1), pp.107–135. doi:<https://doi.org/10.1128/cmr.17.1.107-135.2004>
- Metwally, D.M., Qassim, L.E., Al-Turaiki, I.M., Almeer, R.S. and El-Khadragy, M.F. (2018). Gene-based molecular analysis of COX1 in Echinococcus granulosus cysts isolated from naturally infected livestock in Riyadh, Saudi Arabia. *PloS one*, 13(4), p.e0195016. doi:<https://doi.org/10.1371/journal.pone.0195016>.
- Saleem, S., Ahmed, H., Kaleem Imdad, Zhang, J. and Cao, J. (2023). An Epidemiological Survey to Investigate the Prevalence of Cystic Echinococcosis in Slaughtered Bovine Hosts in Punjab, Pakistan. *Veterinary Sciences*, 10(1), pp.40–40. doi:<https://doi.org/10.3390/vetsci10010040>.

MICROBIAL POLLUTION STUDY OF MAHAWELI RIVER AT WATER TREATMENT INLETS BETWEEN NAWALAPITIYA AND MATALE

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Abstract

The increasing prevalence of antibiotic-resistant bacteria poses a serious global public health challenge, particularly as antimicrobial resistance (AMR) spreads through environmental sources. Aquatic ecosystems, notably, play a critical role in this dissemination. This study aimed to evaluate antibiotic resistance in *E. coli* populations from the Mahaweli River, Sri Lanka's longest river. Isolates were cultured on MacConkey agar to identify *E. coli*, followed by biochemical confirmation through indole and oxidase tests. Susceptibility to antibiotics amoxicillin, cefuroxime, tetracycline, co-trimoxazole, ciprofloxacin and streptomycin was assessed using the disk diffusion method. Among the 14 *E. coli* isolates collected from seven river sites, 47% exhibited resistance to one or two antibiotic classes, while 57% were resistant to three or more. Notably, complete resistance was observed for amoxicillin and cefuroxime, with high overall resistance rates against amoxicillin, cefuroxime and tetracycline compared to the other antibiotics tested. This study sheds light on the antibiotic-resistant *E. coli* presence in the Mahaweli River.

Key words: Antibiotic resistance, Aquatic ecosystems, Disk diffusion method, *Escherichia coli*, Mahaweli River

Introduction

Antibiotic resistance and multidrug resistance are significant global health concerns, causing significant morbidity and mortality. In Sri Lanka, the Mahaweli River is a hotspot for the transmission of antibiotic-resistant bacteria and antibiotic resistance genes, which are dispersed through various routes, including urban runoff, agriculture, aquaculture, animal husbandry, and discharges from wastewater treatment plants and hospitals. *Escherichia coli* strains have acquired resistance genes, enabling them to cause severe infections. A 2021 study in Sri Lanka investigated antimicrobial-resistant *E. coli* in surface waters and hospital effluents from Kandy, which discharge into the Mahaweli River. The study revealed multidrug-resistant *E. coli* strains resistant to beta-lactams, tetracyclines, quinolones, sulfamethoxazole, aminoglycosides, and chloramphenicol, carrying specific resistance genes. This study aims to investigate the prevalence and resistance profiles of *E. coli* isolated from the river, focusing on six commonly used antibiotics, to understand the extent of antibiotic-resistant bacteria presence, the frequency of multidrug-resistant isolates, and the associated risks to public health. (Guruge, *et al.*, 2021). As a facultative pathogen and a common water quality indicator, *E. coli* offers significant data about the patterns and prevalence of antibiotic resistance. Analyzing the resistance patterns in the Mahaweli River is essential for determining the dangers of human exposure and the spread of antibiotic resistance in the environment. The results

will be useful in developing strategies to manage and stop the spread of resistance, safeguarding human and environmental health from the growing threat posed by antibiotic resistance.

Methodology

Study area and sampling

Water samples were collected from seven water treatment plants along the Mahaweli River in the Kandy District, including Heighenford, Elpitiya, University water treatment plant, South Water Treatment Plant, Pahalkondadeniya, Polgolla, and Oya Pahala. Both raw and treated water samples were obtained from the water treatment plants.

The Heighenford Water Treatment Plant is located at Nawalapitiya, Elpitiya Water Treatment Plant is located at Weligalla, University water treatment plant, South Water Treatment Plants are located at Meewatura, Pahalkondadeniya Water Treatment Plant is located at Katugastota, Polgolla Water Treatment Plant is located at Polgolla and Oya Pahala Water Treatment Plant is located at Matale. A total of 100 mL of both raw and treated water was collected at each site in sterile polyethylene bottles, the samples were transported to the laboratory within 12 hours of collection and kept at 6°C until processed for microbial analysis.

Isolation and identification of *E. coli*

E. coli was isolated using the direct plating method in order to test for antibiotic susceptibility. Each water sample was put onto MacConkey agar plates in a 1 mL aliquot, which was then incubated for 24 hours at 37°C. *E. coli* was considered to be the cause of colonies that had a distinctive pink or red color brought on by lactose fermentation. In a biosafety level 2 lab, these colonies were sub cultured onto fresh media while being kept aseptic. Isolates were subjected to oxidase and indole tests to verify their identify as *E. coli*. The presence of *E. coli* was verified by negative oxidase and positive indole findings. Testing for antibiotic susceptibility was then performed on the confirmed isolates.

Antibiotic susceptibility testing

The disk diffusion method was used to assess antibiotic resistance in *E. coli* isolates against six antibiotics: amoxicillin, tetracycline, cefuroxime, ciprofloxacin, co-trimoxazole and streptomycin which were selected for their clinical and environmental significance. The concentrations of the antibiotics used were as follows: amoxicillin 10 mg, cefuroxime 30 mg, tetracycline 30 mg, streptomycin 10 mg, ciprofloxacin 5 mg, and co-trimoxazole 25 mg.

E. coli suspensions were standardized to the 0.5 McFarland turbidity and inoculated onto Mueller-Hinton agar. Antibiotic disks were applied, and plates incubated at 37°C for 18 hours. Inhibition zone diameters were measured per EUCAST guidelines to classify isolates as sensitive, intermediate, or resistant. Isolates resistant to three or more antibiotic classes were classified multidrug-resistant (MDR), highlighting their significant resistance profiles.

Results

Results from cultures of treated water samples.

Treated water samples from all seven treatment plants showed no microbial growth on MacConkey agar, indicating effective purification by Sri Lanka's Water Board.

Results from cultures of raw water samples

From the raw water sample cultures, a total of 28 bacterial isolates were obtained, with four isolates from each sample area. Among these, three isolates from Elpitiya, South water treatment plant, Pahalkondadeniya, and the University Water Treatment Plant were confirmed as *E. coli* through biochemical testing. Additionally, two isolates from each of Heightenford, Polgolla, and Oya Pahala also tested positive for *E. coli* based on the biochemical tests. Due to limited resources, two confirmed *E. coli* isolates from each sample area (14 in total) were selected for antibiotic susceptibility testing to evaluate their resistance profiles.

Resistant patterns of E. coli isolates to antibiotics.

In order to evaluate the patterns of antibiotic susceptibility, isolates were classified based on the amount of resistance and the sensitivity to various antibiotic classes. Among the six antibiotics tested, the *E. coli* isolates showed highest resistance for penicillins and cephalosporins, with all *E. coli* isolates (n=14) showing resistance to amoxicillin and cefuroxime. The *E. coli* isolates exhibited 43% resistance to tetracycline (n=6), followed by 36% resistance (n=5) to sulphonamides. The least resistance was observed for fluoroquinolones and aminoglycosides. Of the isolates, 43% (n=6) were resistant to two antibiotic classes, and 57% (n=8) were multidrug-resistant (resistant to three or more classes), originating from Heightenford, Elpitiya, South Water Treatment plant, Pahalkondadeniya, and Oya Pahala plants. Extensive drug resistance, found in 36% (n=5), was observed in isolates from Elpitiya, south water treatment plant, Katugastota, and Matale plants, resistant to all but one or two antibiotic classes.

For details on the antibiotics susceptibility testing on the isolates see Table 1.

Table 1: Isolates from each sample area and their AMR status (AMX: amoxicillin, TE: tetracycline, CXM: cefuroxime, S: streptomycin, CIP: ciprofloxacin, COT: co-trimoxazole)

<i>E. coli</i> isolated sites	Isolates	AMX	TE	CXM	S	CIP	COT
Heightenford Water Treatment plant	isolate 1	resistant	sensitive	resistant	sensitive	sensitive	sensitive
	isolate 2	resistant	sensitive	resistant	resistant	sensitive	sensitive
Elpitiya Water Treatment plant	isolate 1	resistant	resistant	resistant	sensitive	sensitive	resistant

	isolate 2	resistant	sensitive	resistant	sensitive	sensitive	sensitive
Polgolla Water Treatment plant	isolate 1	resistant	sensitive	resistant	sensitive	sensitive	sensitive
	isolate 2	resistant	sensitive	resistant	sensitive	sensitive	sensitive
South Water Treatment plant	isolate 1	resistant	resistant	resistant	resistant	sensitive	resistant
	isolate 2	resistant	resistant	resistant	sensitive	sensitive	resistant
Pahalkondadeniya Water Treatment plant	isolate 1	resistant	resistant	resistant	sensitive	sensitive	resistant
	isolate 2	resistant	sensitive	resistant	sensitive	sensitive	resistant
University Water Treatment plant	isolate 1	resistant	sensitive	resistant	sensitive	sensitive	sensitive
	isolate 2	resistant	sensitive	resistant	sensitive	sensitive	sensitive
Oya Pahala Water Treatment plant	isolate 1	resistant	resistant	resistant	sensitive	sensitive	sensitive
	isolate 2	resistant	resistant	resistant	resistant	resistant	sensitive

The tested *E. coli* isolates (n=14) showed complete resistance to two antibiotic classes: amoxicillin (penicillin) and cefuroxime (cephalosporin). Resistance to tetracycline (n=6) and co-trimoxazole (n=5) was also notable, while resistance to ciprofloxacin (n=1) and streptomycin (n=3) was observed in few isolates. Most of the Multidrug-resistant isolates were resistant to AMX + TE + CXM (n=6) and while most of the isolates were resistant to AMX+TE+CXM+COT (n=3)

Discussion

Six pathogens, including *E. Coli*, *Staphylococcus aureus*, *K pneumoniae*, *S pneumoniae*, *Acinetobacter baumannii*, and *Pseudomonas aeruginosa*, were found to be responsible for over 250000 deaths linked to Anti-microbial resistance in a 2019 study on the global burden of bacterial antimicrobial resistance. The majority of these deaths were attributed to infections caused by *E. Coli*. One of the most important worldwide health concerns is bacterial AMR. Furthermore, it was found that lower-middle-income nations had the highest AMR all-age mortality rates, indicating that Anti-microbial resistance is not only a significant worldwide health issue but also a particularly severe one for nations like Sri Lanka. (Murray, *et al.*, 2022)

Escherichia coli, pathogenic bacteria, can develop resistance to antibiotics due to exposure to pollutants in landfills. These pollutants, such as used sanitary goods, diapers, and expired medication, can enter rivers through surface runoff, causing *E. coli* to develop antibiotic resistance traits. The bacteria can acquire resistance genes through horizontal gene transfer, allowing them to survive in the presence of antimicrobial agents. These resistant bacteria can be introduced to humans and animals through contaminated water, making it difficult to treat infections using standard antibiotics. The presence of *E. coli* increases the risk of human infectious diseases, as these pathogenic bacteria can neutralize different classes of antibiotics. The ongoing struggle against antibiotic resistance highlights the ongoing struggle against antibiotic-resistant bacteria. (Liyanage, *et al.*, 2024)

In this study, water samples were collected from seven sampling sites across six locations along the banks of the Mahaweli River, including Nawalapitiya, Weligalla, Meewatura, Katugastota, Polgolla, and Matale. Six classes of antibiotics were tested: aminoglycosides, beta-lactams, fluoroquinolones, sulfonamides, tetracyclines, and cephalosporins. The *E. coli* strains tested exhibited the highest resistance to amoxicillin and cefuroxime. In contrast, resistance to streptomycin and ciprofloxacin was observed in only a few isolates.

A study in the Sri Lanka Journal of Medicine assessed the appropriateness of prescribing antibiotics to outpatients with upper respiratory tract infection symptoms lasting less than three days. Antibiotics were prescribed to 71.9% of patients, with amoxicillin being the most common. The misuse of amoxicillin for likely viral infections contributes to increasing antibiotic resistance, posing a serious public health risk. (Madhushani & Kommalage, 2019).

High antibiotic resistance in *E. coli* strains was observed in water samples from Nawalapitiya, Katugastota, and South water treatment plant in the Kandy district.

In Matale, with over 50,000 residents and 30–32 tons of daily waste, poorly managed landfills contribute to groundwater contamination with antibiotics and pharmaceuticals, fostering resistant bacteria. (Hilmy, 2016).

The Mid Canal (Meda Ela) runs through Katugastota. It is a waste water canal that originates from the Kandy Lake and travels through a heavily populated area where several state hospitals, private hospitals and clinical laboratories are located in the city. According to a 2021 study on the link between antimicrobials and antimicrobial-resistant *Escherichia coli* found in Meda Ela, approximately 80% of the *E. coli* isolates were found to be resistant to the tested antimicrobial drugs, with 61% of them being classified as multidrug-resistant. (Guruge, *et al.*, 2021)

The Gohagoda dumping site, 1 km from the Katugastota water treatment plant, likely contributes to the spread of resistant *E. coli* in the Katugastota area through contaminants like antibiotics, pharmaceuticals, and heavy metals.

The absence of identifiable point sources of water pollution in South water treatment plant suggests that further investigation is needed to determine the underlying causes of this elevated antibiotic resistance observed in *E. coli* isolates from water samples in the area.

Our study identified 8 *Escherichia coli* isolates exhibiting multidrug resistance, likely driven by extensive antibiotic use in medicine, animal husbandry, and aquaculture. Comparatively, Odonkor & Addo (2018) reported a 49.48% prevalence of multidrug-resistant *E. coli*, with the highest resistance against penicillin, cefuroxime, erythromycin, and tetracycline. Additionally, 63% of these strains had a MAR index above 0.2, indicating significant exposure to antibiotics. Regions like sub-Saharan Africa and South Asia face high antibiotic-related mortality due to resistant infections and critical illnesses.

In Sri Lanka, increasing *E. coli* resistance, coupled with environmental contamination from waste and antibiotics, highlights an urgent need for improved antibiotic stewardship and waste management to safeguard public health.

Conclusion

The Mahaweli Ganga, Sri Lanka's longest river, is at risk of becoming one of the world's 10 most polluted rivers within the next decade due to activities like soil erosion, chemical and agricultural pollutants, industrial pollution, and solid waste disposal. This has led to the growth of antibiotic-resistant pathogens. Our study on *E. coli* isolates in the Mahaweli river revealed that all 14 tested *E. coli* isolates displayed resistance to beta-lactams, cephalosporins. 6 out of the 14 tested isolates exhibited resistance to tetracyclines, 5 out of the 14 tested isolates showed resistance to sulfonamides, resistance to aminoglycosides was only observed in 3 out of the 14 tested isolates and fluoroquinolones showed resistance to only one isolate. Multi-resistant *E. coli* was found in 8 out of the 14 tested isolates. The study underscores the urgent need for monitoring and addressing antibiotic resistance in environmental settings, as the prevalence of resistance poses significant challenges for effective treatment of bacterial infections.

References

- Guruge, K. S., Tamamura Y A., Goswami P., Tanoue R., Jinadasa K B S N., Nomiya K., Ohura T., Kunisue T., Tanabe S., Akiba M, 2021. The association between antimicrobials and the antimicrobial-resistant phenotypes and resistance genes of *Escherichia coli* isolated from hospital wastewaters and adjacent surface waters in Sri Lanka. *Chemosphere*, Volume 279, p. 130591.
- Liyanage, G. Y., Wijerathna, . P. A. K. C., Bandara, . S. M. T. V. & Pathmalal M. Manage, 2024. Assessment of Virulence Potential and Antibiotic Resistance Profiles in *E. coli* Isolates from Selected Ground Water Samples Around the Control Open Dump Sites in Sri Lanka. *Waste and Biomass Valorization*.
- Hilmy, M., 2016. Solid waste management in Matale, Sri Lanka: a key to unlocking sustainable urban development [Interview] 2016.
- Madhushani, S. & Kommalage, M., 2019. USE OF ANTIBIOTICS FOR PATIENTS PRESENTING WITH SYMPTOMS SUGGESTIVE OF UPPER RESPIRATORY TRACT INFECTIONS OF LESS THAN 3 DAYS TO AN OUTPATIENT DEPARTMENT OF A TERTIARY HOSPITAL IN SRI LANKA. *Sri Lanka Journal of Medicine*, 28(1).
- Murray, C., Christopher J L, Ikuta, Shunji K, Sharara, Fabiana, Swetschinski, Lucien, Rao, Puja, 2022. Global burden of bacterial antimicrobial resistance in 2019: a systematic analysis. *The Lancet*, 399(10325), pp. 629-655.
- Odonkor, S. T. & Addo, K. K., 2018. Prevalence of Multidrug-Resistant *Escherichia coli* Isolated from Drinking Water Sources. *International Journal of Microbiology*, 2018(1), p. 7204013.

RIISING THREAT: TACKLING ANTIMICROBIAL RESISTANCE IN *E. coli* IN POULTRY FARMING

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Abstract

AMR is a global issue affecting both human and veterinary medicine, as antimicrobials are shared across these sectors. In Sri Lanka's poultry industry, antimicrobial use is prevalent, making it essential to screen for resistance to safeguard animal and public health.

The study aimed to identify the frequency of AMR in *E. coli* from poultry and determine the MIC value of colistin needed to inhibit *E. coli* growth during metaphylaxis.

140 poultry isolates were cultured, and gram staining confirmed rod morphology in 129 samples. Biochemical tests identified 98 samples as *E. coli*. Antimicrobial susceptibility testing (AST) was conducted using the Kirby-Bauer method with ten drugs following EUCAST guidelines. MIC testing for colistin was performed using the agar dilution method.

AST showed high resistance to Ampicillin, Tetracycline, and SXT, while Gentamicin had higher susceptibility. Colistin MIC testing peaked at 128 µg/mL, indicating resistance.

Over 50% of poultry *E. coli* samples in Sri Lanka showed AMR, highlighting the urgent need for effective surveillance and antimicrobial resistance monitoring.

Key Words: Antimicrobial Resistance (AMR), Antimicrobial Suseptibility Testing (AST), *Escherichia coli*, Minimum Inhibitory Concentration (MIC)

Introduction

Antibiotics are substances that prevent the growth of microorganisms and are used in both therapeutic and non-therapeutic veterinary practices, such as feed enhancement and disease prevention. However, improper use of antibiotics can result in antimicrobial resistance (AMR) (Hosain *et al.*, 2021). AMR occurs when bacteria, viruses, fungi, and parasites adapt over time, becoming unresponsive to treatments (Chen *et al.*, 2021).

AMR is a growing global issue affecting both human and animal health. In 2019, approximately 4.95 million deaths were linked to AMR, with an expected rise to 10 million deaths by 2050 (Walsh *et al.*, 2023). Most of these deaths will occur in low- and middle-income countries (LMICs) in Asia and Africa, where antimicrobial use regulations are weak (Habiba *et al.*, 2023). Around 829,000 deaths in 2019 were related to *E. coli* infections (Daneman *et al.*, 2023).

E. coli is a gram-negative bacterium commonly found in the gastrointestinal tract of animals. While many strains are harmless, others, like Avian Pathogenic *E. coli* (APEC), cause diseases such as colibacillosis in poultry (Aijuka and Buys, 2019). Colibacillosis is a major concern in the poultry

industry, resulting in economic losses due to high mortality and reduced productivity (Joseph *et al.*, 2023).

The global poultry industry is rapidly expanding, producing 137.8 million tons of meat in 2021, with significant contributions from the USA, China, Brazil, and Asia (FAO). In Sri Lanka, poultry constitutes 70% of the livestock sector. Antibiotics like doxycycline, tetracycline, and ciprofloxacin are commonly used to prevent diseases caused by *E. coli* and *Salmonella* (Hosain *et al.*, 2021). Additionally, colistin, a last-resort antibiotic effective against gram-negative bacteria like *Enterobacteriaceae*, is used in poultry to treat gastrointestinal infections (Walsh *et al.*, 2023). However, the misuse of antibiotics has led to multidrug-resistant (MDR) bacteria, which pose a significant threat to poultry health (Walsh *et al.*, 2023).

The primary objective of this study is to investigate the prevalence of AMR in Sri Lanka, with a specific focus on its implications for the poultry industry.

Methodology

Cell Culturing and Morphology Identification.

Poultry cecum samples (n=140), stored in cryovials with tryptic soy broth (TSB [Oxoid]) at -40°C, were obtained from the Veterinary Research Institute (VRI), Peradeniya. Samples were thawed, cultured on Nutrient Agar (NA, Biolife), and incubated at 37°C for 24 hours. Morphological identification was performed using Gram staining, involving crystal violet, Gram's iodine, decolorizer, and Safranin, followed by microscopic observation of similar colonies.

Identification Test (Biochemical Test)

Gram-negative rod samples (n=129) were sub-cultured on Nutrient Agar (Biolife) at 37°C before biochemical testing. Identification used Simmon's Citrate Agar, Urease Agar, Sulphur Indole Motility, and Triple Sugar Iron Agar, incubated at 37°C for 18-22 hours. Further confirmation involved indole testing with Kovacs reagent and oxidase testing.

Antimicrobial Susceptibility Test (AST)

Antibiotic susceptibility of *E. coli* (n=98) was tested using the Kirby-Bauer disk diffusion method. Isolates were cultured on Nutrient Agar (NA) at 37°C for 18-22 hours, and morphologically similar colonies were suspended in sterile saline (0.89%) and adjusted to 0.5 McFarland standard ($1-2 \times 10^8$ CFU/ml). A cotton swab was used to spread the suspension on Muller-Hinton (MH) agar. Antibiotics were tested using EUCAST guidelines, and ATCC CCM 3954 served as a negative control.

Minimum Inhibitory Concentration (MIC)

Colistin MIC was tested using the agar dilution method following EUCAST and CLSI guidelines. A colistin dilution series (128–0.25 mg/mL) was prepared by sequentially diluting the antibiotic in sterile distilled water. MH agar was autoclaved, cooled to 55°C, mixed with 1 mL antibiotic solution, and poured into plates. Standardized bacterial suspensions (0.05 McFarland) were prepared, and 1 µL was inoculated on plates. Plates were incubated at 37°C for 18-22 hours for MIC determination.

Results

AST Results

Table 1: The number of *E.coli* isolates from poultry that showed Resistance (R), Susceptibility (S), and Intermediate (I) nature for the below Ab (n=98).

Type of Antibiotic	R	S	I
Tetracycline	92	6	-
Ampicillin	96	2	-
Meropenem	25	69	4
Gentamycin	28	68	2
Cefoxitin*	20	29	13
Ceftazidime	26	71	1
Sulfamethaxole/Trimethoprim	80	17	1
Ciprofloxacin	74	14	10
Neomycin **	-	-	-
Amikacin	25	68	5

*CTX is only tested for 62 samples since there was a storage of Ab disks.

**The breakpoint for Neomycin is not indicated in the EUCAST and CLSI manual, therefore this is acting as a limitation.

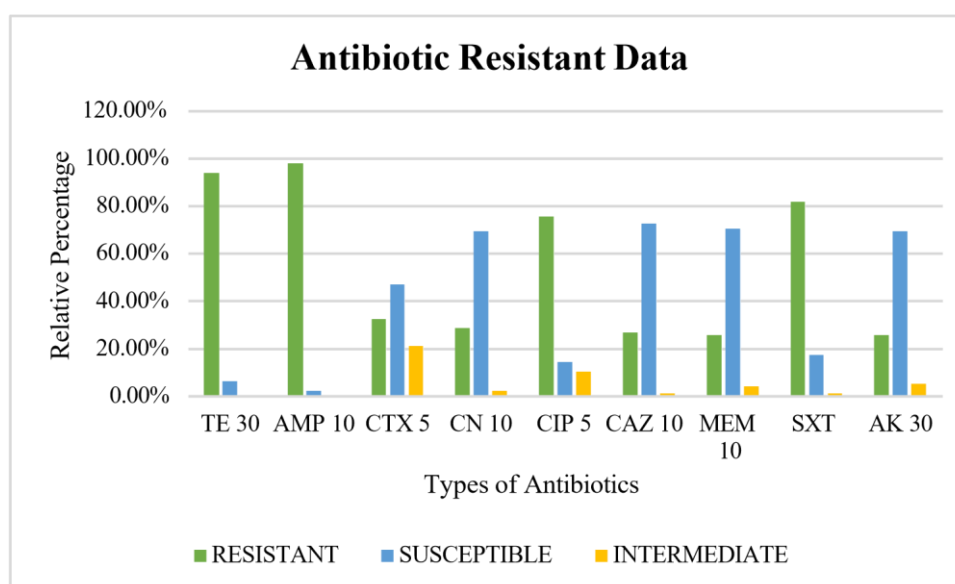


Figure 1: Antibiotic percentage for all the 09 Ab are depicted above.

*Neomycin is not considered here since the breakpoint is not indicated in EUCAST or CLSI manual.

MIC Results

Table 2: The resistant and susceptible percentages for each dilution series.

n=98		No.of strains with MIC (mg/ml)															
Antimicrobial Agent	Dilution Series										Susceptible		Resistant				
	>128	64	32	16	08	04	02	01	0.5	<0.25	[n]	%	[n]	%			
Colistin	28	0	1	1	0	1	3	13	16	35	67	68.37	31	31.63			

The reference values are based on *Enterobacterales* according to the EUCAST manual from 2015.

The | indicates the resistant range, while | indicates the susceptible range.

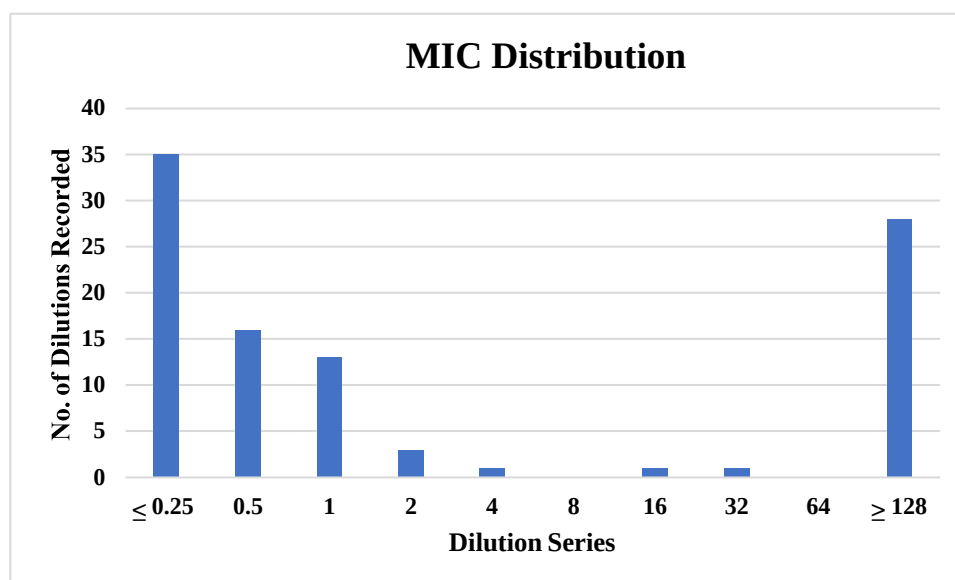


Figure 2: The number of isolates that grew in the dilution series.

AST results (Table 1) were obtained for all biochemically positive samples using 10 antibiotics. Zones of inhibition were measured (mm) and categorized as susceptible, resistant, or intermediate per EUCAST guidelines. Figure 2 shows the percentage distribution of these categories. MIC values (Table 2) follow

EUCAST criteria: $S \leq 2$ mg/mL and $R > 2$ mg/mL. Resistance ranged from ≥ 128 to 4 mg/mL, and susceptibility ranged from ≤ 0.25 to 2 mg/mL. Figure 2 records *E. coli* growth in each dilution.

Discussion

This study explores antimicrobial resistance across ten drugs, including a crucial final-line treatment for *E. coli* in poultry. The growing Sri Lankan poultry industry requires birds to be given antimicrobials for metaphylaxis against *E. coli*-related diseases to meet demand, reflecting trends in the global industry (Ubeysekara *et al.*, 2021).

The study demonstrated significant *E. coli* resistance to Tetracycline (93.90%) and Ampicillin (97.90%), consistent with Mauritius findings of 100% TET resistance, attributed to low cost and accessibility (L and H, 2015).

A study in Thailand on 30 commercial broilers showed 100% resistance to Ampicillin (AMP), while a Nepal study (Koju *et al.*, 2022) reported 99% resistance. The AMP resistance observed in Sri Lanka aligns with these international findings. SXT resistance reached 81.63% in the study. A 2015 Nguyen *et al.* study showed 69.7% resistance in Asia's poultry, reflecting increased antibiotic usage. In Timor-Leste, SXT resistance was 0.3% in live-bird markets. Sri Lanka shows higher SXT resistance due to rising antibiotic consumption. Aminoglycosides, commonly used in animal treatment, pose risks of residual contamination, potentially fostering resistant strains (Nowacka-Kozak *et al.*, 2023).

The study highlights increasing resistance in *E. coli* strains in the Sri Lankan poultry industry against several antibiotics, including CN and AK. CN and AK resistance (28.57% and 25.51%) contrasts with earlier European studies showing 0% resistance (Hasman *et al.*, 2015). In a 2017 European study, CN resistance was 2.9% (Lambrecht *et al.*, 2018). CIP resistance (75.51%) is significant due to unregulated usage in developing countries (Das *et al.*, 2023). MEM shows higher susceptibility (70.40%) in Sri Lanka, similar to Zambia (Steward Mudenda *et al.*, 2023), but contrasting with Bangladesh's 50.9% resistance (Mandal *et al.*, 2021). Neomycin resistance remains untested in Sri Lanka but shows regional variations, with Bangladesh and Africa reporting 7.4% to 38.6% resistance (Imam *et al.*, 2020; Osman *et al.*, 2021). Regarding multidrug resistance (MDR), Sri Lanka exhibits 91.80% MDR prevalence, indicating resistance to combinations of TE, AMP, CIP, CN, and SXT (Sujeewa Ariyawansa *et al.*, 2024). Comparatively, global MDR rates vary, with India and Vietnam showing 94% and 91.5% resistance, respectively (Hedman *et al.*, 2020; Founou *et al.*, 2016). The EU and USA have lower MDR levels due to stricter antimicrobial use policies (Founou *et al.*, 2016).

Colistin resistance, driven by the *mcr* gene, shows a 31.63% resistance rate in Sri Lanka (Mulu Lemlem *et al.*, 2023). MIC distribution suggests high susceptibility (≤ 0.5 mg/mL) but moderate resistance (≥ 128 mg/mL). Genotypic resistance remains unverified in Sri Lanka but mirrors global trends where *mcr* gene transmission occurs through environmental contamination and poultry interactions (Madubuike Umunna Anyanwu *et al.*, 2023). These findings highlight the urgent need for regulated antibiotic use and robust surveillance to address resistance across sectors (Velazquez-Meza *et al.*, 2022).

Conclusion and recommendations

This research investigated AMR patterns in poultry *E. coli*, facing limitations such as missing breakpoint values for Neomycin and limited Colistin resistance data due to the lack of genotypic analysis. Future studies should test higher colistin MIC dilutions (512 and 0.125 mg/ml) and explore colistin's *mcr* genes to understand resistance mechanisms. Additionally, testing last-resort drugs like tigecycline, and linezolid is essential. Expanding research across multiple Sri Lankan processing plants will improve resistance pattern analysis and provide more comprehensive insights. The findings reveal significant AMR in Sri Lanka's poultry industry, with high resistance to AMP and TET and Colistin resistance at 128 µg/ml, highlighting the urgent need for strict antimicrobial policies and further research to protect poultry health, and public safety.

References

- Daneman, N., Fridman, D., Johnstone, J., Langford, B.J., Lee, S.M., MacFadden, D.M., Mponponsuo, K., Patel, S.N., Schwartz, K.L. and Brown, K.A. (2023). Antimicrobial resistance and mortality following *E. coli* bacteremia. *eClinicalMedicine*, 56, p.101781. doi:<https://doi.org/10.1016/j.eclinm.2022.101781>.
- Founou, L.L., Founou, R.C. and Essack, S.Y. (2016). Antibiotic Resistance in the Food Chain: A Developing Country-Perspective. *Frontiers in Microbiology*, 7. doi:<https://doi.org/10.3389/fmicb.2016.01881>.
- Hosain, Md.Z., Kabir, S.M.L. and Kamal, Md.M. (2021). Antimicrobial uses for livestock production in developing countries. *Veterinary World*, [online] 14(1), pp.210–221. doi:<https://doi.org/10.14202/vetworld.2021.210-221>.
- Ubeysekara, H.A., Ranaweera, N.P.N.M., Peris, H.H. and Wijayaratne, W.M.D.G.B. (2021). Antibiotic use in poultry production; a cross-sectional study in a selected district in Sri Lanka. *Galle Medical Journal*, 26(2), p.74. doi:<https://doi.org/10.4038/gmj.v26i2.8050>.
- Velazquez-Meza, M.E., Galarde-López, M., Carrillo-Quiróz, B. and Alpuche-Aranda, C.M. (2022). Antimicrobial Resistance: One Health Approach. *Veterinary World*, [online] 15(3), pp.743–749. doi:<https://doi.org/10.14202/vetworld.2022.743-749>.
- Walsh, T.R., Ana Cristina Gales, Ramanan Laxminarayan and Dodd, P.C. (2023). Antimicrobial Resistance: Addressing a Global Threat to Humanity. *Antimicrobial Resistance: Addressing a Global Threat to Humanity*, [online] 20(7), pp.e1004264–e1004264. doi:<https://doi.org/10.1371/journal.pmed.1004264>.



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Chapter 05:
INFORMATION TECHNOLOGY

SOCIAL ENGINEERING TECHNIQUES IN PHISHING ATTACKS

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Abstract

This study investigates the social engineering techniques employed in phishing attacks, emphasizing psychological manipulation tactics that exploit human vulnerabilities. The research aimed to identify methods used by attackers and evaluate the effectiveness of these techniques. Data was collected through a global survey of internet users, capturing diverse experiences with phishing across platforms. Using a mixed-methods approach, key psychological triggers such as urgency, fear, and authority were analyzed. The findings reveal that phishing attacks frequently exploit low levels of cybersecurity awareness, leading to the unintentional disclosure of sensitive information. The study underscores the critical role of proactive defense mechanisms, including user education, regular phishing simulations, and technical safeguards, in reducing susceptibility to phishing. These measures are vital for strengthening cybersecurity practices at both individual and organizational levels, ultimately enhancing resilience against evolving cyber threats.

Key Words: Cybersecurity, Phishing Attacks, Psychological Manipulation, Social Engineering, User Awareness

Introduction

Phishing attacks, a subset of cybercrimes, have become one of the most significant threats in the digital age. These attacks leverage social engineering techniques, manipulating human psychology to exploit vulnerabilities. By masquerading as trustworthy entities, attackers aim to acquire sensitive information such as usernames, passwords, and financial details. With the increasing integration of technology into daily life, the scope and frequency of phishing attacks have grown exponentially, presenting severe risks to individuals and organizations. This research delves into the sophisticated methods used by cybercriminals, examines the impacts of phishing, and proposes strategies for mitigation.

The evolution of the internet and its integration into business, communication, and information exchange have amplified the risk of cyber threats like phishing. Reports from leading cybersecurity firms indicate that phishing remains a dominant method for cyber intrusions, utilizing psychological triggers such as trust, fear, curiosity, and urgency. Modern phishing attacks are far more sophisticated than the rudimentary fraudulent emails of the past. For example, attackers may exploit fear through alarming claims about compromised bank accounts or leverage trust by impersonating credible organizations to deceive victims. These tactics highlight the central role of social engineering in phishing, targeting human behavior to bypass technological safeguards.

This study aims to investigate the intersection of social engineering and phishing attacks by achieving the following **objectives**:

- Examine the social engineering techniques utilized in phishing attacks
- Analyze the impact of phishing attacks on individuals.
- Evaluate current preventive measures and propose enhanced strategies
- Contribute to ongoing discussions on cybersecurity policy and individual awareness.

By addressing these objectives, the research seeks to contribute to the broader discourse on cybersecurity, emphasizing the need for a proactive approach to counteract phishing and its reliance on human vulnerabilities.

Significance of the Work

This research is significant as it addresses the pressing need to mitigate phishing attacks, one of the most pervasive and evolving threats in the digital age. By exploring the intersection of psychology and cybersecurity, the study sheds light on how social engineering techniques exploit human vulnerabilities to bypass even the most advanced technological defenses. Understanding these manipulative tactics is essential for developing comprehensive strategies to counter phishing effectively. The findings of this research have far-reaching implications. For individuals, it equips them with knowledge to recognize and resist phishing attempts, thereby safeguarding their personal data and financial assets. For organizations, it emphasizes the importance of fostering a culture of cybersecurity awareness, integrating technical safeguards with employee education to fortify defenses. Additionally, this work contributes to the broader cybersecurity discourse by providing actionable insights for policymakers and cybersecurity professionals. It highlights the critical role of user behavior in maintaining security, offering recommendations to enhance training programs, awareness campaigns, and cybersecurity policies. Ultimately, the research not only addresses the technical and human aspects of phishing but also seeks to strengthen the overall resilience of digital ecosystems against evolving cyber threats.

Methodology

This chapter outlines the methodology adopted for investigating social engineering techniques in phishing attacks, focusing on research strategy, data collection methods, and analysis. A **mixed-methods approach** is utilized to provide a comprehensive understanding of phishing behaviors and the effectiveness of countermeasures by combining both quantitative and qualitative methodologies.

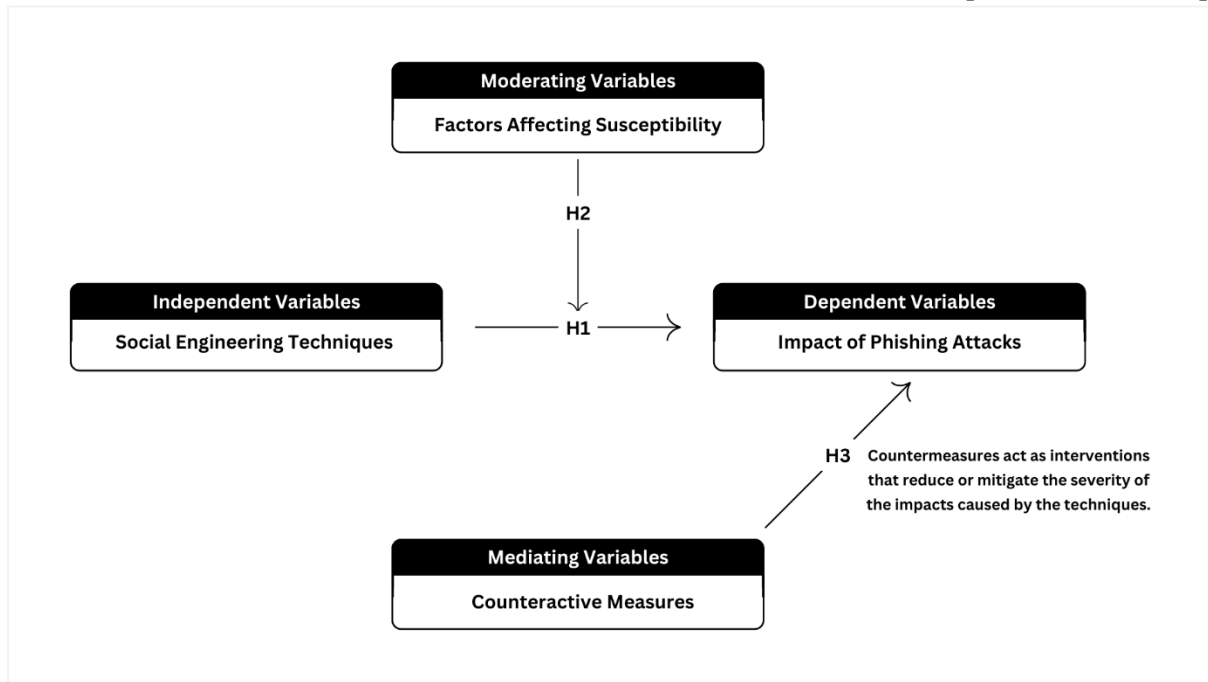


Figure 1 - Hypothesis

H1: Social engineering techniques significantly influence the success rate of phishing attacks.

H2: Higher levels of cybersecurity awareness reduce susceptibility to phishing attacks.

H3: Advanced technical defenses enhance organizational resistance to phishing.

Research Strategy

The study employs a mixed-methods approach to integrate numerical data with contextual insights, enabling a robust analysis of phishing attacks. This approach facilitates an in-depth exploration of the prevalence, patterns, and psychological aspects of phishing.

Quantitative Methodology:

Systematic collection and analysis of numerical data related to phishing behaviors.

Focuses on trends in the frequency of attacks, social engineering tactics, and the effectiveness of defense mechanisms.

Statistical techniques are employed to identify correlations and measure the impact of phishing.

Qualitative Methodology:

Provides contextual depth to the quantitative findings.

Includes document analysis of industry reports (e.g., Cofense Q1 2024) to uncover emerging trends, malware distribution, and evolving phishing tactics.

Explores the psychological manipulation employed in phishing and evaluates the effectiveness of current defense strategies.

By combining these approaches, the study aims to deliver actionable insights into mitigating phishing attacks and enhancing cybersecurity awareness.

Data Collection Methods:

Table 1 - Data Collection Methods

Section	Details
Surveys	Used to collect data on respondents' experiences with phishing attacks, susceptibility to social engineering tactics, and awareness of cybersecurity measures.
	Distributed via email, social media, and online forums to reach a broad audience.
Analytical Insights	Data from Cofense's Q1 2024 report is used to supplement survey findings.
	Provides insights into technical aspects of phishing attacks, including trends and attack vectors.

Data Analysis Techniques:

Table 2 - Data Analysis Technique

Data Analysis Techniques	Description
Quantitative Analysis	
Statistical Analysis	Descriptive Statistics: Summarizes survey data to highlight trends in phishing behaviors and defense mechanisms.
	Inferential Analysis: Draws conclusions about relationships between variables using hypothesis testing.
	Correlation and Pattern Analysis: Identifies significant trends and patterns in phishing behaviors.
Pattern Recognition	Utilizes machine learning algorithms to analyze analytical data from industry reports (e.g., Cofense Q1 2024).
	Techniques include clustering, classification, and anomaly detection to uncover emerging trends and predict future phishing tactics.
Qualitative Analysis	
Document Analysis	Data Familiarization: In-depth review of reports to identify key themes and insights.
	Thematic Coding: Categorizes recurring themes related to phishing attacks, malware trends, and cybersecurity vulnerabilities.

	Pattern Identification: Examines relationships within coded data to identify drivers of phishing attacks.
	Content Analysis: Extracts detailed information about phishing incidents and cybersecurity threats.
Integration of Findings	Combines quantitative survey data and qualitative insights through triangulation.
	Validates results for actionable recommendations to mitigate phishing and enhance cybersecurity awareness.

Quantitative Analysis:

Descriptive statistics were used to summarize survey data, highlighting trends in phishing behaviors and the effectiveness of countermeasures. Tools like Microsoft Excel (or SPSS) were utilized for data cleaning and visualization.

Qualitative Analysis:

Document reviews were analyzed using thematic coding. This helped identify recurring themes such as the psychological manipulation tactics used in phishing campaigns.

Sampling

Table 3- Sampling

Section	Details
Population Definition	Target population includes internet users worldwide, capturing a diverse range of demographics and online behaviors.
Sample Size Determination	Sample size of 100 respondents based on the Morgan Table, ensuring a 95% confidence level and a 5% margin of error for adequate statistical power.
Sampling Technique	Stratified random sampling to ensure diverse representation across age groups, genders, and professional backgrounds.
Sample Frame	Comprised of internet users from online platforms, social media, and digital communities, representing a variety of regions and online behaviors.
Sampling Procedure	Participants recruited through online surveys distributed via email, social media advertisements, and online forums; inclusion criteria focused on active users willing to participate.
Rationale for Sampling Approach	Aligns with research objectives by capturing data from a diverse range of internet users; stratified random sampling allows for generalization of findings regarding phishing susceptibility and defense mechanisms.

Data Analysis Process:

Table 4 - Data Analysis Process

Process	Details
Data Collection	
Survey Administration	Tool Used: Google Forms
	Distribution Channels: Email, social media, and online forums
	Ethical Considerations: Informed consent, confidentiality, and data protection
Document Analysis	Source: Cofense Q1 2024 report
	Purpose: Provided insights into phishing trends and tactics, complementing survey data
Data Analysis	
Quantitative Analysis	Tool Used: SPSS
	Process: Data cleaning, descriptive statistics, and data visualization
	Purpose: Analyzed survey responses to understand experiences with phishing attacks and evaluate defense mechanisms
Qualitative Analysis	Methods: Thematic coding and content analysis
	Source: Cofense report
	Purpose: Gained deeper insights into phishing tactics and cybersecurity trends
Integration of Findings	
Triangulation	Method: Combined survey data and document analysis findings
	Purpose: Provided a comprehensive view of phishing attacks, enhancing validity and applicability of results
	Outcome: Enabled nuanced understanding of social engineering techniques and their implications for cybersecurity

Results

Quantitative Findings

This section outlines the quantitative analysis conducted using survey data from respondents. Key trends and statistics have been extracted to present the significant findings.

Table 5 - Prevalence of Phishing Emails

Category	Percentage of Respondents
Received phishing emails requesting credentials	54%
Emails impersonating familiar entities	36%
Emails using urgent language	42%

Interpretation: As shown in Table 2, the data reveals that over half of the respondents (54%) have encountered phishing emails requesting personal or login credentials, with 42% of those emails using urgent language as a manipulation tactic. Furthermore, 36% of the emails impersonated familiar entities, aligning with the social engineering strategies observed in phishing campaigns.

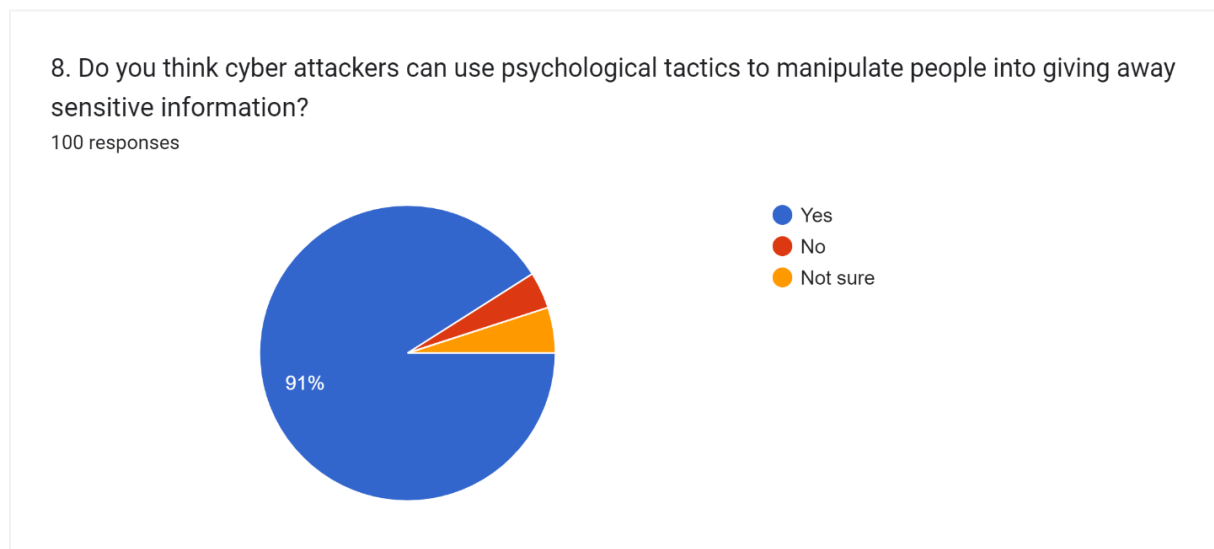


Figure 2 - Success Rate of Phishing Attacks Based on Psychological Manipulation Tactics
Comparison of phishing attack success rates based on different manipulation tactics, showcasing a higher success rate in emails employing urgency or familiarity tactics.

Qualitative Findings

The qualitative analysis is based on thematic analysis of the Cofense Q1 2024 report. The analysis highlights the evolving nature of phishing tactics and the emerging trends within specific sectors.



Figure 3 - Monthly Volume of Credential Phishing Emails (2022-2024)

Monthly volume of credential phishing emails observed in Q4 2022 through Q1 2024, emphasizing the growth of sophisticated phishing campaigns.

From the qualitative data, several themes emerged:

Increased Volume and Quality of Phishing Emails

The report highlights a sharp increase in the volume of phishing emails, often delivering common malware that is inexpensive and easily accessible to threat actors. This reflects a shift towards more aggressive and widespread phishing campaigns.

Targeted Attacks and Advanced Campaigns

The findings suggest a rise in more advanced, small, time-bound campaigns that leverage malware and evasion tactics to bypass traditional email defense mechanisms. These advanced campaigns are often directed at specific sectors, as outlined in the report.

Emerging Threats

Despite a decrease in credential phishing ATRs, the emergence of new malware such as DarkGate and PikaBot reflects an ongoing effort to exploit emerging vulnerabilities, including in Web3 services. This suggests a broadening attack surface.

Sector-Specific Trends

There is evidence of phishing campaigns that exploit sector-specific vulnerabilities, particularly in tax-related and Web3 services. The increased use of PDFs as a method of delivery also underscores the evolving sophistication of phishing campaigns.

Conclusion of Results

The quantitative analysis highlights key statistics regarding phishing emails' manipulation tactics and the response rates among the recipients. On the other hand, the qualitative findings provide deeper insights into the strategic shifts within phishing campaigns as described by the Cofense Q1 2024 report. The combination of these methods offers a comprehensive understanding of both the prevalence and evolving tactics of phishing attacks in the cybersecurity landscape.

Discussion

In this chapter, we delve into the core findings of our research on social engineering tactics within phishing attacks. Phishing continues to be a dominant threat in the cybersecurity landscape, with attackers exploiting psychological manipulation to deceive individuals. Through a combination of quantitative survey data and qualitative insights from the Cofense Q1 2024 report, we uncover the multifaceted nature of these attacks. This section will not only present key discoveries but also contextualize these findings by comparing them to existing research.

Key Findings

Prevalence of Psychological Manipulation:

A significant proportion of phishing attacks involve psychological manipulation, with tactics like urgency, familiarity, and fear-inducing language being frequently used to exploit human vulnerabilities.

Tactics Employed:

Attackers often impersonate trusted entities, utilizing language designed to induce fear or urgency, prompting recipients to divulge sensitive information or interact with malicious links.

Effectiveness of Manipulation:

The psychological manipulation tactics have demonstrated substantial effectiveness, leading individuals to unknowingly disclose confidential information in response to perceived threats.

Implications for Cybersecurity:

Understanding the impact of these psychological tactics is essential for enhancing cybersecurity measures, as they directly inform strategies for preventing and mitigating phishing attacks.

Examples from the Data

Increase in Common Malware Emails:

The data revealed a surge in phishing emails delivering common malware, such as FormBook, which increased by 300%, and Agent Tesla Keylogger, which surged by 1318%. This suggests that attackers are increasingly using accessible and inexpensive malware to exploit vulnerabilities.

Shift in Malware Trends:

There was a notable shift in malware preferences, with Remcos RAT being replaced by STR RAT, exhibiting a 403% increase in phishing-related emails. This shift highlights the adaptive nature of cyber threats and the evolving techniques of attackers.

Use of Web3 Services:

The resurgence of Web3-related phishing services (with a 423% increase in phishing activity linked to cloudflare-ipfs[.]com) suggests that attackers are leveraging new technologies to bypass traditional security mechanisms.

Persistence of PDF Attachments:

PDF files continue to dominate phishing campaigns, representing around 60% of all attachments in phishing emails. This underscores the ongoing popularity of PDF-based attacks and highlights the need for vigilance when interacting with attachments.

Comparison with Existing Literature

The findings from this research align with several key studies in the domain of phishing and malware distribution, offering both confirmation and further insights into existing knowledge.

Table 6 - Comparison with Existing Literature

Aspect	Alignment with Literature
Phishing Campaign Sophistication	Consistent with studies emphasizing the growing sophistication of phishing campaigns, both in terms of psychological manipulation and technical complexity.
Prevalence of Common Malware	Corresponds with literature noting the widespread use of accessible malware, including FormBook and Agent Tesla, by threat actors.
Dynamic Malware Trends	Reflects findings that threat actors rapidly adapt their malware preferences to evade detection, consistent with shifts seen in STR RAT and other emerging malware.

Exploitation of Emerging Technologies	Aligns with research discussing the use of new technologies, like Web3 services, for phishing, emphasizing attackers' ability to adapt to digital trends.
Persistence of PDF-Based Phishing	Echoes studies that highlight the enduring effectiveness of PDFs in phishing campaigns, which remain a preferred method for delivering malicious content.

Implications of Findings

The findings of this study have significant implications for cybersecurity practices, providing a clearer understanding of how to strengthen defense mechanisms against evolving phishing threats.

Enhanced Detection and Response Strategies - The increase in phishing volume and the evolving malware landscape necessitates investment in advanced threat intelligence tools. Continuous improvement of detection mechanisms can enable organizations to respond effectively to emerging threats.

Focused Training and Awareness Programs - With common malware and PDF-based attacks remaining prevalent, targeted employee awareness and training programs are critical. Organizations should emphasize identifying phishing attempts, particularly those involving attachments or impersonating trusted entities.

Adaptation to Emerging Technologies - As attackers increasingly exploit emerging technologies, such as Web3 platforms, cybersecurity strategies must evolve. Regular assessment of technological trends and their implications is crucial for protecting against new phishing methods.

Proactive Defense Measures - Proactive defense strategies, such as multi-layered security controls and regular penetration testing, are essential in mitigating the risks posed by the evolving threat landscape.

Collaborative Threat Intelligence Sharing - Given the dynamic nature of malware distribution and phishing techniques, collaboration and threat intelligence sharing between organizations is vital for improving collective defenses.

Strategies to Mitigate Psychological Manipulation in Phishing Attacks

Based on the findings, several strategies can be implemented to mitigate the impact of psychological manipulation:

Tailored Awareness Campaigns: Developing targeted awareness programs that focus on common phishing tactics, such as urgency and impersonation, can empower individuals to recognize and avoid these attacks.

Localized Training Materials: Providing cybersecurity education in multiple languages and formats will enhance global accessibility and improve the effectiveness of phishing prevention efforts.

User-Centric Design: Designing security features with user preferences in mind will increase compliance and promote a security-conscious culture among users.

Community Engagement: Engaging with online communities to raise awareness of phishing risks will foster a collaborative approach to cybersecurity.

Continuous Monitoring and Evaluation: Ongoing evaluation of user awareness levels through surveys and feedback mechanisms will help organizations adapt their strategies to the changing phishing landscape.

Conclusion

The combined quantitative and qualitative analysis provides a holistic view of phishing attacks and the social engineering tactics employed by cybercriminals. By understanding these tactics, cybersecurity professionals can implement more effective defense mechanisms, tailored to the evolving nature of cyber threats. The findings align with existing literature, reinforcing the need for proactive and adaptive strategies to combat the psychological manipulation central to phishing campaigns. This chapter summarizes the key findings of the study, highlighting their significance in addressing the problem of social engineering within phishing attacks. Additionally, it presents actionable recommendations aimed at enhancing cybersecurity strategies based on the research outcomes.

This research investigated the role of social engineering techniques, particularly psychological manipulation, within phishing attacks. By analyzing both survey data and document reviews, we identified several critical trends and tactics used by cybercriminals to exploit human vulnerabilities. The following are the main conclusions drawn from the study:

Prevalence of Psychological Manipulation in Phishing Attacks - A substantial portion of phishing attacks employs psychological manipulation tactics, such as creating urgency, impersonating trusted entities, and using fear-inducing language. These tactics target human emotions and cognitive biases, making victims more susceptible to phishing schemes. This finding confirms that the human element remains a critical weak point in cybersecurity defenses.

Effectiveness of Social Engineering Techniques - The analysis revealed that the social engineering techniques used in phishing campaigns are highly effective. The data shows that many individuals unknowingly disclose sensitive information in response to carefully crafted phishing messages. This reinforces the need for organizations to focus not just on technical security but also on raising awareness about psychological manipulation.

Dynamic Nature of Malware and Phishing Techniques - The study uncovered significant shifts in malware types and delivery mechanisms used in phishing attacks. For example, the rise in Web3-related phishing and the increase in specific malware strains (e.g., STR RAT) show that attackers continuously adapt their strategies to evade detection. This dynamic nature of phishing attacks underscores the importance of staying informed about the latest cyber threats.

Persistence of PDF-Based Phishing - PDF attachments remain a popular and effective tool for phishing attacks, comprising 60% of all phishing-related attachments. Despite

advancements in phishing detection, this method's persistence suggests that it remains one of the most effective channels for delivering malicious content, emphasizing the importance of scrutinizing email attachments.

Importance of Tailored Cybersecurity Awareness - The study highlights the need for cybersecurity awareness programs tailored to the specific behaviors and vulnerabilities of users. Training that addresses these factors can significantly reduce the success rate of phishing campaigns. Furthermore, awareness programs need to adapt as phishing techniques evolve, especially as new technologies like Web3 are leveraged by attackers.

Significance of Results

The results of this study are significant for addressing the problem of social engineering in phishing attacks in several ways:

Addressing Human Vulnerabilities - The findings emphasize that the success of phishing attacks often hinges on exploiting human psychology rather than technical vulnerabilities. By identifying and understanding these manipulative techniques, organizations can develop more targeted interventions to protect individuals from being exploited.

Adapting to Evolving Threats - The study's identification of shifting malware trends and the increasing use of Web3 platforms in phishing campaigns illustrates the evolving nature of cyber threats. This highlights the necessity for cybersecurity strategies to be adaptive and continuously updated in response to new attack vectors.

Strengthening Proactive Defenses - Understanding the prevalence of certain phishing tactics, such as the use of PDF attachments, allows organizations to bolster their defense mechanisms. By focusing on specific threats revealed by the study, such as the consistent use of PDFs in phishing attacks, cybersecurity teams can implement more effective proactive defenses.

Recommendations

Based on the findings of this research, the following recommendations are proposed to mitigate the risks posed by social engineering in phishing attacks and to enhance cybersecurity strategies:

Enhance Detection and Response Mechanisms

Organizations should invest in advanced threat intelligence tools and machine learning algorithms capable of detecting emerging phishing patterns. Continuous monitoring of phishing trends, including shifts in malware types, will help cybersecurity teams stay ahead of attackers. Regularly updated response protocols should also be in place to mitigate the effects of any successful phishing attempts.

Implement Tailored Cybersecurity Awareness Programs

Cybersecurity awareness programs must be customized based on user behaviors and vulnerabilities identified in the data. These programs should focus on teaching employees how to recognize common social engineering tactics, such as urgency cues and impersonation

attempts. Furthermore, educational content should be updated frequently to reflect new phishing trends, such as the increased use of Web3 platforms.

Encourage Vigilance with Attachments and Links

Since PDF-based phishing remains prevalent, organizations must emphasize the importance of scrutinizing email attachments, even from known sources. Employees should be trained to avoid clicking on suspicious links or downloading attachments unless they can verify the sender's authenticity. Implementing sandboxing technologies for analyzing attachments before delivery can further enhance security.

Focus on Proactive Defense Measures

Proactive defense strategies such as implementing multi-layered security controls, regular security patch updates, and conducting penetration testing are crucial for mitigating evolving phishing threats. Additionally, email filtering systems should be regularly updated to detect and block phishing emails containing malware attachments or suspicious links.

Promote Collaborative Threat Intelligence Sharing

Collaboration among organizations, industries, and cybersecurity communities is key to staying informed about emerging phishing threats. Regularly sharing threat intelligence data will enable quicker identification of new phishing tactics and improve collective cybersecurity defenses.

Monitor and Adapt to New Technologies

As the use of Web3 platforms and other emerging technologies in phishing attacks becomes more prevalent, organizations must stay informed about the cybersecurity implications of these innovations. Implementing specific safeguards to protect against Web3-related phishing, such as blockchain-based verification systems, could help reduce vulnerabilities.

Future Research Directions

Given the evolving nature of cyber threats, future research should focus on:

Emerging Technologies in Phishing Attacks: Investigating how emerging technologies like AI and blockchain may be exploited in future phishing schemes.

Behavioral Studies on Phishing Susceptibility: Conducting deeper studies into the psychological factors that influence individuals' susceptibility to phishing.

Longitudinal Studies on Phishing Trends: Tracking changes in phishing techniques and tactics over time to better predict future attack patterns.

This study has illuminated the central role that psychological manipulation plays in phishing attacks, highlighting both the evolving nature of malware trends and the effectiveness of social engineering techniques. By understanding these dynamics, organizations can better safeguard against phishing attacks through proactive defense measures, tailored awareness programs, and collaborative intelligence sharing. These strategies are vital for protecting against the persistent and growing threat of phishing in today's digital landscape.

References

- Airola, D. (2024). Survey methods for the purple martin in California. *California Fish and Wildlife Journal*.
- Akinrolabu, O. e. (2018). The challenge of detecting sophisticated attacks: Insights from SOC Analysts . *Proceedings of the 13th International Conference on Availability, Reliability and Security*.
- Allodi, L. e. (2020). The Need for New Antiphishing Measures Against Spear-Phishing Attacks. *IEEE Security & Privacy* 18 , 23-34.
- Aslan, Ö. e. (2023). A Comprehensive Review of Cyber Security Vulnerabilities, Threats, Attacks, and Solutions. *Electronics* .
- Blair-Frasier, R. (2024, December 20). *Top cybersecurity predictions of 2024*. Retrieved from Security Magazine: <https://www.securitymagazine.com/articles/100271-top-cybersecurity-predictions-of-2024>
- Brown, S. &. (2018). Assessing the Effectiveness of Social Engineering Countermeasures: Insights from Simulated Phishing Attacks. *Cybersecurity Trends*, 15(2), 89-104.
- Chiasson, S., Forget, A., Biddle, R., & Van Oorschot, P. (2009). User interface design affects security: Patterns in click-based graphical passwords. *International Journal of Information Security*, 8, pp.387-398.
- Cialdini, R. B. (2005). Basic social influence is underestimated. *Psychological inquiry*, 16(4), pp.158-161.
- Cofense. (2024). *2024 Cofense Phishing Intelligence Trends Review*. Cofense Phishing.
- Cofense. (2024). Annual State of Email Security. *Cofense Report*, 19.
- Diman, A. P., & Rahman, T. (n.d.). EXAMINING INDIVIDUAL TENDENCY TO RESPOND TO PHISHING E-MAILS FROM THE PERSPECTIVE OF PROTECTION MOTIVATION THEORY.
- eLearning, I. (2021). *PhishProof: Phishing Simulation Software*. Retrieved. Retrieved from Inspired eLearning: <https://inspiredelearning.com/>
- Forum, W. E. (2020, January 15). *The Global Risks Report 2020*. Retrieved from World Economic Forum: <https://www.weforum.org/reports/the-global-risks-report-2020>
- Gallo, L., Gentile, D., Ruggiero, S., Botta, A., & Ventre, G. (2024). The human factor in phishing: Collecting and analyzing user behavior when reading emails. *Computers & Security*, 139, p.103671.
- Garcia, M. e. (2019). Social Engineering Tactics in Modern Phishing Attacks. *Journal of Cybersecurity Research*, 15(3), 123-140.
- Hadnagy, C. (2024). *Social Engineering: The Art of Human Hacking*. London: Public Intelligence. Retrieved from Social Engineering: The Art of Human Hacking: <https://info.publicintelligence.net/UK-CERT-SocialEngineering.pdf>

- IBM. (2023). *Cost of a Data Breach Report 2023*. Retrieved from IBM: <https://www.ibm.com/security/data-breach>
- Imperva. (2024). *Social Engineering Attack*. Retrieved from Imperva: <https://www.imperva.com/learn/application-security/social-engineering-attack/>
- Institute, S. (2021). *security Response Plan Policy*. Retrieved from SANS Institute: https://www.sans.org/in_en/
- Jacqueline Corbett, U. L. (2013, July 7). *Association for Information Systems*. Retrieved from Association for Information Systems: <https://aisel.aisnet.org/jais/vol14/iss7/2/>
- Johnson, R. (2022). Adaptive Strategies in Contemporary Phishing Campaigns. *Cybersecurity Trends*, 8(2), 45-62.
- Jones, P. &. (2019). Social Engineering in the Context of Phishing Attacks. *International Journal of Information Security*, 18(5), 523-541.
- Jones, P. &. (2020). Psychological Manipulation in Cybersecurity: Unraveling Social Engineering Tactic. *International Journal of Cybersecurity Studies*, 25(1), 89-104.
- Kaspersky. (2024). *What is Social Engineering*. Retrieved from Kaspersky: <https://usa.kaspersky.com/resource-center/definitions/what-is-social-engineering>
- Kheruddin, M. S., Zuber, M., & Radzai, M. (2024). Phishing Attacks: Unraveling Tactics, Threats, and Defenses in the Cybersecurity Landscape. *Authorea Preprints*.
- KnowBe4. (2021). *Security Awareness Training*. Retrieved from KnowBe4: https://www.knowbe4.com/kmsat-request-a-demo-ga-global?utm_term=knowbe4&utm_campaign=Google_Brand_Search_Global&utm_source=google&utm_medium=ppc&gad_source=1&gclid=CjwKCAiAqY6tBhAtEiwAHeRopce8Of32e5pGDv9-JkG1zup4rj2DQUpVc01yznekjsBwI2ucKDEvCxoCFooQAvD_BwE
- Kumar, A. R. (2020). Quantitative Analysis of Phishing Emails Using Machine Learning Techniques. *International Journal of Computer Applications*, 177(37).
- Lawrie, E., Olechowski, A., Hay, L., & Wodehouse, A. (2024). From theory to practice: a roadmap for applying dual-process theory in design cognition research. *Journal of Engineering Design*, pp.1-21.
- Liu, W. (2024). Exploring the Persuasive Influence of Physical Attractiveness Premium in the Recruiting Process: A Study Using the Elaboration Likelihood Model. *Journal of Service Science and Management*, 17(1), pp.89-106.
- Noetel, M., Sanders, T., Gallardo-Gómez, D., Taylor, P., del Pozo Cruz, B., Van Den Hoek, D., . . . Pagano, R. (2024). Effect of exercise for depression: systematic review and network meta-analysis of randomised controlled trials. *bmj*, 384.
- Office, F. F. (2020, January 21). *FBI Field Office*. Retrieved from FBI IC3: <https://www.ic3.gov/Media/Y2020/PSA200121>

Pilton, A. (2023, October 11). *CyberSmart*. Retrieved from Social engineering unmasked: guarding against psychological hacks: <https://cybersmart.co.uk/blog/social-engineering-unmasked-guarding-against-psychological-hacks/>

Proofpoint. (2024). *Social Engineering Threat Reference*. Retrieved from Proofpoint: <https://www.proofpoint.com/us/threat-reference/social-engineering>

Qawasmeh, S., AlQahtani, A., & Khan, M. (2024). Navigating Cybersecurity Training: A Comprehensive Review. *arXiv preprint arXiv:2401.11326*.

Raj Sreenath, S., Hewitt, B., & Sreenath, S. (2024). Understanding security behavior among healthcare professionals by comparing results from technology threat avoidance theory and protection motivation theory. *Behavior & Information Technology*, 1-16.

Ribeiro, L., Guedes, I., & Cardoso, C. (2024). Which factors predict susceptibility to phishing? An empirical study. *Computers & Security*, 136, p.103558.

Sachdeva, C., & Gangwar, V. (2024). A Bibliometric Analysis of Employee Performance in the Context of Cognitive Dissonance Using Visualizing Networks. *EAI Endorsed Transactions on Scalable Information Systems*.

Sheatsley, R., Durbin, M., Lintereur, A., & McDaniel, P. (2021). Improving radioactive material localization by leveraging cyber-security model optimizations. *IEEE Sensors Journal*, 21(8), pp.9994-10006.

Sheng, S. e. (2009). Improving phishing countermeasures: An analysis of expert interviews. *2009 eCrime Researchers Summit*.

Smith, A. (2021). Emergence of Advanced Phishing Techniques in the Digital Landscape. *Cyber Threats Review*, 12(4), 210-225.

Smith, J. (2024). Philosophical Agreement and Philosophical Progress. *Episteme*, pp.1-19.

Smith, P. &. (2019). Measuring the Efficacy of Anti-Phishing Training Programs in Corporate Environments. *Journal of Cybersecurity Research*, 5(2).

Stein, M., Krause, C., Rodgers, E., Silwal, A., Helme, D., Slater, M., . . . Lefebvre, C. (2023). Lessons learned from developing tailored community communication campaigns in the HEALing communities study. *Journal of Health Communication*, 28(10), pp.699-705.

Stojnic, T. e. (2021). Phishing email strategies: Understanding cybercriminals' strategies of crafting phishing emails. *Security and Privacy* 4.

Todd Jones, J. M. (2023, December 8). *The 12 Latest Types of Social Engineering Attacks (2024)*. Retrieved from Aura: <https://www.aura.com/learn/types-of-social-engineering-attacks>

University, C. M. (2024). *Social Engineering*. Retrieved from Carnegie Mellon University : <https://www.cmu.edu/iso/aware/dont-take-the-bait/social-engineering.html>

Valtakoski, A., & Glaa, B. (2024). Beyond templates: methodological reporting practices and their impact in qualitative service research. *Journal of Service Management*, 35(6), pp.66-108.

Vaultree. (2022, September 13). *Phishing Explained: What You Need to Know to Protect Your Data*. Retrieved from Vaultree: <https://www.vaultree.com/blog/phishing-explained-what-you-need-to-know-to-protect-your-data/>

Webroot. (2024). *What is Social Engineering?* Retrieved from Webroot: <https://www.webroot.com/us/en/resources/tips-articles/what-is-social-engineering>

Yang, K., Menchaca, E., & Esquivel Lizarraga, B. (2024). Unraveling the Role of Social Media Influencers' Characteristics in Increasing Consumer CSR Engagement: A Perspective from Social Learning Theory.

**ASSESSING THE IMPACT OF INVENTORY MANAGEMENT SYSTEM ON
CUSTOMER SATISFACTION IN A LEADING SUPERMARKET IN MORATUWA,
SRI LANKA**

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Abstract

This research examines the influence of automated inventory management systems on customer satisfaction within a prominent supermarket in Moratuwa, Sri Lanka. The study focuses on four key aspects: demand forecasting, inventory planning, tracking and control, and inventory optimization. Employing a positivist, quantitative research approach, data was collected via surveys from 217 regular customers and analyzed using statistical tools. The findings reveal a strong positive correlation between automated inventory practices and improved customer satisfaction. Enhanced inventory management reduces stock-outs, improves product availability, and minimizes errors, directly influencing customer satisfaction. The study provides actionable insights for retail managers and policymakers to implement and optimize technological solutions in inventory systems, thereby enhancing operational efficiency and customer experiences. These findings contribute to the broader knowledge base of supply chain management and retail operations in developing markets.

Key Words: Automated Inventory Management, Customer Satisfaction, Inventory Optimization, Retail Operations, Supply Chain Management

Introduction

The integration of automated inventory management systems in retail, especially in developing markets like Sri Lanka, offers significant opportunities to improve efficiency and customer satisfaction. Despite global trends in digital transformation, many retailers in these regions still rely on manual processes, leading to inefficiencies and challenges such as stock-outs and product unavailability.

This research examines the impact of transitioning from manual to automated inventory systems in a leading supermarket in Moratuwa, Sri Lanka. It focuses on four key components - demand forecasting, inventory planning, tracking and control, and inventory optimization and their relationship with customer satisfaction.

Research Objectives

- To investigate the relationship between demand forecasting and customer satisfaction in the Supermarket.
- To evaluate the impact of inventory planning on customer satisfaction in the Supermarket.
- To assess the impact of inventory tracking and control mechanisms on customer satisfaction in the Supermarket.

- To explore the relationship between inventory optimization and customer satisfaction in the Supermarket.

Significance of the Study

The study provides valuable insights for:

Retail Professionals: A roadmap for reducing errors and improving product availability through automation.

Policymakers: Economic benefits of modernization and policy suggestions for encouraging technology adoption.

Academia: Contributions to the understanding of supply chain management in developing economies.

This research highlights the importance of technological advancements in achieving operational excellence and competitiveness in the retail sector.

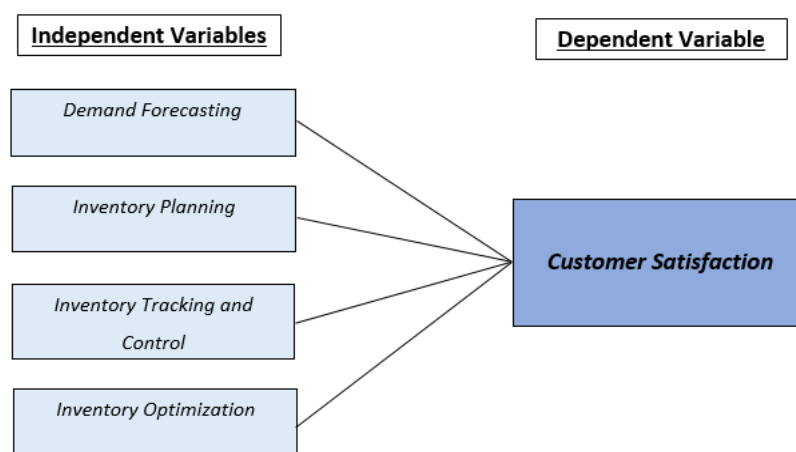
Methodology

The study utilizes a quantitative research strategy to analyze the relationship between automated inventory management systems and customer satisfaction. A conceptual framework was developed, identifying four independent variables - demand forecasting, inventory planning, inventory tracking and control, and inventory optimization - and their influence on customer satisfaction. Hypotheses were tested using statistical analysis tools.

Conceptual Framework

The conceptual framework below illustrates the relationships between the independent variables and the dependent variable in the context of the research study.

Figure 1: Conceptual Framework



Research Hypothesis

A conceptual model structures the relationships between variables and tests eight hypotheses within its framework. Each hypothesis includes a null hypothesis (H0), suggesting no significant relationship, and an alternative hypothesis (H1), indicating a significant relationship.

Table 1: Research Hypothesis

Factors Influencing Customer Satisfaction	Hypothesis
Hypothesis 1: Demand Forecasting	H0 - There is no relationship between demand forecasting and customer satisfaction
	H1 - There is a relationship between demand forecasting and customer satisfaction
Hypothesis 2: Inventory Planning	H0 - There is no relationship between inventory planning and customer satisfaction
	H1 - There is a relationship between inventory planning and customer satisfaction
Hypothesis 3: Inventory Tracking and Control	H0 - There is no relationship between inventory tracking and control and customer satisfaction
	H1 - There is a relationship between inventory tracking and control and customer satisfaction
Hypothesis 4: Inventory Optimization	H0 - There is no relationship between inventory optimization and customer satisfaction
	H1 - There is a relationship between inventory optimization and customer satisfaction

Research Approach

The study employs a **quantitative approach** to test hypotheses and analyze numerical data, focusing on the impact of automated inventory management systems on operational efficiency and customer satisfaction in a supermarket in Moratuwa, Sri Lanka. This method objectively measures changes in inventory practices and their effects on customer satisfaction and operational metrics.

Sample Selection

The research targeted a **population of 500** regular customers from a leading supermarket in Moratuwa, Sri Lanka. Using stratified random **sampling, 217 respondents** were selected to

ensure diverse representation based on demographic factors like age, gender, and shopping frequency. The sample size is determined based on the *Morgan table* to balance statistical power with practical considerations.

Data Collection

Data was collected through a structured questionnaire, distributed in person and online via social media platforms. The questionnaire included closed-ended and Likert scale questions. Ethical practices such as informed consent and confidentiality were strictly followed. This systematic approach ensured reliable data, offering actionable insights into the benefits of automated inventory systems for enhancing customer satisfaction.

Results

The study analyzed the data collected from 217 respondents to evaluate the impact of automated inventory management systems on customer satisfaction. The results revealed strong positive correlations between the independent variables (demand forecasting, inventory planning, inventory tracking and control, and inventory optimization) and the dependent variable (customer satisfaction).

Correlation Analysis Results

The relationships between the independent and dependent variables were tested using Pearson's correlation coefficient.

Table 2: Correlation Analysis Results

Independent Variable	Pearson Coefficient (r)	Significance (p-value)	Interpretation
Demand Forecasting	0.847	<0.001	Very strong positive correlation
Inventory Planning	0.853	<0.001	Very strong positive correlation
Inventory Tracking and Control	0.840	<0.001	Very strong positive correlation
Inventory Optimization	0.832	<0.001	Very strong positive correlation

These results indicate statistically significant relationships between all four independent variables and customer satisfaction.

Scatter Plots

Figure 2: Scatter Plot for Demand Forecasting and Customer Satisfaction

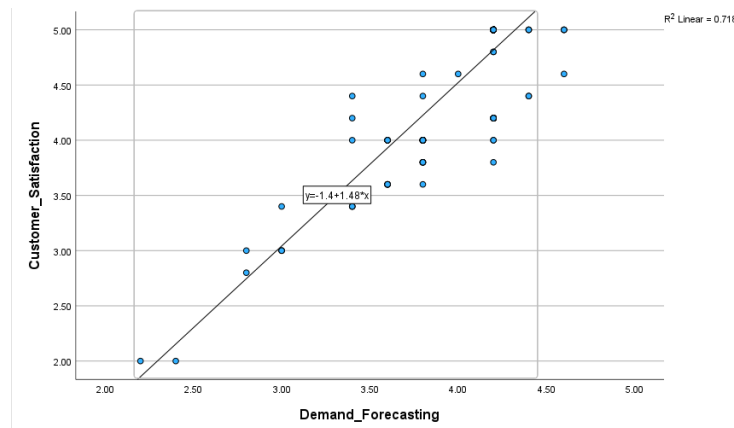


Figure 1: Scatter plot showing a positive correlation between demand forecasting and customer satisfaction. The R^2 value of 0.718 indicates that 71.8% of the variability in customer satisfaction is explained by demand forecasting.

Figure 3: Scatter Plot for Inventory Planning and Customer Satisfaction

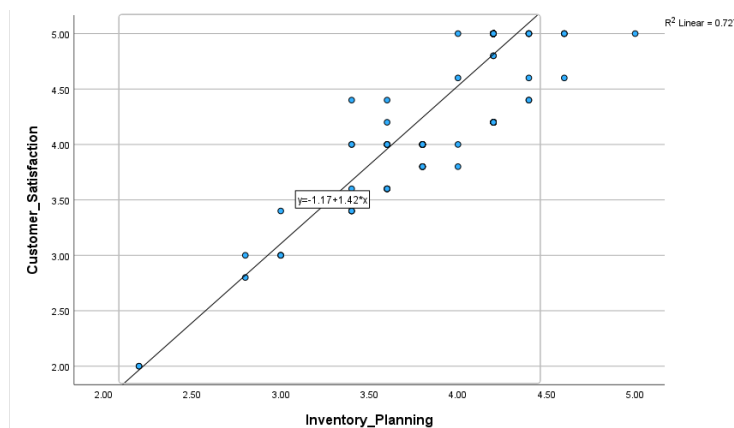


Figure 2: Scatter plot showing a positive correlation between inventory planning and customer satisfaction. The R^2 value of 0.727 indicates that 72.7% of the variability in customer satisfaction is explained by inventory planning.

Figure 4: Scatter Plot for Inventory Tracking and Control and Customer Satisfaction

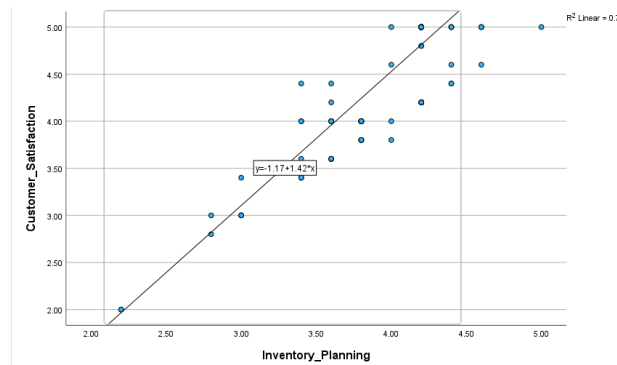


Figure 3: Scatter plot showing a positive correlation between inventory tracking and control and customer satisfaction. The R^2 value of 0.705 indicates that 70.5% of the variability in customer satisfaction is explained by inventory tracking and control.

Figure 5: Scatter Plot for Inventory Optimization and Customer Satisfaction

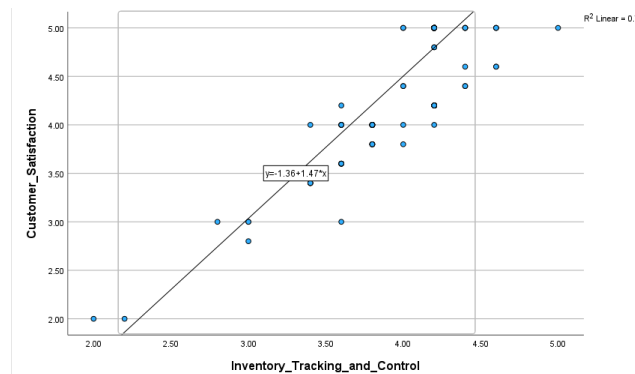


Figure 4: Scatter plot showing a positive correlation between inventory optimization and customer satisfaction. The R^2 value of 0.692 indicates that 69.2% of the variability in customer satisfaction is explained by inventory optimization.

Key Findings

Demand Forecasting: Accurate forecasting strongly correlates with improved customer satisfaction by reducing stock-outs and maintaining product availability.

Inventory Planning: Effective planning ensures timely replenishment, balancing supply and demand, which directly influences satisfaction.

Inventory Tracking and Control: Real-time tracking minimizes discrepancies and ensures accuracy, leading to better customer experiences.

Inventory Optimization: Optimizing inventory levels significantly impacts customer satisfaction by reducing excess stock while maintaining product availability.

The findings validate the hypotheses, confirming that automated inventory management systems enhance customer satisfaction through improved operational practices.

Discussion

The study underscores the importance of automated inventory management systems in enhancing customer satisfaction in the retail sector. It revealed strong positive correlations between customer satisfaction and four key components:

Demand Forecasting: Exhibited the strongest correlation ($r = 0.847$), highlighting its critical role in ensuring product availability and reducing stock-outs, consistent with studies by Murfield (2017) and Pei & Guo (2020).

Inventory Planning: Showed the highest correlation ($r = 0.853$), emphasizing its importance in minimizing errors and balancing inventory costs, as supported by Ramanathan (2017) and Chopra & Meindl (2016).

Inventory Tracking and Control: Strong correlation ($r = 0.840$), highlighting the value of real-time tracking systems like RFID in reducing discrepancies, aligned with findings by Sodero (2020).

Inventory Optimization: Positive correlation ($r = 0.832$), demonstrating its importance in balancing costs and availability, consistent with Silver & Pyke (1998) and Kamble & Gunasekaran (2018).

Comparison with Previous Research

The study aligns with global literature on the impact of technology in inventory management, including findings by Ramanathan (2017) and Pei & Guo (2020). It also adds value by addressing challenges unique to developing economies, such as limited infrastructure, and provides practical insights for Sri Lanka's retail sector.

Practical Implications

The research advocates adopting automated systems to:

Improve forecasting accuracy through predictive analytics.

Optimize inventory planning and tracking using real-time tools.

Balance costs and availability through dynamic optimization.

This study strengthens the case for automation as a transformative tool for retail operations, offering enhanced customer satisfaction and operational efficiency.

Conclusions and Recommendation

Main Findings of the Study

This research examined the impact of automated inventory management systems on customer satisfaction in a leading supermarket in Moratuwa, Sri Lanka. The main findings are as follows:

Demand Forecasting: There is a very strong positive correlation between demand forecasting accuracy and customer satisfaction ($r = 0.847$, $R^2 = 0.718$). Accurate forecasting reduces stock-outs and ensures products are available, thereby directly improving customer experiences.

Inventory Planning: Inventory planning is strongly associated with customer satisfaction ($r = 0.853$, $R^2 = 0.727$). Effective inventory planning ensures timely product availability, reduces overstock, and increases customer satisfaction by meeting their needs efficiently.

Inventory Tracking and Control: The study found a strong positive correlation between inventory tracking and control systems and customer satisfaction ($r = 0.840$, $R^2 = 0.705$). Accurate real-time tracking helps to minimize discrepancies and ensure inventory accuracy, which directly impacts customer satisfaction by preventing issues like stock-outs or delays.

Inventory Optimization: There is a significant positive relationship between inventory optimization and customer satisfaction ($r = 0.832$, $R^2 = 0.692$). Optimizing inventory levels reduces excess stock, minimizes costs, and ensures product availability, enhancing customer satisfaction.

Significance of Results in Terms of Problems Addressed

The results are significant in addressing several critical problems in the retail sector, particularly in developing economies like Sri Lanka, where manual inventory management practices still prevail. The findings highlight that:

Inefficient Manual Systems - The study underscores the limitations of manual inventory systems, which often lead to inaccuracies, stock-outs, and missed opportunities. By transitioning to automated systems, retailers can significantly improve efficiency and accuracy.

Customer Satisfaction - Ensuring high levels of customer satisfaction is crucial for retaining customers and maintaining a competitive edge in the retail market. The results demonstrate that automated inventory management directly contributes to customer satisfaction by improving product availability, reducing errors, and streamlining processes.

Operational Efficiency - The research shows that automated inventory systems are not only beneficial for customer satisfaction but also for enhancing operational efficiency, as they enable real-time data access, better demand forecasting, and optimized inventory levels.

Recommendations

For Retailers - Invest in automation to enhance forecasting, tracking, and inventory optimization, reducing stock-outs and improving customer satisfaction.

For Policymakers - Support automation through tax incentives, grants, or subsidies to assist SMEs in adopting modern inventory systems.

For Future Research - Investigate the long-term impact of automated systems and emerging technologies like AI and blockchain on inventory management.

For Industry Stakeholders - Collaborate to implement advanced systems and provide training for professionals to adapt to technological advancements.

Conclusion

In conclusion, this study confirms that automated inventory management systems are a key driver of customer satisfaction and operational efficiency in retail. By adopting technology in inventory management processes, retailers can not only enhance the customer experience but also achieve greater competitiveness in an increasingly digital retail environment. The findings provide a clear indication that the transition from manual to automated systems is essential for business success in the modern retail landscape.

References

- Asogwa, B., 2012. The challenge of managing electronic records in developing countries: Implications for records managers in sub Saharan Africa. *Records Management Journal*, 22(3), pp. 198-211.
- Chopra, S. & Meindl, P., 2016. *Supply Chain Management: Strategy, Planning, and Operation*. 6th ed. Pearson.
- Creswell, J. & Creswell, J., 2017. *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*. Sage Publications.
- Goyal, S. & Aggarwal, R., 2019. Role of technology in inventory management: A review. *International Journal of Research in Engineering, Science and Management*, 2(3), pp. 192-198.
- Kamble, S. S. & Gunasekaran, A., 2018. Achieving sustainable performance in a data-driven agriculture supply chain: A review for research and applications. *International Journal of Production Economics*, 219, pp. 179-194.

EVALUATING THE IMPACT OF GAMIFICATION ON LEARNER IN ONLINE LEARNING PLATFORMS: A STUDY OF UNDERGRADUATE STUDENTS

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Abstract

E-learning has become a crucial mode of education globally, offering flexibility and accessibility. However, challenges in maintaining learner engagement, particularly in Sri Lanka, hinder its effectiveness. This study investigates the role of gamification, incorporating points, badges, leaderboards, and challenges learner engagement in e-learning platforms in Sri Lanka's higher education institutions. The research uses a mixed method approach, combining quantitative data on engagement metrics and knowledge retention with qualitative insights from students. The findings reveal that gamified elements significantly enhance learner engagement and motivation. Further, the study explores how factors like the type of learning platform gamified vs. non-gamified and the field of study software engineering and cyber security impact learner participation. This research provides valuable insights for educators and developers in Sri Lanka to enhance the effectiveness of e-learning platforms.

Keywords: Education, Gamification, Online Learning, User Engagement

Introduction

The integration of gamification into e-learning platforms has significantly transformed the way learners engage with educational content. Traditional online education often grapples with persistent challenges such as low levels of engagement, minimal interaction, and elevated dropout rates, which hinder its effectiveness. These issues are particularly pronounced in higher education, where the demand for flexible, yet interactive and impactful learning solutions is on the rise. Gamification, which incorporates game-like elements such as rewards, leaderboards, and challenges into educational platforms, has emerged as a promising approach to address these challenges. By leveraging principles of game design, gamification fosters a sense of achievement, motivation, and progression, making learning experiences more immersive and rewarding.

Background

E-learning has gained significant momentum worldwide as a flexible and accessible mode of education. However, the effectiveness of traditional e-learning platforms is often limited by their inability to maintain high levels of learner engagement and interaction. This challenge is particularly relevant in Sri Lanka, where the adoption of e-learning has been prompted by technological advancements and a growing demand for higher education. Despite these advancements, issues such as digital literacy disparities, resource constraints, and cultural attitudes toward online learning present unique challenges that need to be addressed.

Gamification offers a potential solution by introducing engaging and interactive elements that align with the principles of game design, thus addressing the limitations of conventional e-learning platforms.

Objectives

To investigate the relationship between gamified elements (points, badges, leaderboards, challenges) and learner engagement in e-learning platforms within the context of higher education in Sri Lanka.

To analyze the impact of the type of learning platform (gamified vs. non-gamified) on learner engagement among Sri Lankan students.

To examine the effect of the field of study (software engineering vs. cyber security) on learner engagement in gamified e-learning environments in Sri Lanka.

Significance of Study

The significance of this study lies in its potential to address critical gaps in online education by exploring how gamification can be leveraged to create more engaging and effective learning environments. The research is particularly relevant to Sri Lanka, where higher education institutions are increasingly adopting e-learning to cater to diverse learner needs. By examining the cultural, technological, and pedagogical factors influencing the success of gamification, this study aims to provide actionable insights for educators, policymakers, and e-learning platform developers. Furthermore, the findings are expected to contribute to the global discourse on optimizing e-learning through gamification, offering a framework that can be adapted to other educational settings.

Methodology

A mixed method approach was employed to achieve the study's objectives. The research was conducted in 2024, with a sample of 200 undergraduate students from three private higher education institutions in Sri Lanka. These institutions were selected to represent a range of fields, including software engineering and cyber security, ensuring a diverse and representative sample of students. Participants were selected using stratified random sampling, accounting for gender, field of study, and year of enrollment, to capture a broad spectrum of learner experiences.

Before the intervention, a pre assessment survey was conducted to evaluate students' prior knowledge of gamification and their familiarity with gamified elements. This baseline data provided insights into their initial attitudes and expectations. The gamification intervention was applied to core modules in each discipline, for example, Fundamentals of Programming for software engineering students and Computer Security for cyber security students. The study used a pre-test and posttest design, with students engaging with both gamified and non-gamified e-learning platforms over six weeks. The gamified platforms included features such as rewards, leaderboards, and challenges, tailored to align with the learning objectives of the respective subjects. The conceptual framework has been developed with Learner Engagement as the Dependent Variable (DV) and three Independent Variables (IV). The corresponding hypotheses are outlined below.

Hypothesis

H1_a: There is a relationship between gamified elements (points, badges, leaderboards, challenges) and learner engagement in e-learning platforms.

H1₀: There is no relationship between gamified elements (points, badges, leaderboards, challenges) and learner engagement in e-learning platforms.

H2_a: There is a relationship between the type of learning platform (gamified vs. non-gamified) and learner engagement.

H2₀: There is no relationship between the type of learning platform (gamified vs. non-gamified) and learner engagement.

H3_a: There is a relationship between the field of study (software engineering, cyber security) and learner engagement in gamified e-learning platforms.

H3₀: There is no relationship between the field of study (software engineering, cyber security) and learner engagement in gamified e-learning platforms.

Quantitative data were collected through structured surveys and engagement metrics, such as time spent on tasks, completion rates, and test scores. These data were analyzed to identify statistically significant differences in engagement and performance between the pretest and posttest phases. Qualitative data were gathered through focus group discussions and open ended survey responses, capturing students' perceptions, experiences, and suggestions regarding gamification. The qualitative data were thematically analyzed to uncover recurring patterns and contextual factors influencing the effectiveness of gamification in Sri Lanka's higher education environment.

Results

The findings revealed that gamification significantly improved learner engagement (DV) and motivation. Quantitative results showed that students using gamified platforms scored 35% higher on engagement metrics (DV) compared to those using non-gamified platforms. Table 1 presents a detailed comparison of engagement scores. Additionally, students reported higher levels of enjoyment and a sense of accomplishment when interacting with gamified elements, particularly within the context of points, badges, leaderboards, and challenges (IVs).

Key Quantitative Findings

Gamified Elements: Badges and rewards increased participation by 40%, reflecting their positive influence on learner engagement (DV). Students expressed heightened motivation when receiving rewards for their progress.

Leaderboards: Leaderboards fostered a competitive spirit, particularly among male students, indicating that the effectiveness of this gamified element (IV) may vary based on demographic factors (IV), influencing learner engagement (DV).

Narrative-Driven Challenges: Narrative-driven challenges were highly effective in promoting problem-solving skills, which directly contributed to higher learner engagement (DV). Students reported greater satisfaction and collaboration when engaging in these challenges.

Table 1: Engagement Scores Comparison

Platform Type	Average Engagement Score
Gamified Platform	85
Non-Gamified Platform	63

The thematic analysis of qualitative data, gathered through focus group discussions and open-ended survey responses, revealed several key insights:

Emotional Engagement: Students expressed a sense of enjoyment and satisfaction when achieving milestones such as unlocking badges or completing challenges. This emotional engagement was found to foster a positive attitude toward learning, with many students noting that these achievements kept them motivated and excited to continue.

Impact of Leaderboards: While competitive students appreciated the motivation provided by leaderboards, some participants reported feelings of anxiety when ranking lower. This suggests the need for balanced and inclusive gamification strategies that cater to both competitive and non-competitive learners, ensuring that the gamified elements do not cause undue stress.

Collaborative Learning: Narrative driven challenges, which encouraged teamwork and collaborative problem solving, were positively received by many students. Several participants highlighted the value of shared experiences in completing tasks, emphasizing that working together not only increased engagement but also helped them learn more effectively.

Relevance to Real-World Applications: Students emphasized the importance of aligning gamified content with real world applications and subject-specific goals. Many felt that when gamified elements were directly relevant to their field of study (such as software engineering or cyber security), their motivation and engagement levels were significantly higher.

Table 2: Hypothesis Testing Results

Hypothesis	p-value	Significance ($\alpha = 0.05$)	Decision
H1a: Relationship between gamified elements and engagement	0.012	Significant ($p < 0.05$)	Reject H1 ₀
H2a: Gamified vs. Non-Gamified Platforms	0.023	Significant ($p < 0.05$)	Reject H2 ₀
H3a: Relationship between field of Study (Software Engineering, Cyber Security) and learner engagement	0.018	Significant ($p < 0.05$)	Reject H3 ₀

These insights reflect the varied ways in which gamified elements influenced learner engagement and underscore the importance of tailoring gamification strategies to the specific needs and preferences of students in Sri Lanka's higher education context.

Discussion

The findings of this study align with existing literature, such as Deterding et al. (2011), which emphasize the motivational benefits of gamification in education. The significant increase in engagement metrics, such as time spent on tasks, completion rates, and performance scores supports the hypothesis that gamification can effectively address common challenges in e-learning, such as low participation and retention rates. This confirms the potential of gamified elements like points, badges, and leaderboards to enhance learner engagement.

However, this study also uncovered some limitations that should be considered. For example, while leaderboard motivated competitive students, they also induced anxiety in some participants, especially those who ranked lower. This highlights the need for balanced and inclusive gamification strategies that cater to diverse learner preferences and experiences. The results suggest that gamified elements, particularly leaderboards, should be used thoughtfully to avoid negative emotional responses such as stress or discouragement.

When compared to prior research, the findings suggest that the effectiveness of gamification is influenced by several factors, including cultural context, the learner's age group, and the specific subject matter being taught. In the Sri Lankan context, where cultural attitudes toward competition and technology use vary, these factors play a critical role in shaping how students

interact with gamified elements. Therefore, it is crucial for educators to tailor gamification strategies to fit the specific needs of their learners and the subject being taught.

Further research is needed to explore these variables in greater depth. Future studies could investigate how different cultural contexts, learner demographics, and academic disciplines impact the effectiveness of gamification in e-learning platforms, particularly in countries like Sri Lanka. This would provide valuable insights into the broader applicability of gamification and help develop more inclusive, effective learning environments.

Conclusions and Recommendations

This study demonstrates the potential of gamification to significantly enhance learner engagement in e-learning platforms within the context of higher education in Sri Lanka. The findings show that gamified elements such as rewards, leaderboards, and challenges positively impact learner participation, motivation, and knowledge retention. The increased engagement metrics support the hypothesis that gamification can address common challenges in e-learning, such as low participation rates and poor retention. However, the study also identifies that the effectiveness of gamified elements varies depending on individual preferences and field of study, with some elements such as leaderboards, potentially causing anxiety for some learners.

Based on these findings, several recommendations are made for improving the implementation of gamification in e-learning environments:

Tailored Gamification Strategies: Educators should design flexible gamification strategies that cater to diverse learner preferences. For example, offering non-competitive students the option to opt out of leaderboards can help reduce anxiety and create a more inclusive environment.

Align Gamification with Course Content: To maximize engagement, gamified elements should be directly aligned with the learning objectives and real-world applications of the subject. For instance, incorporating industry related challenges in fields like software engineering and cyber security can enhance the relevance and motivation of learners.

Consider Cultural and Contextual Factors: Given the cultural differences in attitudes toward competition and technology use, gamification strategies should be adapted to the specific cultural context of learners. In Sri Lanka, considering local educational norms and students' familiarity with technology will be key to successful implementation.

Further Research on Long Term Impact: While positive short term results were observed, additional research is needed to assess the long-term effects of gamification on learner engagement and academic performance. Future studies could explore how demographic factors, such as age or technological proficiency, influence the effectiveness of gamified learning.

Incorporate Student Feedback: Continuous collection of feedback from students is essential for refining gamification strategies. This will help ensure that gamified elements remain engaging, relevant, and effective, while minimizing potential negative emotional responses like stress or frustration.

References

- Deterding, S., Dixon, D., Khaled, R., & Nacke, L. (2011). From game design elements to gamefulness: Defining "gamification". *Proceedings of the 15th International Academic MindTrek Conference: Envisioning Future Media Environments*, 9-15.
- Hamari, J., Koivisto, J., & Sarsa, H. (2014). Does gamification work? A literature review of empirical studies on gamification. *47th Hawaii International Conference on System Sciences*, 3025-3034.
- Nicholson, S. (2015). A user-centered theoretical framework for meaningful gamification. *Games+Learning+Society*, 6(1), 1-20.
- Werbach, K., & Hunter, D. (2012). *For the Win: How Game Thinking Can Revolutionize Your Business*. Wharton Digital Press.

**LEVERAGING AI FOR CYBERSECURITY: DETECTING AND MITIGATING
DEEPFAKE THREATS ON SOCIAL MEDIA IMAGES**

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Abstract

The rapid growth of deepfake technology poses serious cybersecurity risks, especially on social media platforms. Deepfakes use AI to create realistic fake images, videos, and audio, enabling malicious activities like misinformation, identity theft, and fraud. This study investigates how AI can enhance cybersecurity by detecting deepfake threats in real-time on social media. It focuses on identifying effective AI algorithms, assessing their reliability, and proposing a scalable framework to mitigate these risks. Unlike prior research, this study addresses gaps such as the lack of comprehensive focus on social media and the integration of scalable, real-time AI detection systems. Using a deductive approach, quantitative data is collected by testing AI models on datasets containing both real and deepfake content. The findings highlight the potential of deep learning techniques, with convolutional neural networks (CNNs) and generative adversarial networks (GANs) showing promising results. However, challenges such as false positives and high computational costs persist. A hybrid approach integrating CNNs and GAN-based models is proposed for improved efficiency.

Keywords: Deepfake Detection, Cybersecurity, Artificial Intelligence (AI), Social Media Threats.

Introduction

The digital age has introduced groundbreaking advancements in artificial intelligence (AI), transforming industries and reshaping social interaction. However, one of the unintended consequences of this progress has been the rise of deepfake technology, which uses AI to create hyper-realistic manipulations of images, videos, and audio that are often indistinguishable from authentic content (Chesney & Citron, 2019). Deepfakes rely on machine learning models, particularly generative adversarial networks (GANs), to synthesize realistic media that can easily deceive viewers. While this technology offers entertainment and educational applications, it also presents a formidable cybersecurity challenge, especially within social media platforms that are susceptible to rapid content dissemination and widespread influence (Dolhansky et al., 2020).

Social media platforms, where users are constantly exposed to vast amounts of content, have become a fertile ground for deepfake threats. Malicious actors exploit deepfakes for various purposes, including misinformation campaigns, identity fraud, and online harassment (Nguyen et al., 2022). These threats are amplified in the current era of post-truth, where digitally manipulated content can influence public opinion, destabilize political environments, and erode trust in media sources (Vaccari & Chadwick, 2020). In 2020, for instance, researchers

estimated that over 85,000 deepfake videos were circulating online, a number that has only increased with improvements in AI accessibility and computational power (Agarwal et al., 2020).

Traditional detection methods have proven inadequate against the sophistication of deepfake technology, as they are not equipped to handle the subtle nuances of AI-generated media. This has spurred a growing interest in AI-driven cybersecurity solutions capable of real-time deepfake detection, especially within social media ecosystems that operate on high-volume and high-speed content sharing (Rossler et al., 2019). These AI-based systems leverage advanced algorithms such as convolutional neural networks (CNNs) and recurrent neural networks (RNNs) to analyse subtle cues like pixel inconsistencies, unnatural facial movements, and audio-visual mismatches that are typical of deepfake content (Hussain et al., 2021).

Despite advances in detection technology, substantial challenges remain in making these systems effective for real-world application. One issue is scalability: social media platforms process billions of daily interactions, requiring detection systems that can operate with both high accuracy and low latency across large networks (Gupta et al., 2023). False positives are another concern, as erroneously flagging genuine content as deepfake can undermine the credibility of detection systems and create privacy implications for users (Li & Lyu, 2020). Addressing these challenges requires collaborative efforts between social media companies, cybersecurity experts, and AI researchers to develop, refine, and scale detection technologies effectively.

The objective of this study is to develop a framework for real-time AI-driven deepfake detection that is specifically designed for social media environments. This study aims to explore the effectiveness of various AI algorithms in identifying deepfake content, assess their limitations in terms of computational cost and reliability, and provide strategic recommendations for improving detection accuracy. By employing a mixed-methods approach, the research will combine quantitative analysis of detection model performance with qualitative insights from industry experts to uncover practical challenges and suggest improvements (Zhou et al., 2021). This approach not only bridges the gap in current research on social media-centric deepfake detection but also contributes to the larger field of cybersecurity by addressing an urgent and evolving threat.

This study aims to provide actionable insights into AI's role in countering deepfake-based cybersecurity risks on social media, emphasizing the need for standardized protocols and ethical frameworks for collaboration between platforms and cybersecurity firms. The goal is to advance cybersecurity by providing a robust framework for detecting deepfake threats and safeguarding online communities. (Jiang et al., 2020).

Methodology

This study employs a quantitative methodology, enabling a comprehensive analysis of AI model performance while addressing the technical and practical challenges of deploying real-time deepfake detection systems at scale.

Research Design

The research design consists quantitative analysis, a representative sample of both real and deepfake content will be gathered from well-known, publicly available datasets, as well as specific media sources on social platforms. The study will utilize recognized datasets like the Deepfake Detection Challenge Dataset, FaceForensics++, Kaggle.

Data Collection

The study aims to collect quantitative data on deepfake detection on social media platforms. Data will be gathered from publicly available sources such as the Deepfake Detection Challenge Dataset, Face Forensics++, and user-generated content on platforms. The dataset will include various forms of manipulated media, including images.

Model Selection

The study evaluates CNNs, RNNs, GAN-based adversarial models, and hybrid CNN-RNN architectures.

Experimental Design

AI models will be trained and tested on the datasets, with 80% of the dataset used for training and 20% for validation and testing. Key performance metrics will be calculated, including accuracy, precision, recall, F1-score, and computational efficiency.

Testing Procedure

Each model is tested on unseen deepfake samples to assess its detection capability. Statistical comparisons are conducted using ANOVA, t-tests, and additional machine learning-specific evaluation techniques such as cross-validation and confusion matrix analysis.

Results and Discussion

This section presents the results of a quantitative analysis of AI detection model performance on deepfake content, detailing the effectiveness of detection models, identified practical challenges, and a proposed framework.

Results

The quantitative analysis focused on evaluating the performance of various AI models (e.g., CNN, RNN, GAN-based adversarial models) for real-time detection of deepfake content on social media. Models were assessed on metrics such as accuracy, precision, recall, F1-score, and computational efficiency.

Table 1: Comparison of AI Model Performance for Detecting Deepfake Content across Metrics.

Model Type	Accuracy (%)	Precision (%)	Recall (%)	F1-Score (%)	Latency (ms)
CNN Model	92.3	91.8	93.1	92.4	25
RNN Model	89.5	90.2	88.6	89.4	30
GAN-Adversarial	94.7	93.9	95.1	94.5	40
Hybrid CNN + RNN	93.4	92.5	94.2	93.3	28

The study analysed the detection accuracy of AI models in identifying deepfake content on social media. The GAN-adversarial model showed the highest accuracy (94.7%) and F1-score (94.5%), suggesting its potential for real-time detection. However, it had the highest latency (40 ms), making it less suitable for real-time applications. The CNN model, on the other hand, achieved high accuracy (92.3%) with low latency (25 ms), making it a viable option for real-time detection.

Discussion

The study investigates the role of artificial intelligence (AI) in detecting deepfake-based cybersecurity threats on social media platforms. It identifies that advanced AI models, particularly those using GAN-based adversarial techniques, achieve high accuracy in identifying deepfake content. However, they face limitations in real-time application due to high latency and computational demands. CNN models, with lower latency, emerge as a viable alternative for immediate detection, albeit with moderate accuracy that may require supplementary enhancements for highly complex deepfake content.

The study suggests social media platforms adopt a hybrid approach, integrating both CNN-based and GAN-enhanced models to balance detection accuracy with operational efficiency. Collaborative frameworks with cybersecurity firms can further enhance detection capabilities, as shared resources and standardized protocols are essential for managing the evolving nature of deepfake threats.

Future research should focus on optimizing AI models to reduce latency and computational costs, expanding datasets, retraining models regularly, and interdisciplinary research on ethical implications for establishing guidelines that balance detection efficacy with user rights.

Conclusions and Recommendations

The study investigates the role of artificial intelligence (AI) in detecting deepfake-based cybersecurity threats on social media platforms. It identifies that advanced AI models, particularly those using GAN-based adversarial techniques, achieve high accuracy in identifying deepfake content. However, they face limitations in real-time application due to high latency and computational demands. CNN models, with lower latency, emerge as a viable alternative for immediate detection, albeit with moderate accuracy that may require supplementary enhancements for highly complex deepfake content.

The qualitative analysis highlights practical challenges associated with AI detection systems on social media, including scalability, high false-positive rates, ethical considerations, Ethical and privacy concerns also require careful management, with an emphasis on transparency and privacy-protective measures to maintain user trust.

The study suggests social media platforms adopt a hybrid approach, integrating both CNN-based and GAN-enhanced models to balance detection accuracy with operational efficiency. Collaborative frameworks with cybersecurity firms can further enhance detection capabilities, as shared resources and standardized protocols are essential for managing the evolving nature of deepfake threats.

Future research should focus on optimizing AI models to reduce latency and computational costs, expanding datasets, retraining models regularly, and interdisciplinary research on ethical implications for establishing guidelines that balance detection efficacy with user rights. Additionally, standardized cybersecurity frameworks must be developed to ensure ethical AI deployment in real-world applications.

References

- Agarwal, S., Farid, H., Gu, Y., He, M., Nagano, K. & Li, H. (2020) 'Protecting World Leaders Against Deep Fakes', Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition (CVPR).
- Chesney, R. & Citron, D. K. (2019) 'Deepfakes and the New Disinformation War: The Coming Age of Post-Truth Geopolitics', Foreign Affairs.
- Dolhansky, B., Howes, R., Pflaum, B., Baram, N. & Ferrer, C. C. (2020) 'The Deepfake Detection Challenge Dataset', arXiv preprint arXiv:2006.07397.
- Gupta, A., Lalwani, P., Manuja, M. & Singh, P. (2023) 'Real-Time Detection and Mitigation of Deepfakes in Social Media', Journal of Cybersecurity and Privacy.
- Hussain, S., Hussain, S. & Muhammad, K. (2021) 'Artificial Intelligence-Driven Cybersecurity in the Era of Smart Cities: Systematic Review and Open Challenges', IEEE Access.
- Jiang, L., Yin, X., Wang, J. & Zhang, Y. (2020) 'Deepfake Detection and Segmentation Using Convolutional Neural Networks', IEEE Access.

Li, Y. & Lyu, S. (2020) ‘Deepfake Forensics: Fighting Against Artificial Intelligence-Synthesized Fake Media’, IEEE Security & Privacy Magazine.

Nguyen, T. T., Nguyen, C. M., Nguyen, D. T., Nguyen, D. T. & Nahavandi, S. (2022) ‘Deep Learning for Deepfakes Creation and Detection: A Survey’, Artificial Intelligence Review.

Rossler, A., Cozzolino, D., Verdoliva, L., Riess, C., Thies, J. & Nießner, M. (2019) ‘FaceForensics++: Learning to Detect Manipulated Facial Images’, IEEE Transactions on Pattern Analysis and Machine Intelligence.

Vaccari, C. & Chadwick, A. (2020) ‘Deepfakes and Disinformation: Exploring the Impact of Synthetic Political Video on Deception, Uncertainty, and Trust in News’, Social Media + Society.

Zhou, P., Han, X., Morariu, V. I. & Davis, L. S. (2021) ‘Two-Stream Neural Networks for Tampered Face Detection’, Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition (CVPR).

**FACTORS INFLUENCING THE IMPLEMENTATION OF BLOCKCHAIN
TECHNOLOGY BASED SHARED KNOW-YOUR-CUSTOMER BY THE CENTRAL
BANK OF SRI LANKA**

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Abstract

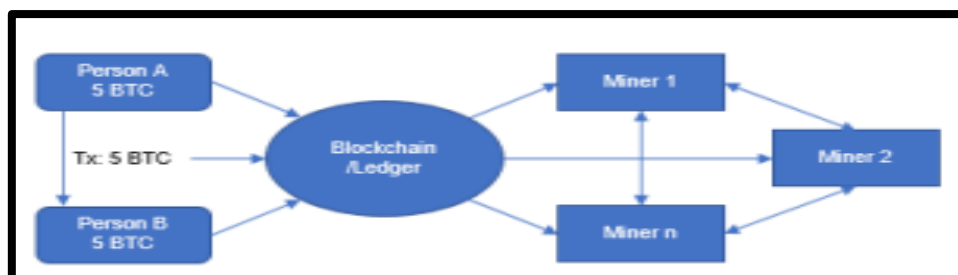
Despite the fact that Block Chain Technology (BCT) has several benefits for businesses, its adoption is very rare in Sri Lanka (SL). This study attempted to explore the factors influencing the implementation of BCT based shared Know-Your-Customer (KYC) verified by Central Bank of Sri Lanka (CBSL). A qualitative research approach was used in the investigation and an interview guide was developed and conducted among IT specialists, banking professionals, and an expert from Telecommunication Company. Thematic Analysis was used to analyze different views of these interviewees. Key findings were brought under four themes for the implementation of BCT based shared KYC in the SL banking sector. As such, this process is made possible by driving forces like increased customer satisfaction and high encryption levels as well as enhancing sources like regulation. Restraining forces like resistance and high infrastructure costs are addressed by a number of mitigating sources, including long-term savings, digital marketing campaigns etc.

Key Words: Banking Sector, Block Chain, CBSL, Fintech, Shared KYC

Introduction

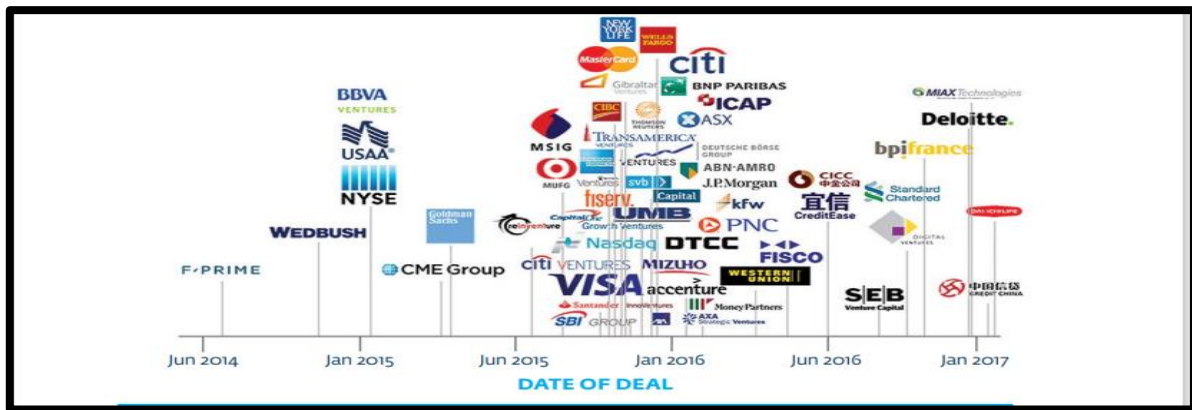
By doing away with the need for a trustworthy third party, BCT was initially presented as an electronic payment system designed to use cryptographic proof rather than trust, enabling direct communication between any two interested parties. (Nakamoto, 2008) Investment in the BCT business maintained at \$550 million in 2015, up from \$5 million in 2012, reflecting the industry's expanding trend globally. (Miller, et al., 2019).

Figure 1: Block chain transaction infrastructure (*Li, et al., 2018*)



Due to their decentralized structure, security, transparency, and anti-tampering capabilities, DLT applications outside of crypto-currency are growing in popularity. (Polyviou, et al., 2019) Among them, the financial industry has a number of applications, including Shared KYC.

Figure 2: The march of financial services firms into bitcoin and block chain start-ups, 2014 to February 2017 (Miller, et al., 2019)



A recent Forbes article claims that a small number of banks are spending about \$500 million annually to enhance and oversee their KYC and AML processes. (KPMG, 2024) There was a significant ransomware attack against Lanka Government Cloud on August 26, 2023 (Poireault, 2023) Luz & Farias (2020) emphasizes that new methodologies must be adopted to learn more about BCT. Sachitra & Dayaratna (2023) and Abesekara & Kumarawadu (2022) states that there are insufficient studies relevant to BCT in SL. Further, prior studies implies that there is also a gap in the literature in terms of unobservable traits and lack of the knowledge from diverse parties. (Sachitra & Dayaratna, 2023) A group of European banks is leveraging BCT to greatly improve the efficacy of customer verification procedures through a shared KYC system. (IntellectEU, 2024)

In June 2021, the CBSL and 10 regional banks completed the development and testing of a Proof-Of-Concept (POC) for Shared KYC based on BCT. (CBSL, 2021) The deployment and POC testing phase was completed successfully. A number of secure block chain capabilities were discovered throughout the examination. (Sachitra & Dayaratna, 2023) However, the launch and implementation phase of this application has not been announced by CBSL.

As no prior studies researched the implementation of BCT based Shared KYC in SL and having all three research gaps, the main objective of this research was to explore the factors influencing the implementation phase of the POC verified while contributing new knowledge to the literature which would assist in developing an implementation framework. Although this study will immensely be beneficial to bankers, educationists and practitioners, the CBSL has the priority in the modification and formulation of policies in favour of exploiting the BCT. Further, in order to prevent money laundering and terrorism financing that could arise from the Port City complex and other noteworthy developments, this kind of BCT-based Shared KYC will essentially become a mandatory initiative in SL. SL is also vulnerable to cyber-attacks because cloud sources store the data.

Methodology

Since the research must gather subjective data without any previous research, an Interpretivist Philosophy has been applied to examine the knowledge. (Saunders, et al., 2003) As a result, an inductive research approach was used to conduct the study. According to the main objective and its exploratory nature, the suitable methodology of this research was qualitative.

The study was conducted among six participants from various industries.

Figure 3: Details of participants (Source – Researcher’s Interviews)

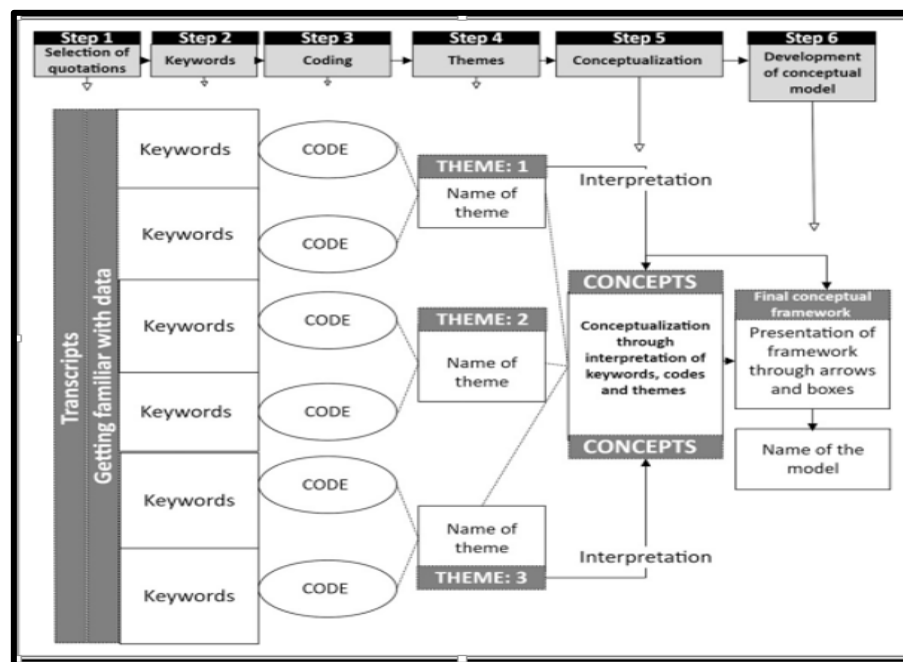
<u>Industry/ Sector</u>	<u>Designation of the Participant</u>	<u>Experience</u>	<u>Qualifications</u>	<u>Respondent ID</u>
Software Company	Chief Technology Officer	More than 20 Years	MSc-Computer Systems, BSc-Electronics and Teleco. Engineering	P1
Telco Company	General Manager	More than 20 Years	FCA, FSCMA, MBA, MCIM	P2
Software Company	Co-Founder & CEO	More than 20 Years	B.Sc. Economics	P3
Overseas Banking Sector	Senior Compliance Officer	More than 9 Years	CIMA Foundation and OTHM Level 7 (SM & Leadership)	P6
Local Banking Sector	Banking Officer SA 1	More than 10 Years	DBF (IBSL)	P8
Block Chain Software Company	Founder and Community Lead	More Than 6 Years	MBA in Business Analytics	P9

Note: P1 & P2 were directly involved with the development of the POC by CBSL and P3 was one of the members of digital roadmap committee.

The intended study sample was chosen using a non-probability sampling technique with reference to a purposive sample. In order to overcome the limitations of a prior study, a diverse group of interviewees was chosen. (Sachitra & Dayaratna, 2023) Despite the small sample size, the study's objective was to explore a new phenomenon rather than statistically evaluate measurable hypotheses. The data collected from the six participants was therefore adequate. (Saunders, et al., 2003)

Open-ended, semi-structured interviews using a non-standardized set of questions derived from a literature review were used to collect the data. With the participants' consent, audio and video recordings of the interviews, which ranged in duration from 22 to 60 minutes, were made. The method for analyzing the qualitative data was thematic analysis. Six steps were involved in this thematic analysis to create a conceptual frame, in accordance with the systematic thematic analysis process: A novel six-step process for conceptual model development in qualitative research proposed by Naeem, et al. (2023).

Figure 4: A systematic thematic analysis process: A novel six-step process for conceptual model development in qualitative research (Naeem, et al., 2023)



Results & Discussion

First, using 10 sets of data and ten semi-structured interview questions, the study looked at opinions regarding the implementation of BCT-based shared KYC under the thematic analysis format. The quotations' key words are chosen and emphasized using the 6Rs as a guide proposed by Naeem, et al. (2023)

Figure 5: 6R's for Keyword (Naeem, et al., 2023)

6Rs for Keyword Selection	Definitions
Realness	Words that reflect the genuine experiences and perceptions of the participants
Richness	Words that are rich in meaning and provide a detailed understanding of the phenomenon being studied
Repetition	Words that frequently occur in the data, which indicates their significance and relevance to the participants
Rationale	Words that are connected to the theoretical or philosophical foundation of the research
Repartee	In general, repartee refers to quick, witty conversation or a quick, witty reply. However, when used in the context of thematic analysis and in selecting keywords from the data, "repartee keywords" are words that are insightful, evocative, and stimulate further discussion or consideration
Regal	Words that are central to understanding the phenomenon under study and contribute significantly to the literature through adding new insight

In order to create "codes," highlighted keywords are grouped according to their common features. The codes are then further condensed and transformed into "themes," which are meant to represent the accomplishment of the study goal.

Figure 6: Key words, Codes and Themes (Source – Researcher's Original Construct)

S/N	Key Words	Codes	Themes
1	improves customer satisfaction	Specific Benefits	Driving Forces
2	high security		
3	ability to streamline the KYC process		
4	cost savings		
5	within a few minutes		
6	adapt to a more digital world	Work Culture	
7	shift toward a collaborative approach		
8	real-time	Process Benefits	
9	certain documents		
10	entering the same data	Cyber-Security	
11	High levels of encryption		
12	vulnerable to cyber-attacks	Customer Benefits	
13	improved privacy control		
14	process once	Regulatory Benefits	Enhancing Sources
15	compliance in Sri Lanka there's none		
16	regulated by CBSL		
17	consortium		
18	facilitate collaboration		
19	digital road map committee		
20	permission block chain		
21	regulatory sandboxes	Feasibility	
22	operates block chain is only for sharing KYC information		
23	technically it is certainly possible		
24	financially we could run	Infrastructure	
25	find a proper chain		
26	certainly capable		
27	servers network infrastructure		

28	Cyber-security measures		
29	Integration Layer		
30	Training Programs		
31	Interoperability	Technical Issues	Restraining Forces
32	integrate		
33	digital literacy		
34	encryption broken		
35	stringent data privacy regulations		
36	scalability		
37	Cross-border data sharing introduces complexity	Regulatory Limitations	
38	no concept of deleting		
39	operational feasibility concerns	Feasibility Concerns	
40	updating current legal frameworks		
41	internal cultures	Challenges in Banking Sector	
42	customers may struggle to adapt		
43	high cost		
44	resistant to adopting new technologies		
45	certain Acts that need to be amended		
46	government organization getting something rolled out		
47	lack of technical expertise		
48	upgrading legacy systems		
49	Hybrid Solutions to facilitate integration	Solutions	Mitigating Sources
50	use this Shared KYC system as a separate one	Regulatory Reliefs	
51	establish the clear guidelines		
52	Central Bank leadership	Acceptance	
53	digital marketing campaigns		
54	workshops and training programs		

Accordingly, four themes were identified from the results. The term "driving forces" describes the intrinsic advantages of the BCT with regard to shared KYC. While 66.66% of participants

emphasized the specific benefits to adopt this process, 100% of them were in favor for this due to its cyber-security feature. The primary benefits of BCT based Shared KYC are reduced redundancy and quicker processing times. In particular, this approach results in reduced expenses, increased efficiency, the elimination of duplication, transparent transactions, and improved end-user satisfaction. (Patil & Sangeetha, 2022) A strong basis for fine-grained privacy control is provided by the requirement that client authorization be obtained before accessing their information for KYC (or other) purposes. (Polyviou, et al., 2019)

“Enhancing Sources” refers to the enhanced advantages to the BCT based shared KYC made by related parties. All participants emphasized that CBSL should regulate this process. 50% of them were of view to implement this process by forming a consortium. 83.33% of the participants were agreed of technical and financial feasibility of this process. According to Sachitra & Dayaratna (2023), it is imperative that the central bank embrace the implementation of BCT and encourage its use. On the other hand, the biggest banks in India have joined forces to create a new company called the "Indian Bank's Blockchain Infrastructure Company Private Limited" (IBBIC) with the goal of advancing the use of BCT in banking. (Jindal, et al., 2022)

“Restraining Forces” refers to the forces which act as the barriers of the implementation of BCT based Shared KYC. 83.33% of the participant commented on interoperability issues. 50% of them were in view of high cost and resistance as the main obstacles of implementing the process. When implementing blockchain solutions, the SL finance sector encounters a number of challenges, such as doubts about the emerging technology, insufficient governance and legislation, a lack of standardization, high implementation costs, and issues with legacy system interoperability. (Abesekara & Kumarawadu, 2022) Consumers may simply be resistant to accepting and learning, or staff members may be resistant because they lack experience and knowledge and are afraid of being displaced by new technologies. (Sachitra & Dayaratna, 2023)

“Mitigating sources” states how to overcome the restraining forces when implementing the BCT based Shared KYC. 66.66% of the participants mentioned that establishing clear guidelines would address the most of the issues identified. The CBSL ought to establish a set of rules and regulations that will allow the banking sector in the nation to adopt BCT. (Sachitra & Dayaratna, 2023)

Conclusions & Recommendations

The main objective of the study has been achieved with the identification of the four themes that cover the factors influencing the implementation of BCT-based Shared KYC in the SL banking sector. BCT has some driving forces, and when combined with enhancing sources in the banking industry, they can launch a BCT-based shared KYC process in SL. However, there are certain restraining forces preventing its full implementation, most of which can be addressed by the mitigating sources available in the country's banking industry, which is led by the CBSL.

There are two key findings which are driving the implementation such as Increased Customer Satisfaction and High levels of Encryptions. I.e. Control ability of customers and high security. Another main finding is that the BCT based Shared KYC is lacking a Regulator. To enhance the process, CBSL needs to regulate or allow a consortium of banks to initiate this information system through BCT. There are another two key findings which restrains the implementation such as High Cost of Infrastructure and Resistance. The banking industry in SL can readily address all other issues aside from the filtered findings.

To mitigating challenges, the CBSL and other government agencies should form a committee to work together and regulate the BCT-based Shared KYC in the banking industry followed by implementing a digital awareness roadmap. Every bank should use an investment appraisal tool like net present value (NPV) to inform customers about long-term cost savings. It should also make sure that the benefits outweigh the costs, and small rural banks can receive government subsidies if they are unable to acquire new technology. To overcome resistance, the regulator should arrange awareness campaigns, workshops, and training programs in addition to digital marketing campaigns and apps.

References

- Abesekara, M. C. & Kumarawadu, P., 2022. Analysis of factors influencing blockchain implementation in finance sector in Sri Lanka. *HCMCOUJS-Economics and Business Administration*, II(12), pp. 3-14.
- CBSL, 2021. *CBSL Successfully Completed the Process of Developing and Testing a Blockchain Technology based Shared Know-Your-Customer (KYC) Proof-Of-Concept (POC)*. [Online]
Available at: <https://www.cbsl.gov.lk/en/news/cbsl-successfully-completes-the-process-of-developing-and-testing-a-blockchain-technology-based-shared-kyc-poc>
[Accessed 9 March 2024].
- IntellectEU, 2024. *The Future of Identity: Blockchain-based Verification in KYC Processes*. [Online]
Available at: <https://www.intellecteu.com/blog/the-future-of-identity-blockchain-based-verification-in-kyc-processes>
[Accessed 18 March 2024].
- Jindal, P., Kaur, J. & Sood, K., 2022. Process Innovation and Unification of KYC Document Management System with Blockchain in Banking. In: P. Jindal, J. Kaur & K. Sood, eds. *Blockchain Technology in Corporate Governance: Transforming Business and Industries*. Punjab: Scrivener Publishing LLC, pp. 199-216.
- KPMG, 2024. *Combating financial crime*. [Online]
Available at: <https://kpmg.com/lk/en/home/insights/2019/03/combating-financial-crime-fs.html>
[Accessed 18 March 2024].

Kumar, P. P. & Punitha, R., 2020. A study on regulatory compliance of KYC in financial service Industry. *Journal of Contemporary Issues in Business and Government*, XXVI(2), pp. 579-584.

Li, Y. et al., 2018. *Blockchain Technology in Business Organizations: A Scoping Review*. Hawaii, Proceedings of the 51st Hawaii International Conference on System Sciences | 2018.

Luz, M. A. d. & Farias, K., 2020. *The Use of Blockchain in Financial Area: A Systematic Mapping Study*. New York, Association for Computing Machinery - Proceedings of the XVI Brazilian Symposium on Information Systems.

Miller, D. et al., 2019. *BLOCKCHAIN Opportunities for Private Enterprises in Emerging Markets*, Washington: International Finance Corporation - World Bank Group.

Naeem, M., Ozuem, W., Howell, K. & Ranfagni, S., 2023. A Step-by-Step Process of Thematic Analysis to Develop a Conceptual Model in Qualitative Research. *International Journal of Qualitative Methods*, Volume XXII, pp. 1-18.

Nakamoto, S., 2008. *Bitcoin: A Peer-to-Peer Electronic Cash System*. [Online] Available at: <https://assets.pubpub.org/d8wct41f/31611263538139.pdf> [Accessed 9 March 2024].

Natarajan, H., Krause, S. & Gradstein, H., 2017. *Distributed Ledger Technology*, Washington: World Bank Group.

Patil, P. & Sangeetha, M., 2022. Blockchain-based Decentralized KYC Verification Framework for Banks. *4th International Conference on Innovative Data Communication Technology and Application*, Volume CCXV, pp. 529-536.

Poireault, K., 2023. *Ransomware Attack Wipes Out Sri Lankan Government Data*. [Online] Available at: [https://www.infosecurity-magazine.com/news/ransomware-sri-lanka-government/#:~:text=Investigations%20have%20begun%20into%20a,Center%20\(CERT%7CCC\).](https://www.infosecurity-magazine.com/news/ransomware-sri-lanka-government/#:~:text=Investigations%20have%20begun%20into%20a,Center%20(CERT%7CCC).) [Accessed 14 March 2024].

Polyviou, A., Velanas, P. & Soldatos, J., 2019. *Blockchain Technology: Financial Sector Application beyond Cryptocurrencies*. Greece, MDPI.

Sachitra, V. & Dayaratna, D., 2023. Examine the Feasibility of Implementing Blockchain Technology in the Sri Lankan Banking System. *Asian Journal of Advanced Research and Reports*, XVII(9), pp. 115-125.

Saunders, M., Lewis, P. & Thronhill, A., 2003. *Research Methods for Business Students*. 3rd ed. Harlow: Pearson Education Limited.

Wavetec, 2023. *The Importance of KYC in Banking*. [Online] Available at: <https://www.wavetec.com/blog/banking/kyc-in-banking/#:~:text=KYC%20forms%20a%20critical%20part,can%20identify%20money%20la undering%20risks.> [Accessed 18 March 2024].

**ASSESS THE IMPACT OF NFC AND IOT TECHNOLOGIES ON ATTENDEE
ENGAGEMENT IN FRANCE HEALTHCARE CONFERENCES**

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Abstract

France is a leading country which hosts major events annually. The country's appeal as a top conference destination attracts many attendees. However, effective management is crucial for engagement, efficiency, and addressing key challenges. Traditional conference management methods are often associated with many drawbacks. Therefore, this study examines how participant's engagement for France healthcare conferences can be enhanced by integrating Near Field Communication (NFC) Internet of Things (IoT).

Quantitative approach was used as the research method. Technology Acceptance Model (TAM) was used as the theoretical framework to assess perceived usefulness (PU) and Perceived Ease of Use (PEOU) of these two technologies and their impact on attendee engagement. An online questionnaire was distributed to attendees of healthcare conferences in France. The findings show that NFC boosts participation through efficient registration and connection, while IoT enhances real-time information sharing and attendee satisfaction.

Key words: Attendee Engagement, France, Healthcare Conferences, Internet of Things (IoT), Near Field Communication (NFC), Perceived Ease of Use (PEOU), Perceived Usefulness (PU), Technology Acceptance Model (TAM).

Introduction

France is a leader when it comes to major event hosting, with 380,000 hosting events per year with an annual economic impact of €32 billion (Paris je t'aime, n.d.). It means that France is a great place for conferences, trade shows and other large-scale events due to its infrastructure – with 18,500 hotels and enough venues to suit such large crowds that make for easy running of an event.

The country's unique context to attract millions of participants to its conferences and events, many of which revolve around healthcare, makes the integration of NFC and IoT technologies interesting to analyze in order to optimize attendee engagement and streamline event management.

Also, in Lyon, France, the MONICA project clearly shows that IoT technologies are useful to increase attendee engagement through more effective crowd monitoring and real-time interactions in large-scale events (Abadi et al. 2019) report on a number of successful cases of NFC use at small-scale events but no record of its use at upscale events in the Healthcare field (Coskun et al. 2015; Ahmadi et al. 2019; Pal et al. 2021).

New technologies such as NFC and the IoT are some of the trends in the advanced sectors, including the appointment of events and conferences. NFC allows communication between devices within a close range useful in attendee check-ins, digital ticketing, and networking via an iPhone or an NFC badge (Want 2011). On the other hand, IoT can interconnect several devices and thus help the conference organizers to observe the attendees' activity, deliver the targeted content, and control the event's flow better (Sunkaraneni 2021a).

The healthcare conferences are no longer mere knowledge-sharing platforms; they are events that ought to be dynamic, involving an individual for each attendee. Based on NFC and IoT applications, the organizational committees of healthcare conferences will be able to assist attendees with real-time information and services, with location-based services being one identified usage, and with adapting schedules in accord with attendee's preferences being another.

These technological advancements also help the organizers to collect lots of data concerning the behavior of the attendees that can be used to make proper conclusions regarding the following technological advancements (Li et al. 2022).

Methodology

Thus, the research utilizes a positivist research ontology and epistemology so as to provide a highly systematized analysis of NFC and IoT technologies on attendee experience. According to research on Saunders, Lewis, and Thornhill (2019), two broad methods of reasoning can be recognised like inductive and deductive reasoning approaches. Simply, deductive reasoning approach-based studies engage to test hypothesis(s) depending on existing theory on the other hand inductive reasoning approach-based research studies engage to build a new theory or modify existing theory with generating themes (Creswell and Plano Clark, 2007).

According to that clearly recognising the differences between each approach to adapt with the most suitable approach for this study, deductive reasoning approach can be recognised as the most suitable research approach to examine the impact of IoT and NFC technologies on the attendee engagement for healthcare conferences in France adapting with the existing theory of Technology acceptance model (TAM).

Moreover, following the theory, this study derives hypotheses regarding the theory to examine relationship between NFC and IoT technologies with attendee engagement including the investigation of mediating relationship of perceived usefulness and ease of use as the two determinants of the TAM theory for the relationship between NFC and IoT technologies with attendee engagement.

Figure 1: Technology Acceptance Model TAM (Venkatesh and Davis 2000)

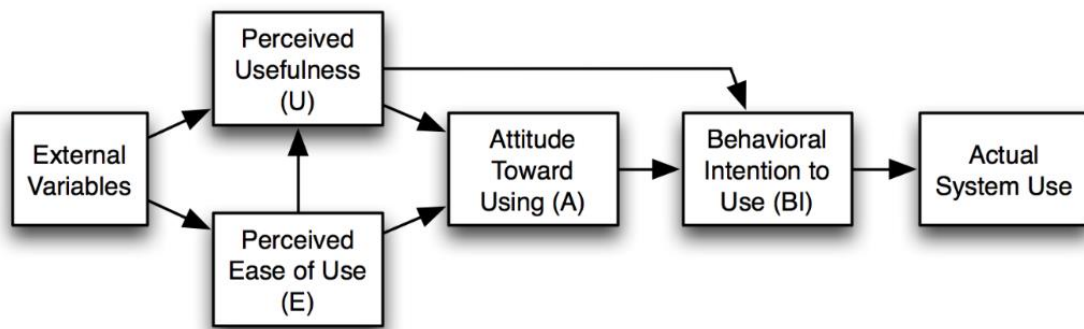
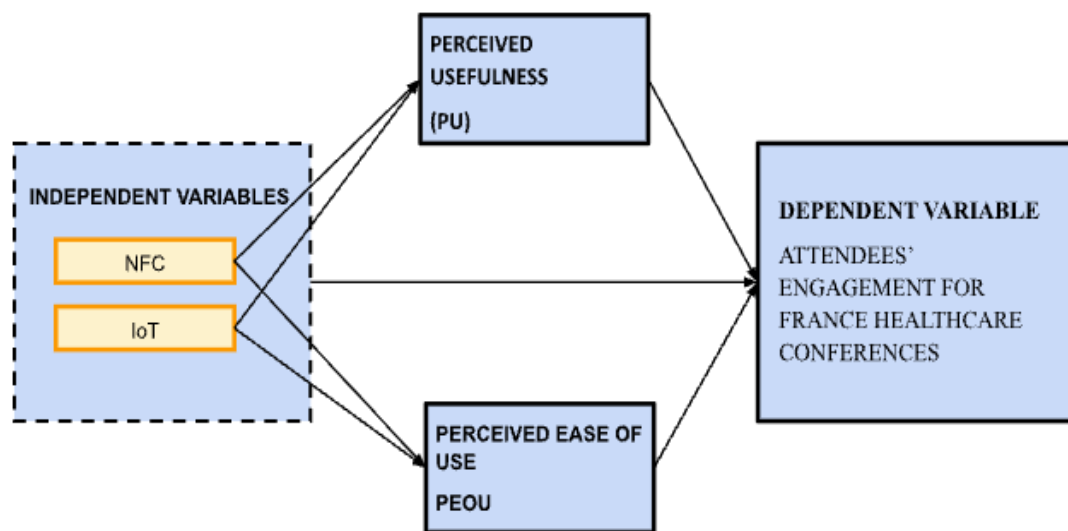


Figure 2: Conceptual Framework



Conceptual Framework

Table 1: Hypothesis

No.	Alternative Hypothesis (H1–H6)	Null Hypothesis (H0)
H1	Use of NFC can significantly enhance attendee engagement in healthcare conferences.	The use of NFC does not significantly enhance attendee engagement in healthcare conferences.
H2	Use of IoT can significantly enhance attendee engagement in healthcare conferences.	The use of IoT does not significantly enhance attendee engagement in healthcare conferences.
H3	Perceived usefulness can make a significant positive mediating impact on the relationship between the use of NFC and attendee engagement.	Perceived usefulness does not make a significant positive mediating impact on the relationship between the use of NFC and attendee engagement.
H4	Perceived usefulness can make a significant positive mediating impact on the relationship between the use of IoT and attendee engagement.	Perceived usefulness does not make a significant positive mediating impact on the relationship between the use of IoT and attendee engagement.
H5	Perceived ease of use can make a significant positive mediating impact on the relationship between the use of NFC and attendee engagement.	Perceived ease of use does not make a significant positive mediating impact on the relationship between the use of NFC and attendee engagement.
H6	Perceived ease of use can make a significant positive mediating impact on the relationship between the use of IoT and attendee engagement.	Perceived ease of use does not make a significant positive mediating impact on the relationship between the use of IoT and attendee engagement.

The approach used in the current study was a survey because of its effectiveness in providing data from a relatively large population. Questionnaire was developed which contained a set of questions and a rating scale. The questions were divided into demographic sections and ten self-designative and five-like Likert scale questions covering the NFC and IoT technologies adoption, perceived usefulness, perceived ease of use and attendees' interaction.

The online questionnaire targeted healthcare conference participants in France, including researchers, event organizers, IT specialists, and healthcare providers. Convenience sampling was used to gather responses from those experienced with NFC and IoT technologies.

The survey generated 122 responses which trimmed down to 104 responses due to those that were incomplete or given by people who have limited knowledge about conference technologies. This sample size, while moderate, was good enough to provide a sufficient data set for the analysis at this point.

SPSS was used for analysis, including respondent characteristics, reliability (internal consistency), and normality tests for parametric suitability. Pearson correlations and multiple regression addressed relational involvement, while mediation analysis examined PU and PEOU per Baron and Kenny's (1986) steps.

Results & Discussion

STEP 1: Descriptive Statistics

Descriptive statistics provided an overview of the data distribution for key variables:

Table 2: Descriptive Statistics

Variable	N	Mean	Standard Deviation
UON (Use of NFC)	104	4.19	0.60
UOI (Use of IoT)	104	3.74	0.59
PU (Perceived Usefulness)	104	4.11	0.50
PEU (Perceived Ease of Use)	104	3.83	0.54
AE (Attendee Engagement)	104	3.71	0.64

The mean scores suggest a positive perception of NFC and IoT technologies, with the highest scores observed for perceived usefulness (PU).

STEP 2: Reliability Analysis

Cronbach's Alpha was calculated to ensure the internal consistency of the scales measuring variables.

Table 3: Reliability Analysis

Variable	Cronbach's Alpha
UON (Use of NFC)	0.865
UOI (Use of IoT)	0.850
PU (Perceived Usefulness)	0.829
PEU (Perceived Ease of Use)	0.812
AE (Attendee Engagement)	0.845

Interpretation: All variables demonstrated high reliability, with Cronbach's Alpha values above 0.8.

STEP 3: Correlation Analysis

Correlation analysis was used to assess the relationships between the variables.

Table 4: Correlation Analysis

Variable Pair	Correlation (r)	Significance (p-value)
UON and AE	0.499	< 0.001
UOI and AE	0.548	< 0.001
PU and AE	0.472	< 0.001
PEU and AE	0.528	< 0.001

Interpretation: All relationships were significant at $p < 0.001$, with moderate positive correlations between NFC, IoT, and attendee engagement.

STEP 4: Regression Analysis

Regression models were applied to evaluate the strength and significance of predictors (UON, UOI, PU, and PEU) on AE.

Table 5: Model Fit

Model Summary	R ²	F-Statistic	p-value
Model Fit	0.36	28.44	< 0.001

Table 6: Regression Analysis

Predictor	Beta (β)	t-Value	Significance (p-value)
UON	0.289	3.057	0.003
UOI	0.394	4.734	< 0.001

Interpretation: UON and UOI together explained 36% of the variance in AE. Both predictors had a significant positive impact on AE, with UOI showing a stronger effect.

Model 2: Mediators (PU and PEU) on AE

Table 7: Mediators

Predictor	Beta (β)	t-Value	Significance (p-value)
PU	0.472	5.561	< 0.001
PEU	0.528	6.018	< 0.001

Interpretation: Both perceived usefulness (PU) and perceived ease of use (PEU) significantly impacted attendee engagement, with PEU demonstrating a slightly stronger influence.

STEP 5: Final Outcomes

Direct Impact of UON and UOI on AE:

Both NFC and IoT technologies directly and significantly enhanced attendee engagement.

IoT had a stronger influence on AE compared to NFC.

Mediating Impact of PU and PEU:

PU and PEU mediated the relationship between UON/UOI and AE.

PEU had a slightly greater mediating effect than PU, indicating the importance of ease of use.

Key Tables

Table 8: Mediators

Model	R ²	Predictor	Beta (β)	p-value
UON and UOI on AE	0.36	UON	0.289	0.003
		UOI	0.394	< 0.001
PU and PEU on AE	-	PU	0.472	< 0.001
		PEU	0.528	< 0.001

Result Conclusion

Objective one: To examine the impact of the use of NFC (UON) on attendee engagement (AE) in healthcare conferences in France.

With testing hypothesis 1, this study obtained a highly significant positive impact on UON and AE in healthcare conferences in France with $\beta=0.308$ and $p=0.003$. Moreover, UON has significantly and positively correlated with AE including correlation of 0.499 and significance of <0.001.

Objective two: To examine the impact of using IoT (UOI) on attendee engagement (AE) in healthcare conferences in France.

Not only NFC technology but also IoT can be recognised as the most famous and popularly utilising conference mobile application in order to that as the empirical study, this study aimed to examine the impact of the use of IOT (UOI) on the attendee engagement based on the healthcare conferences in France. Depending on the obtained statistical results of the study, UOI has highly significant moderately positive impact on AE with $\beta=0.425$ and $p=<0.001$.

Objective three: To examine the mediating impact of perceived usefulness (PU) and perceived ease of use (PEU) on the relationship between the use of NFC (UON) and IoT (UOI) technologies with attendee engagement (AE) in healthcare conferences in France.

Depending on the results of the study obtained through Baron and Kenny's (1986) mediator analysis addressing the third objective, this study found a highly significant and moderate level of mediating impact of PU and PEU on the relationship between the use of NFC and IoT technologies with AE in healthcare conferences in France. Depending on the Technology Acceptance Model (TAM), this study was able to identify UOI and UON have significant positive impact on two determinants of TAM such as PU and PEU.

Conclusion and Recommendation

This study initially focused on the healthcare conferences in France. Without limiting to France, this study-based findings can be used to provide insights for practitioners with emphasizing potentials of the use of NFC and IoT technologies to effectively revolutionize event management as well as engagement of participants. Simply, NFC technology can be recognised as one of the advanced technologies which offers efficient solutions to streamline the number of processes of different events such as check-in, access control, tracking real time interaction and those features have recognised as the ways to improve operational efficiency with improving attendees' active engagement.

Because of that technology ensures time saving and delivers personalised experience. This study emphasises that the utilization of NFC technology is an effective way for conference planners and organizers to attain a seamless and more interactive event environment while ensuring attendees satisfaction.

Moreover, IoT technology is mostly used in event management industry and other industry with aiming gain its benefits in order to that conference management as one of part of event management industry, IoT technology can be utilised to make highly interactive and connected environment with allowing attendee of conferences to interact with each other and event ecosystem as well because if that initially IoT aims to facilitate personalised and on time interactive experience.

As the way, this study-based findings motivate healthcare conference organizers to use and connect these technologies effectively and in a more strategic way to ensure a significant level of attendee engagement with creating a more responsive and active conference environment.

References

- Abadi, M.J., Luceri, L., Hassan, M., Chou, C.T. and Nicoli, M., 2019. A cooperative machine learning approach for pedestrian navigation in indoor IoT. *Sensors (Switzerland)*, 19(21). doi: 10.3390/s19214609.
- Ahmadi, H., Arji, G., Shahmoradi, L., Safdari, R., Nilashi, M. and Alizadeh, M., 2019. The application of internet of things in healthcare: a systematic literature review and

classification. *Universal Access in the Information Society*, 18(4), pp.837–869. Available at: <https://link.springer.com/article/10.1007/s10209-018-0618-4> [Accessed 14 October 2024].

Coskun, V., Ozdenizci, B. and Ok, K., 2015. The survey on near field communication. *Sensors*, 15(6), pp.13348–13405. Available at: <https://www.mdpi.com/1424-8220/15/6/13348/htm> [Accessed 14 October 2024].

Li, S., Zhao, S., Gope, P. and Da Xu, L., 2022. Data privacy enhancing in the IoT user/device behavior analytics. *ACM Transactions on Sensor Networks*, 19(2). doi: 10.1145/3534648.

Paris je t'aime - Tourist Office - Convention Bureau, n.d. France: the perfect destination for large-scale events. Available at: <https://en.parisinfo.com/> [Accessed 5 October 2024].

Sunkaraneni, S., 2021. IoT based event management system using RFID. *SSRN Electronic Journal*. Available at: <https://papers.ssrn.com/abstract=3918249> [Accessed 13 October 2024].

Venkatesh, V. and Davis, F.D., 2000. A theoretical extension of the technology acceptance model: Four longitudinal field studies. *Management Science*, 46(2), pp.186–204.

Want, R., 2011. Near field communication. *IEEE Pervasive Computing*, 10(3), pp.4–7. doi: 10.1109/MPRV.2011.53.

Baron, R.M. and Kenny, D.A., 1986. The moderator–mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. *Journal of Personality and Social Psychology*, 51(6), pp.1173–1182.

Pal, P., et al., 2021. A review on emerging smart technological innovations in healthcare sector for increasing patient's medication adherence. *Global Health Journal*, 5(4), pp.183–189. doi: 10.1016/j.glohj.2021.11.006.

Dutot, V., 2015. Factors influencing near field communication (NFC) adoption: An extended TAM approach. *Journal of High Technology Management Research*, 26(1). doi: 10.1016/j.hitech.2015.04.005.

Saunders, M.N.K., Lewis, P. and Thornhill, A., 2019. *Research methods for business students*. Pearson.

Creswell, J.W. and Plano Clark, V.L., 2007. *Designing and conducting mixed methods research*. Thousand Oaks, CA: Sage Publications.

Rahman, M.K., Akter, S., Hossain, M.M. and Hassan, A., 2022. Pilgrimage and Halal tourism event: Application of technology. In: *Technology Application in Tourism Fairs, Festivals and Events in Asia*. Singapore: Springer, pp.63–75.

“FLAMING X” FIRE DETECTION & SUPPRESSION SYSTEM

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Abstract

The IoT-based fire detection and suppression system is an innovative solution designed to improve fire safety in various environments by combining advanced sensors, real time communication, and automated suppression mechanisms. The system leverages technologies like temperature, smoke, and flame detectors, thermal cameras, and Embedded C programming for real time, accurate detection and response. Alerts are sent through a SIM module to notify users remotely, ensuring prompt action. Testing phases, including performance and unit testing, confirm its reliability under challenging conditions. The project prioritizes human safety, energy efficiency, and environmental sustainability, making it a scalable and ethical solution to fire risks.

Key words: IOT (Internet of things), GPIO (General purpose Input/Output), HVAC System (Heating, Ventilation, and Air Conditioning), IR (infrared), GSM (global system for mobile telecommunications), GPRS (General packet radio service)

Introduction

Fire detection and alarm systems have significantly evolved, showcasing humanity's dedication to safety and innovation. From von Steinle's basic manual system to today's advanced AI-powered technologies, each advancement has made these systems faster, smarter, and more reliable (Smith, 2019; Ahmed et al., 2022). As technology progresses, future systems promise even greater capabilities, focusing on prevention and integration with smart devices, ensuring better protection of lives and property while creating a safer world for everyone (Singh & Patel, 2022).

Fire detection systems are critical for safeguarding lives and assets, especially in increasingly complex environments like industrial facilities and smart buildings. Traditional systems such as smoke and heat detectors often fall short due to false alarms, slow responses, or inability to address modern challenges (Garcia & Lee, 2021). The introduction of IoT and advanced technologies like multi-sensor networks and thermal imaging has transformed fire detection systems, offering faster, more reliable, and adaptable solutions (Clark, 2021). This project addresses these gaps by developing an IoT enabled system with remote monitoring capabilities and automated responses, catering to the unique requirements of diverse settings. And the safety is further confirmed by the automatic fire extinguishing system. It can also be said that by using the one right fire extinguishing liquid for every fire, it is suitable for every place (Miller, 2020).

Methodology

The system's development followed a prototype-based methodology, a structured approach that emphasises iterative design improvements to ensure the final product meets user needs and performs reliably. This methodology involves creating an initial prototype, testing its functionality, identifying areas for improvement, and refining the design in successive iterations. Such an approach allows developers to address any shortcomings early in the process and incorporate user feedback to enhance the system's adaptability and effectiveness. (TechTarget, 2024)

The system integrates advanced sensors, including thermal cameras, which play a pivotal role in detecting fire hazards by monitoring temperature variations and identifying potential threats in real time. These sensors are supported by embedded systems programmed in Embedded C, ensuring seamless and efficient communication between all components. This programming language is particularly suited for real-time systems as it offers low-level access to hardware, making it possible to achieve precise and reliable operation.

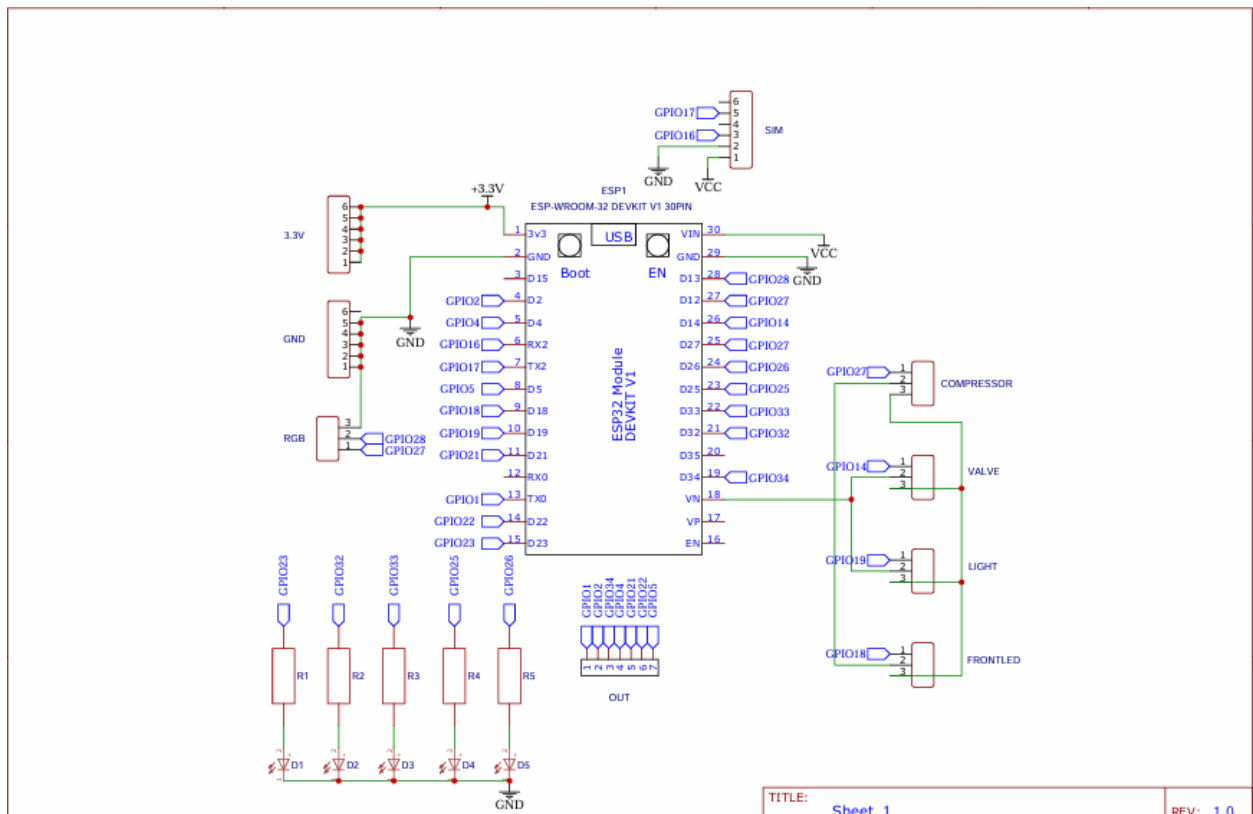
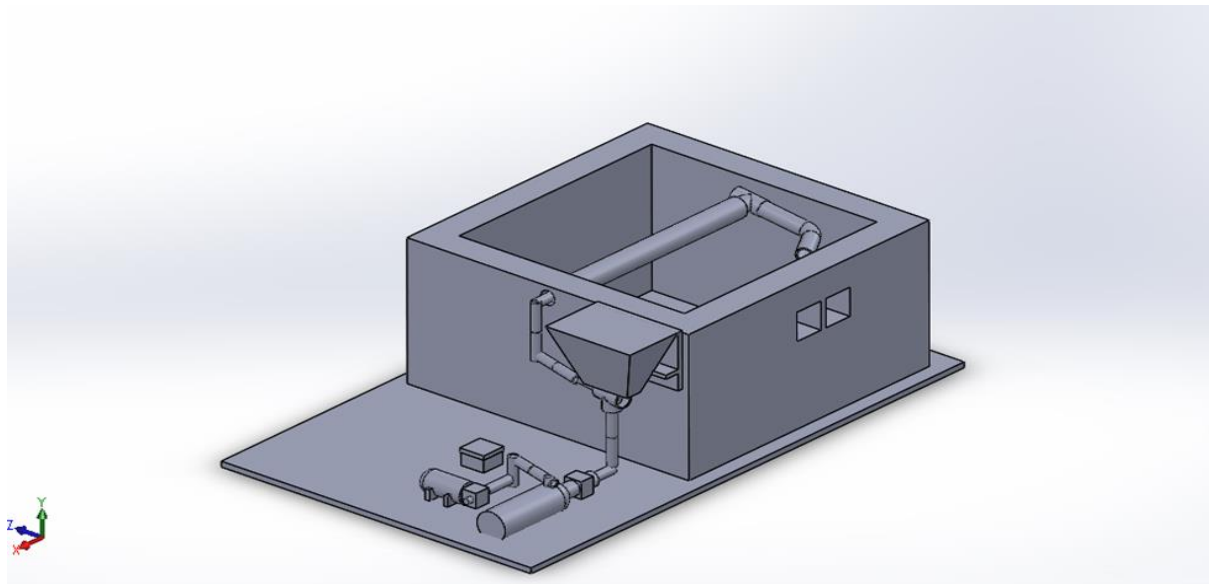
Once a potential fire hazard is detected, the sensors process the data in real time and communicate it to a central control unit. This control unit analyses the information and triggers necessary actions. Alerts are sent to users via a SIM module, enabling remote notifications through text messages or calls. This feature ensures that users are promptly informed of potential dangers, even when they are not physically present at the location.

Additionally, the system is equipped with a dry powder suppression mechanism that activates automatically when a fire hazard is confirmed. Dry powder is a versatile extinguishing agent suitable for various fire types, making the system effective in diverse environments.

Extensive testing was conducted to ensure the system's reliability and functionality. Smoke tests were performed to validate sensor responsiveness, unit tests were carried out to verify individual component functionality, and performance tests were conducted to evaluate the system's overall efficiency under different conditions.

The iterative nature of the prototype-based methodology allowed for continuous refinement of the system based on test results and user feedback. This adaptability ensures that the system remains relevant and effective, catering to evolving user requirements and offering a reliable solution for fire detection and suppression. (Project Managemnt.com, 2024)

System Architecture



GPIO 17 – 22
GPIO 02 – Flame Sensor
GPIO 34 – Gas Sensor (Analog)
GPIO 04 – Gas Sensor (Digital)
GPIO 21 – MLX SDA
GPIO 22 – MLX SCL
GPIO 16 – Buzzer
GPIO 23 – LED
GPIO 26 – LED
GPIO 25 – LED
GPIO 33 – LED
GPIO 32 – LED
GPIO 12 – RGB
GPIO 13 – RGB
GPIO 01 – Sim module RX
GPIO 03 – Sim Module TX
GPIO 18 -Relay module
GPIO 19 – Relay module
GPIO 14 – Relay Module
GPIO 27 – Relay module

System Validation and Performance Results

To validate the performance and reliability of "Flaming X" IoT-based fire suppression and detection, a range of tests have been conducted. The tests assured that the system met the requirements for design, operated correctly, and could respond to scenarios of fires in a variety of environments.

1. Performance Benchmark

System Response Time-

The time taken for sensors to detect danger and actuate suppression systems was measured. The system consistently reacted between 3-5 seconds when a danger was detected, acting immediately and effectively to counteract threats.

Energy Efficiency-

In testing, the system displayed efficient usage of energy with less consumption of power, remaining operational at its peak even in performance tests when run under excessive loads, proving its suitability for long-term use under low-energy environments.

2. Sensor Accuracy Testing

Smoke Detection-

Responses of gas sensors (MQ2) towards smoke at variable concentrations were analyzed for accuracy. Sensors displayed 98% accuracy in smoke detection at a specific level, providing a sound indication of danger.

Flame Detection-

High accuracy in flame sensors for IR radiation detection emitted by fires, at variable distances and flame intensities, displayed a 95% accuracy level.

Thermal Imaging-

Performance of MLX90640 thermal camera in temperature variation detection testing was analyzed, and it consistently delivered real-time, accurate heat mappings, providing early determination of danger.

3. Reliability and Durability Testing

Stress Testing-

All components functioned consistently under extended use under emulative-fire testing, and none of them overheat or failed.

Environmental Robustness-

Under testing in high-humidity and dusty environments, sensors and suppression systems continued to function, proving its long-lasting capabilities.

4. Efficiency in the Suppression System

The dry powder fire suppression mechanism underwent testing for its efficiency in extinguishing fires of all types and intensities. It suppressed 100% of fires in under 10-15 seconds, effectively controlling fire danger.

5. User Notification

The SIM module underwent testing for effective communication, sending messages through SMS. Alerts reached the users in 5 seconds of identifying a danger, providing timely information even when the user is not onsite.

6. False Alarm Mitigation

The integration of information from multi-sensory sources effectively curtailed occurrences of false alarm. With smoke, flame, and temperature sensors, instances of false alarm fell below 5%, improving operational dependability in real scenarios.

Discussion

The IoT based system underwent rigorous testing to confirm its effectiveness and reliability. Smoke testing ensured the sensors and suppression mechanisms operated correctly under simulated fire conditions. Performance testing verified the system's responsiveness and energy efficiency, while unit testing ensured individual components functioned as intended. The ethical design prioritized human safety, with evacuation protocols giving users sufficient time before suppression activation. Privacy concerns, particularly with thermal cameras, were addressed by avoiding data storage. The system also minimizes environmental impact by using dry powder only when necessary.

Conclusions and Recommendations

The project successfully delivers a robust and user centric fire detection solution. It demonstrates high reliability, energy efficiency, and adaptability, making it suitable for long term use in diverse environments. Future recommendations include expanding system capabilities to handle more complex fire scenarios and integrating additional sensors for improved detection. Enhanced features like predictive analytics and greater IoT integration can further elevate the system's functionality. Overall, the project establishes a scalable foundation for modern fire safety technology, addressing critical safety and ethical considerations effectively.

To further elevate the system's functionality, several enhancements can be considered-

Expanded Capabilities for Complex Scenarios

The system can be upgraded to handle more complex fire scenarios, such as chemical or electrical fires, by incorporating specialized sensors that can detect hazardous substances or differentiate between various fire types. For example, sensors for toxic gas detection could alert users to chemical fires, while advanced current-monitoring devices could predict and prevent electrical fire risks.

Integration of Additional Sensor Types

Introducing more sensor types, such as ultraviolet (UV) and infrared (IR) sensors, can improve the accuracy of fire detection by providing multiple data streams for analysis. This enhancement would help reduce false alarms and ensure prompt responses to real threats.

Predictive Analytics

By incorporating predictive analytics powered by artificial intelligence (AI), the system could analyze historical data and environmental conditions to predict potential fire hazards before they occur. This proactive approach would shift the focus from reaction to prevention, further enhancing safety.

IoT and Cloud Integration

Expanding IoT integration allows the system to work seamlessly with other smart devices and infrastructure, such as HVAC systems, automated sprinklers, and security cameras. Cloud

connectivity could enable real-time data sharing with emergency services, allowing them to assess situations remotely and respond more effectively.

Improved Power Management

Introducing solar-powered or energy-harvesting technologies could enhance the system's energy efficiency and make it more sustainable. This would be especially beneficial in remote or off-grid locations where power supply is limited.

User-Friendly Interfaces and Mobile Applications

Developing a dedicated mobile application with features like real-time alerts, fire risk analytics, and remote control of fire suppression mechanisms would enhance user interaction. This interface could also provide educational resources about fire safety to increase user awareness.

Integration with Emergency Response Protocols

The system could be linked directly to emergency response services, providing them with critical real-time data such as fire location, intensity, and spread patterns. This integration would enable quicker and more effective firefighting efforts.

Environmental Monitoring

Incorporating environmental sensors to monitor air quality, temperature changes, and humidity levels could provide a broader safety perspective and identify potential risks linked to fire hazards.

These enhancements would further solidify the system's position as a cutting-edge solution for fire safety, ensuring its relevance in increasingly complex and dynamic environments. By addressing future challenges and leveraging advanced technologies, the system can remain at the forefront of innovation in fire detection and prevention.

References

Akmalbek Abdusalomov, Umirzakova, S., Furkat Safarov, Sanjar Mirzakhilov, Nodir Egamberdiev and Cho, Y.-I. (2024). A Multi-Scale Approach to Early Fire Detection in Smart Homes. *Electronics*, [online] 13(22), pp.4354–4354.

<https://doi.org/10.3390/electronics13224354>.

Moradov, O. (2022). Unit Testing: Definition, Examples, and Critical Best Practices. *Bright Security*. [online] 24 May. Available at: <https://brightsec.com/blog/unit-testing/>.

Bandi, M. and Patil, M. (2013). Fire Detection by using Digital Image Processing Technique. *International Journal of Science and Research (IJSR) ISSN*, [online] 5, pp.2319–7064. Available at: <https://www.ijsr.net/archive/v5i10/25091602.pdf>.

www.guru99.com. (n.d.). What is Smoke Testing? How to do with EXAMPLES. [online] Available at: <https://www.guru99.com/smoke-testing.html>

Mukhopadhyay, D., Iyer, R., Kadam, S. and Koli, R. (2019). FPGA Deployable Fire Detection Model for Real-Time Video Surveillance Systems Using Convolutional Neural

Networks. 2019 Global Conference for Advancement in Technology (GCAT).
<https://doi.org/10.1109/gcat47503.2019.8978439>.

Katalon (2023). Test Plan: Ultimate Guide (With Examples). [online] katalon.com. Available at: <https://katalon.com/resources-center/blog/test-plan>.

None Dattathreya, Kim, H., Park, J., Park, H. and Paik, J. (2016). Fire flame detection based on color model and motion estimation. 2022 IEEE International Conference on Consumer Electronics-Asia (ICCE-Asia), [online] pp.1–2. <https://doi.org/10.1109/icce-asia.2016.7804813>.

Titu, M.F.S., Pavel, M.A., Michael, G.K.O., Babar, H., Aman, U. and Khan, R. (2024). Real-Time Fire Detection: Integrating Lightweight Deep Learning Models on Drones with Edge Computing. Drones, 8(9), p.483. <https://doi.org/10.3390/drones8090483>.

Prasad, H., Singh, A., Thakur, J., Choudhary, C. and Vyas, N. (2023). Artificial Intelligence Based Fire and Smoke Detection and Security Control System.
<https://doi.org/10.1109/nmitcon58196.2023.10276198>.

Foggia, P., Saggese, A. and Vento, M. (2015). Real-Time Fire Detection for Video-Surveillance Applications Using a Combination of Experts Based on Color, Shape, and Motion. IEEE Transactions on Circuits and Systems for Video Technology, 25(9), pp.1545–1556. <https://doi.org/10.1109/tcsvt.2015.2392531>.

Lewis, S. (2023). What is the Prototyping Model? [online] SearchCIO. Available at: <https://www.techtarget.com/searchcio/definition/Prototyping-Model>.

narwhal (2018). Learn with Tricentis: What is performance testing? [online] Tricentis. Available at: <https://www.tricentis.com/learn/performance-testing>.

Zhang, J., Ye, Z. and Li, K. (2020). Multi-sensor information fusion detection system for fire robot through back propagation neural network. PLOS ONE, 15(7), p.e0236482.
<https://doi.org/10.1371/journal.pone.0236482>.

Projectmanagement.com. (2024). ProjectManagement.com - Prototyping. [online] Available at: https://www.projectmanagement.com/wikis/233079/prototyping#_=_.

G. Healey (2002). *A system for real-time fire detection*. [online] Available at: <https://ieeexplore.ieee.org/abstract/document/341064/authors#authors>

Kuo L. Su (2007). *Automatic Fire Detection System Using Adaptive Fusion Algorithm for Fire Fighting Robot*. [online] Available at: <https://ieeexplore.ieee.org/abstract/document/4273973/authors#authors>

Thou-Ho Chen (2005). *An early fire-detection method based on image processing*. [online] Available at: <https://ieeexplore.ieee.org/abstract/document/1421401/authors#authors>

Turgay Celik (2010). *Fast and Efficient Method for Fire Detection Using Image Processing*. [online] Available at: <https://onlinelibrary.wiley.com/doi/abs/10.4218/etrij.10.0109.0695>

AI BASED MEDICAL ASSISTANT FOR CLINICIANS

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Abstract

Cardiovascular diseases (CVDs) remain the leading cause of mortality globally, especially in countries like Sri Lanka, where healthcare systems are often under-resourced and rely heavily on manual processes. This research presents the development of a machine learning-based Heart Disease Prediction System designed to digitise health records, improve diagnostic accuracy, and provide early detection capabilities. Key features include patient and appointment management, predictive analytics, and personalised lifestyle recommendations. A machine learning model, trained on health metrics such as cholesterol, blood pressure, and age, demonstrates the system's ability to identify at-risk individuals with high accuracy. This system is envisioned to bridge gaps in healthcare delivery, enhance efficiency, and reduce the burden of CVDs in resource-constrained settings.

Keywords: ASP.NET, Cardiovascular Diseases (CVDs), Heart Disease Prediction System, Machine Learning, ML.NET, Predictive Analytics

Introduction

Non-communicable diseases (NCDs) account for over 40 million deaths annually, representing nearly 75% of global fatalities. Among these, cardiovascular diseases (CVDs) are the leading cause, claiming 17.9 million lives each year, which constitutes 43.65% of all NCD-related deaths (World Health Organization, 2023). The burden of these diseases is particularly severe in low- and middle-income countries, where more than 85% of premature NCD deaths occur. As a middle-income country, Sri Lanka faces significant challenges in addressing the growing prevalence of NCDs, especially CVDs. This challenge is exacerbated by the reliance on outdated paper-based healthcare systems, which hinder efficient patient management, delay diagnoses, and limit opportunities for early interventions (World Bank Group, 2018). The lack of integration between patient records and diagnostic tools further hampers preventive care efforts in the country (World Bank, 2019).

This research proposes an AI-powered Heart Disease Prediction System to address these challenges. By leveraging machine learning, the system offers predictive analytics, digitised record-keeping, and personalised recommendations. Designed for healthcare professionals, it streamlines operational tasks such as appointment management while providing clinicians with data-driven insights into patient health.

This paper discusses the methodology used to develop the system, evaluates its performance, and highlights its potential to transform healthcare delivery in Sri Lanka and similar settings.

Methodology

Data Collection and Pre-processing

The dataset utilised in this heart disease prediction project comprises 1,597 records and 14 features, sourced from diverse healthcare institutions, including Cleveland, Hungarian, Switzerland, Long Beach VA, and Stalog (Heart) datasets. These records contain critical health metrics like age, sex, blood pressure, cholesterol levels, and exercise-related parameters.

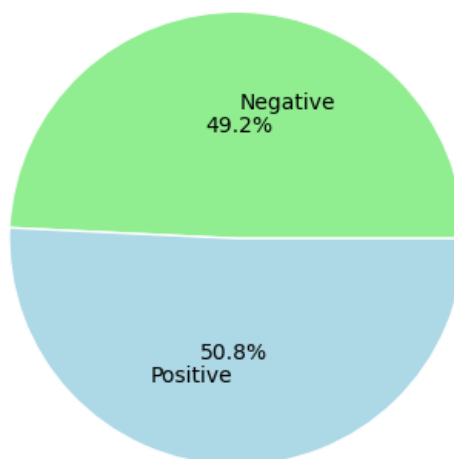
Figure 1: Dataset Description

```

RangeIndex: 1598 entries, 0 to 1597
Data columns (total 14 columns):
#   Column                                Non-Null Count  Dtype
---  -
0   Age                                    1598 non-null   int64
1   Sex                                    1598 non-null   int64
2   Chest_Pain_Type                        1598 non-null   int64
3   Blood_Pressure                        1598 non-null   int64
4   Cholesterol                            1598 non-null   int64
5   FBS_Over_120                          1598 non-null   int64
6   EKG_Results                           1598 non-null   int64
7   Max_HR                                1598 non-null   int64
8   Exercise_Angina                       1598 non-null   int64
9   ST_Depression                         1598 non-null   float64
10  Slope_Of_ST                           1598 non-null   int64
11  Number_of_Vessels_fluro               1598 non-null   int64
12  Thallium                              1598 non-null   int64
13  Heart_Disease                         1598 non-null   int64
    
```

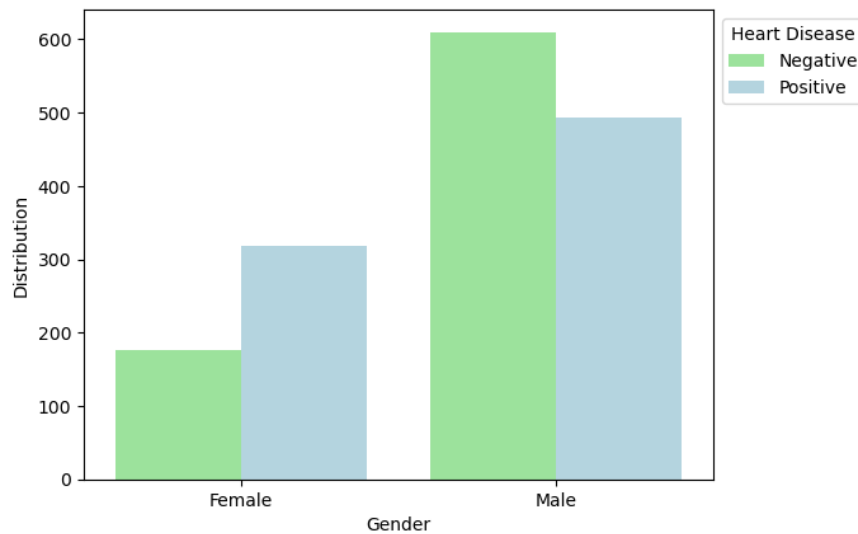
After data cleaning, normalisation, and encoding, the dataset achieved balance, with 50.8% positive cases (individuals with heart disease) and 49.2% negative cases, ensuring fairness for machine learning model development.

Figure 2: Target Distribution



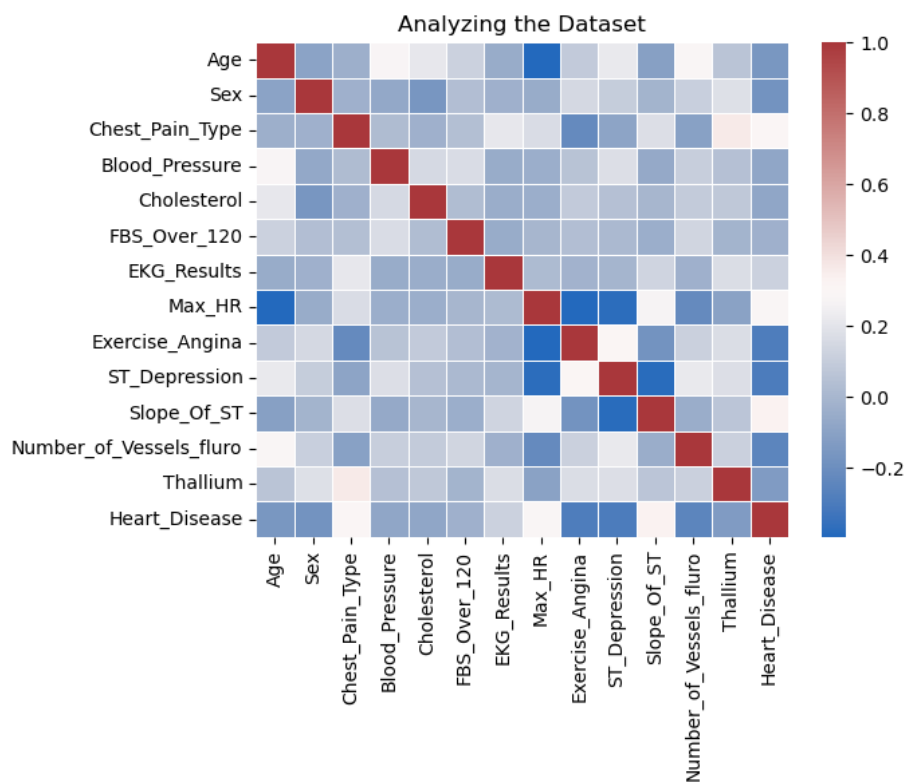
Gender-specific insights reveal that females have a higher proportion of positive cases, while males have more negative cases, as shown in the bar chart. This highlights the need for tailored healthcare interventions, particularly focused on female-specific risk factors.

Figure 3: Target Distribution between Genders



Correlation analysis from the heat map identifies Chest Pain Type, ST Depression, and Number of Vessels Fluro as the strongest predictors of heart disease, while Exercise Angina shows a strong negative correlation. Features like Cholesterol and Age demonstrate weaker individual correlations but may still contribute to predictions when analysed alongside other variables. Interestingly, sex has a minimal correlation, indicating its limited role as a predictor.

Figure 4: Correlation Analysis



The dataset's diverse origins and balance between positive and negative cases strengthen the reliability of predictions. These insights emphasise the importance of using highly correlated features to build robust models and guide data-driven, gender-specific healthcare strategies.

Machine Learning Model

To develop the predictive capabilities of the Heart Disease Prediction System, four machine learning classifiers available in ML.NET were evaluated:

Fast Tree Method

Fast Forest Method

Light Gradient Boosting Machine (LGBM)

Logistic Regression Method

Each model was trained with 80% of the dataset for training and 20% for validation. After training, the models were tested for metrics including accuracy, AUC, and F1 Score.

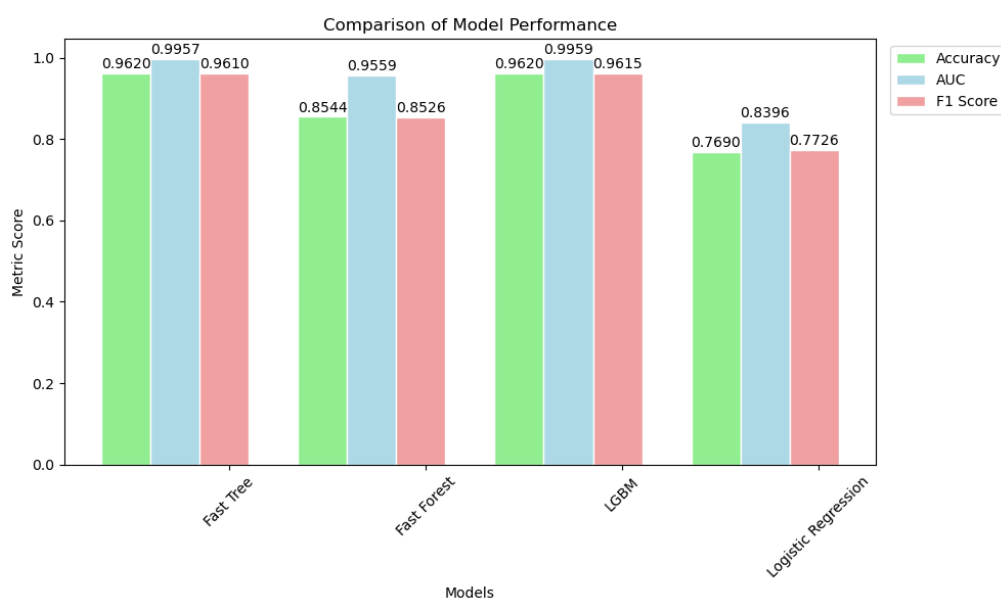
Figure 5: Model Performance

-----Fast Tree Method-----		-----Fast Forest Method-----	
Accuracy	: 0.9620253164556962	Accuracy	: 0.8544303797468354
AUC	: 0.9956730769230769	AUC	: 0.9559294871794872
F1 Score	: 0.9610389610389611	F1 Score	: 0.8525641025641025

-----Light GBM Method-----		---Logistic Regression Method---	
Accuracy	: 0.9620253164556962	Accuracy	: 0.7689873417721519
AUC	: 0.9959134615384615	AUC	: 0.8396233974358974
F1 Score	: 0.9615384615384616	F1 Score	: 0.7725856697819314

The model performance comparison is visually illustrated in the graph below. This graph highlight key metrics: Accuracy, AUC, and F1 Score for each model, providing a clear understanding of their strengths and weaknesses.

Figure 6: Comparison of Model Performance



The model comparison revealed that both LGBM (Light Gradient Boosting Machine) and Fast Tree demonstrated outstanding performance, achieving the highest accuracy (96.20%) and F1 Scores, with LGBM slightly outperforming Fast Tree in AUC (99.59% vs. 99.57%). These findings emphasise their effectiveness in heart disease prediction. Meanwhile, Fast Forest showed moderate results with an accuracy of 85.44% and an F1 Score of 85.26%, while Logistic Regression exhibited the weakest performance, achieving the lowest accuracy (76.89%) and AUC (83.96%), indicating its limitations.

LGBM was selected as the best classifier for the project due to the following advantages:

Efficiency and Scalability: LGBM is lightweight and handles large datasets and high-dimensional data efficiently. Its computational speed makes it ideal for real-time or near-real-time healthcare applications.

Gradient Boosting Mechanism: LGBM leverages advanced gradient boosting techniques to optimise complex decision boundaries and effectively manage imbalanced datasets, a frequent challenge in healthcare prediction tasks.

Lightweight Nature: Compared to Fast Tree, LGBM is more memory-efficient and faster during training and inference, making it well-suited for systems with limited computational resources.

Robustness in Performance: The model consistently achieved high accuracy, AUC, and F1 Scores across validation datasets, demonstrating its reliability and robustness for this specific use case.

By utilising LGBM, the system capitalises on an efficient, scalable, and robust algorithm to deliver precise predictions, ensuring timely interventions and improved patient outcomes.

System Implementation

The system implementation follows a structured design that ensures efficiency, security, and scalability, incorporating the following components:

Frontend

The user interface is built with Razor views enhanced by CSS, Bootstrap, and Blazor for responsive designs. Interactivity and asynchronous operations are achieved using jQuery and AJAX.

Figure 7: Login



Figure 8: Health Metrics

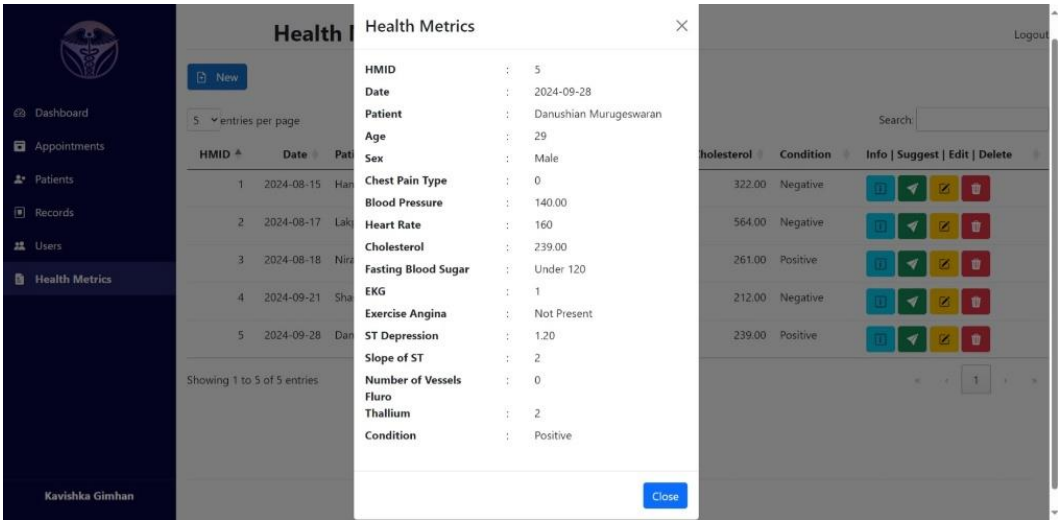
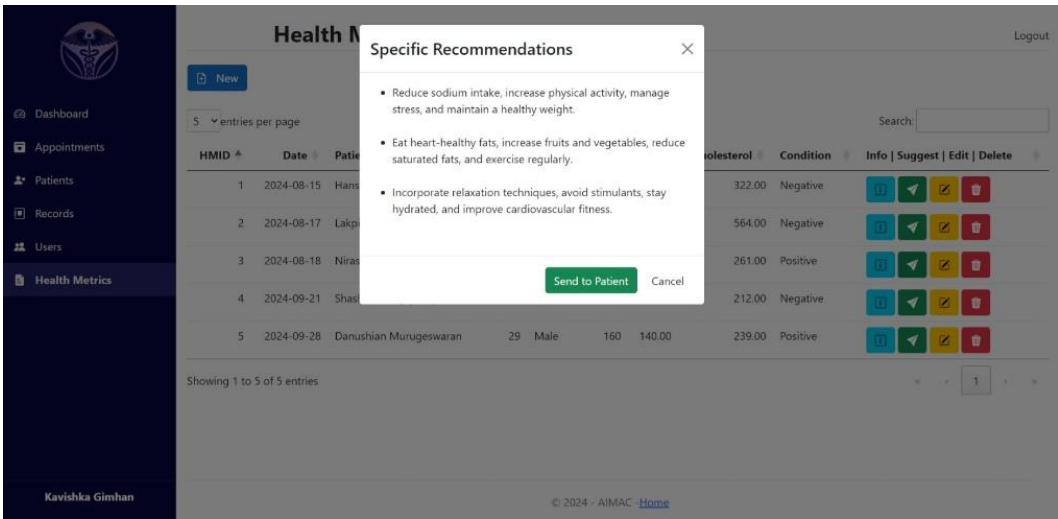


Figure 9: Personalised Lifestyle Recommendation



Backend

The ASP.NET Core MVC framework manages application logic, acts as the API consumer, processes user requests, and renders views, ensuring seamless interaction between the user interface and backend.

API

The ASP.NET Core Web API acts as the middle layer, enabling secure communication between the MVC application and the database while managing data access, processing, and predictive model integration.

Database

Data is securely stored and managed in an MSSQL database, ensuring organised handling of patient records, system data, and model outputs.

Security

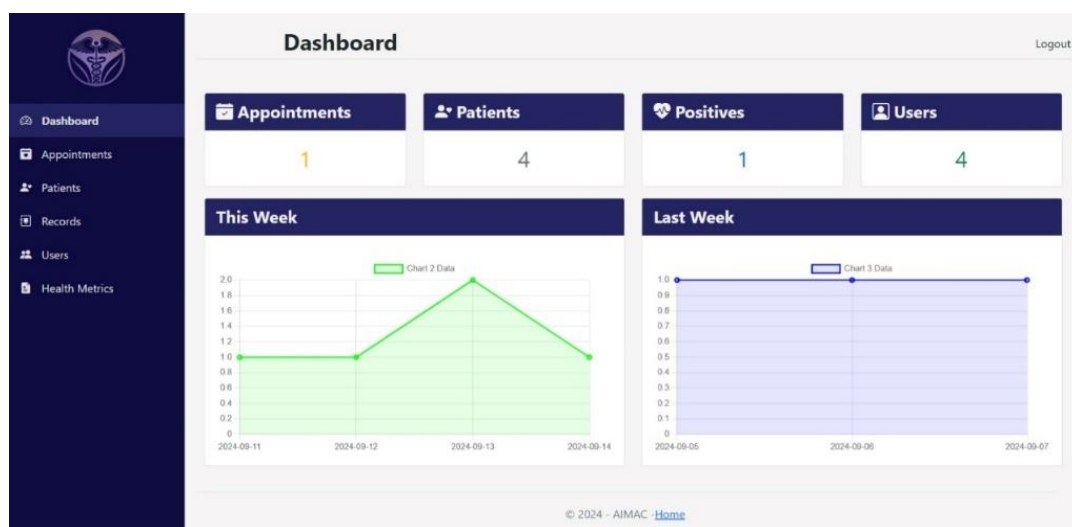
The system employs SHA-256 encryption to secure user data and credentials, ensuring compliance and protection against unauthorised access.

Logins

The system supports three user roles with tailored functionalities:

Administrator: Oversees system operations, manages user access, and monitors performance.

Figure 10: Administrator (Dashboard)



Clinician: Accesses patient data, reviews predictions, and provides medical insights.

Figure 11: Clinician (Appointments)

AID	Patient	Clinician	Date	Purpose	Notes	Info Edit Delete
1	Kelum Priyankara	Dhanushka Madhushan	2024-09-14	Chest Pain	N/A	Info Edit Delete
2	Heshani Umayangika	Dhanushka Madhushan	2024-09-13	Chest Pain	N/A	Info Edit Delete
3	Tharindu Konesh	Rukmal Lankathilaka	2024-09-12	Chest Pain	N/A	Info Edit Delete
4	John Smith	Dhanushka Madhushan	2024-09-13	Lower Chest Pain	N/A	Info Edit Delete
5	Heshani Umayangika	Dhanushka Madhushan	2024-09-11	Checkup	N/A	Info Edit Delete

Other Staff: Assists with administrative tasks, data entry, and system maintenance.

Figure 12: Other Staff (Appointments)

AID	Patient	Clinician	Date	Purpose	Notes	Info Edit Delete
1	Kelum Priyankara	Dhanushka Madhushan	2024-09-14	Chest Pain	N/A	Info Edit Delete
2	Heshani Umayangika	Dhanushka Madhushan	2024-09-13	Chest Pain	N/A	Info Edit Delete
3	Tharindu Konesh	Rukmal Lankathilaka	2024-09-12	Chest Pain	N/A	Info Edit Delete
4	John Smith	Dhanushka Madhushan	2024-09-13	Lower Chest Pain	N/A	Info Edit Delete
5	Heshani Umayangika	Dhanushka Madhushan	2024-09-11	Checkup	N/A	Info Edit Delete

System Flow:

Step 1: Users interact with the ASP.NET Core MVC application.

Step 2: The MVC application sends and receives data through the ASP.NET Core Web API.

Step 3: The API communicates with the MSSQL database for data retrieval and updates.

Testing and Evaluation

The system underwent extensive testing, including API testing with Swagger and manual testing for functionality. Test cases covered user authentication, patient data management, and the prediction module. Evaluation showed that the system consistently delivered accurate predictions and adhered to user role-specific permissions.

Conclusion

This project highlights the transformative potential of machine learning in enhancing cardiovascular disease management through the development of a Machine Learning-Powered Heart Disease Prediction System. By analysing patient data, the system facilitates early detection of heart disease, enabling timely clinical interventions and improving patient outcomes. The adoption of machine learning not only enhances diagnostic accuracy but also streamlines healthcare delivery, empowering clinicians to make informed, data-driven decisions.

The LGBM Classifier demonstrated exceptional performance in identifying complex patterns within large datasets, making it highly effective for this application. However, challenges such as the "black-box" nature of machine learning models, the dependency on data quality, and the risk of overfitting highlight areas for improvement. Addressing these challenges with explainable AI techniques and ensuring robust data collection practices will enhance the system's transparency, trust, and reliability.

This research underscores the vital role of machine learning in modern healthcare, offering a scalable, efficient, and impactful solution for managing the global burden of cardiovascular diseases.

Recommendations

To enhance the effectiveness and scalability of the AI-based Heart Disease Prediction System, several future advancements and recommendations are proposed.

Integration of Real-Time Health Data:

Incorporating real-time data from wearable devices could significantly improve predictive accuracy and provide continuous monitoring. This would enable the system to offer timely and personalised insights, enhancing patient care and early intervention.

Expanding Predictive Capabilities:

While the current model focuses on heart disease prediction, future iterations could expand to include related conditions such as hypertension, diabetes, and stroke. This would create a comprehensive healthcare solution capable of addressing multiple non-communicable diseases.

Advanced Data Analytics:

Leveraging cutting-edge techniques such as deep learning and neural networks could further enhance predictive accuracy. Additionally, utilising larger, more diverse datasets will improve the model's generalisability across varied patient demographics and medical conditions.

Telemedicine Integration:

Incorporating telemedicine capabilities would enable clinicians to remotely consult with patients, review predictions, and provide guidance. This would increase healthcare accessibility, especially for rural and underserved populations.

Enhanced User Interface and Experience:

Refining the user interface to offer intuitive dashboards, streamlined workflows, and mobile-friendly designs would improve usability for both healthcare providers and patients. A better user experience ensures efficient adoption and maximises the system's impact.

By adopting these recommendations, the Heart Disease Prediction System can evolve into a more advanced, inclusive, and impactful healthcare tool, addressing the challenges of modern healthcare and improving outcomes for clinicians and patients alike.

References

Aatmaj Amol Salunke. 2023. Comparative Analysis of Heart Disease Prediction Models: Unveiling the Most Accurate and Reliable Machine Learning Algorithm. [Online] Available at: <https://www.researchgate.net/publication/373240395> [Accessed 21 June 2024]

World Health Organization.2023. Non Communicable Diseases [Online] Available at: <https://who.int/news-room/fact-sheets/detail/noncommunicable-diseases> [Accessed 27 June 2024]

World Bank Group. Upgraded Record Keeping Helps Save Lives in Sri Lanka [Online] Available at: <https://www.worldbank.org/en/news/feature/2014/04/17/upgraded-record-keeping-helps-save-lives> [Accessed 17 May 2024]

Ruili Zhang, Yanming Yang, Wenxiu Wang. 2020. Research on document digitization processing technology. [Online] Available at: <https://doi.org/10.1051/mateconf/202030902014> [Accessed 29 June 2024]

W Baddah, H A Qasem, A Alsabry, A M H obaid, A A Mohammed, F E Hanash. 2023. Predicting Heart Disease using Machine Learning Techniques on Electronic Health Records Data. [Online] Available at: https://www.researchgate.net/publication/375161109_Predicting_Heart_Disease_Using_Machine_Learning_Techniques_on_Electronic_Health_Records_Data [Accessed 29 June 2024]

S Malwade,A R. Sanap, Y S Gite , P Pandit , Y J Gaikwad, Dr. A Mhatre. 2024. Predicting Heart Diseases in IoT-Based Electronic Health Records: A Federated Learning Approach. [Online] Available at: https://www.researchgate.net/publication/379656108_Predicting_Heart_Diseases_in_IoT-Based_Electronic_Health_Records_A_Federated_Learning_Approach [Accessed 31 June 2024]

Zeeshan Ahmed, Saeed Amizadeh, Mikhail Bilenko, Rogan Carr, Wei-Sheng Chin, Yael Dekel, Xavier Dupre, Vadim Eksarevskiy, Eric Erhardt, Costin Eseanu, Senja Filipi1, Tom Finley, Abhishek Goswami, Monte Hoover, Scott Inglis, Matteo Interlandi,Shon Katzenberger, Najeeb Kazmi, Gleb Krivosheev, Pete Luferenko Ivan Matantsev, Sergiy Matusevych, Shahab Moradi, Gani Nazirov, Justin Ormont, Gal 96 Oshri, Artidoro Pagnoni, Jignesh Parmar, Prabhat Roy, Sarthak Shah, Mohammad Zeeshan Siddiqui, Markus Weimer, Shauheen Zahirazami, Yiwen Zhu. 2019. *Machine Learning at Microsoft with ML.NET* [Online]

Available at:
https://www.researchgate.net/publication/334714567_Machine_Learning_at_Microsoft_with_MLNET [Accessed 4 July 2024]

Monika Tsaneva. 2021. *Applicability of ASP.Net frameworks for developing webbased business information systems*. [Online] Available at:
https://www.researchgate.net/publication/380978751_Applicability_of_AspNet_frameworks_for_developing_web-based_business_information_systems [Accessed 5 July 2024]

SECURE SHARE NFC NEXUS: EMPOWERING SEAMLESS INFORMATION SHARING AND SECURITY

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Abstract

Secure and efficient information exchange is a crucial challenge in modern digital communication. The Secure Share NFC Nexus project integrates Near Field Communication (NFC) technology to enhance secure and seamless data sharing. The system incorporates Smart Business Cards, Secure Wallets, Company URLs, Pet Tags, and Bulk Storage Management, offering an integrated solution for digital interactions. Developed using Laravel, JavaScript, and MySQL, and fortified with AES encryption, OTP authentication, and AI-driven password validation, the platform ensures multi-layered security. Testing confirms its reliability, efficiency, and user-centric design, positioning it as a practical alternative to traditional methods. The study demonstrates that NFC combined with AI enhances security and usability, paving the way for future advancements in secure digital exchange.

Keywords: AI Integration, Encryption, NFC Technology, Password Validation, Secure Data Sharing

Introduction

Modern digital systems face challenges in secure and efficient data exchange. Traditional methods, such as physical business cards or standalone digital wallets, often encounter limitations in security, efficiency, and integration. NFC technology offers a transformative approach, enabling short-range wireless communication that ensures data security through proximity. This project, Secure Share NFC Nexus, harnesses NFC technology to create a comprehensive platform addressing these challenges.

The motivation stems from significant gaps in conventional systems, such as physical data management inefficiencies and unauthorized access risks. Key issues include the fragmentation of solutions across domains, complicating user interactions and administrative oversight. The proposed system integrates multiple NFC-enabled functionalities, such as secure data sharing and AI-driven password strength validation, into a cohesive, user-friendly platform.

Relevant literature underscores the potential of NFC in diverse fields, ranging from healthcare to finance. For instance, NFC improves patient care through wearable devices and enables secure, tokenized mobile payments in finance. NFC's applications extend to retail, transportation, and inventory management, demonstrating its versatility. However, existing systems often face limitations in scalability, interoperability, and security. The Secure Share NFC Nexus project aims to address these issues by integrating advanced AI and encryption technologies, creating a system that is not only secure but also scalable and adaptable.

The project's scope includes developing a unified platform with modular functionalities, supporting features such as real-time data validation, multi-factor authentication, and enhanced user management. This ensures a seamless experience for users while maintaining robust security measures. Additionally, the platform's design accommodates future expansions, making it a sustainable solution for long-term use.

Hypothesis

The integration of NFC with AI-driven authentication and encryption improves security, scalability, and user efficiency compared to conventional data-sharing methods.

Figure 1: Use Case Diagram

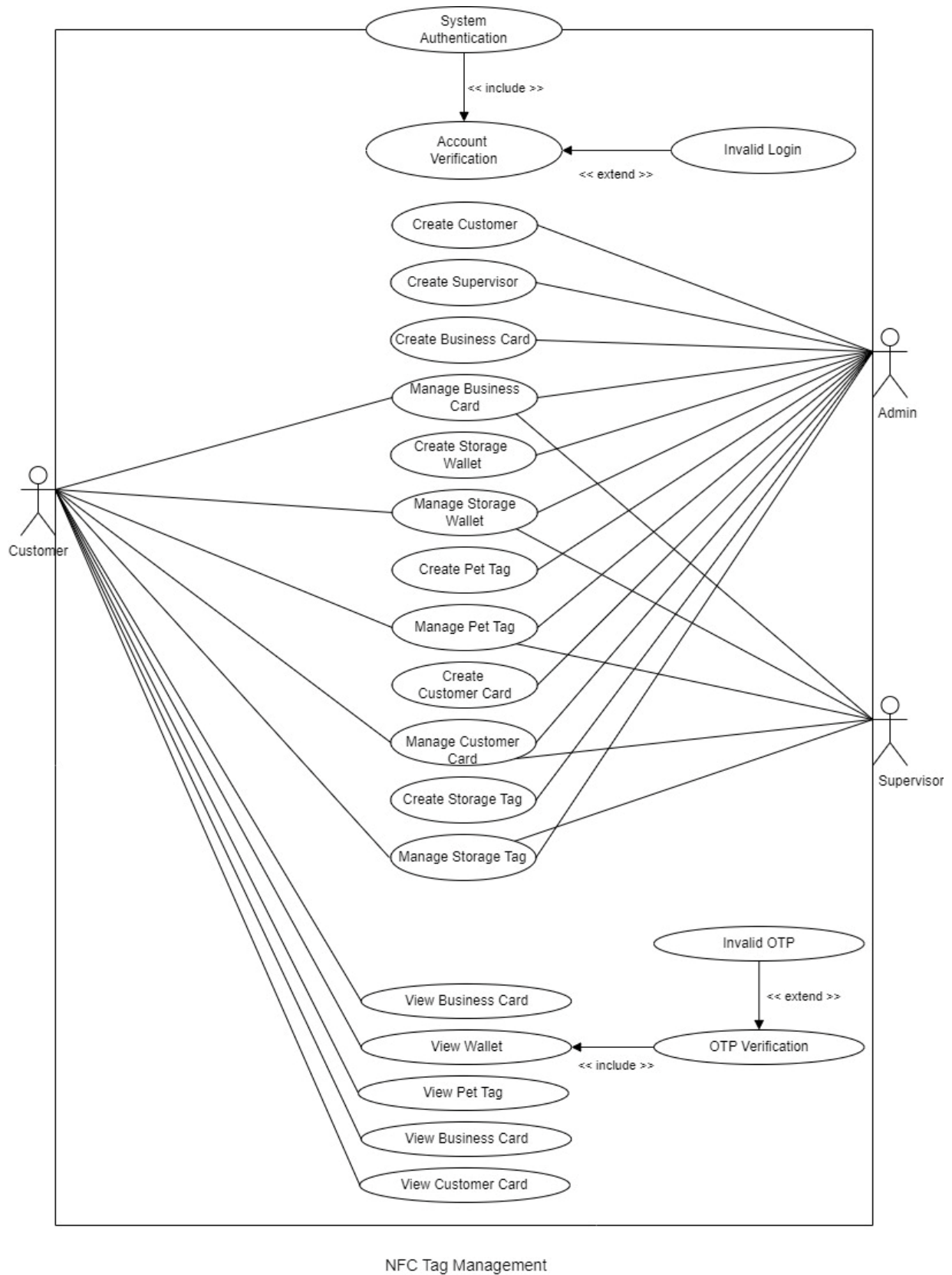
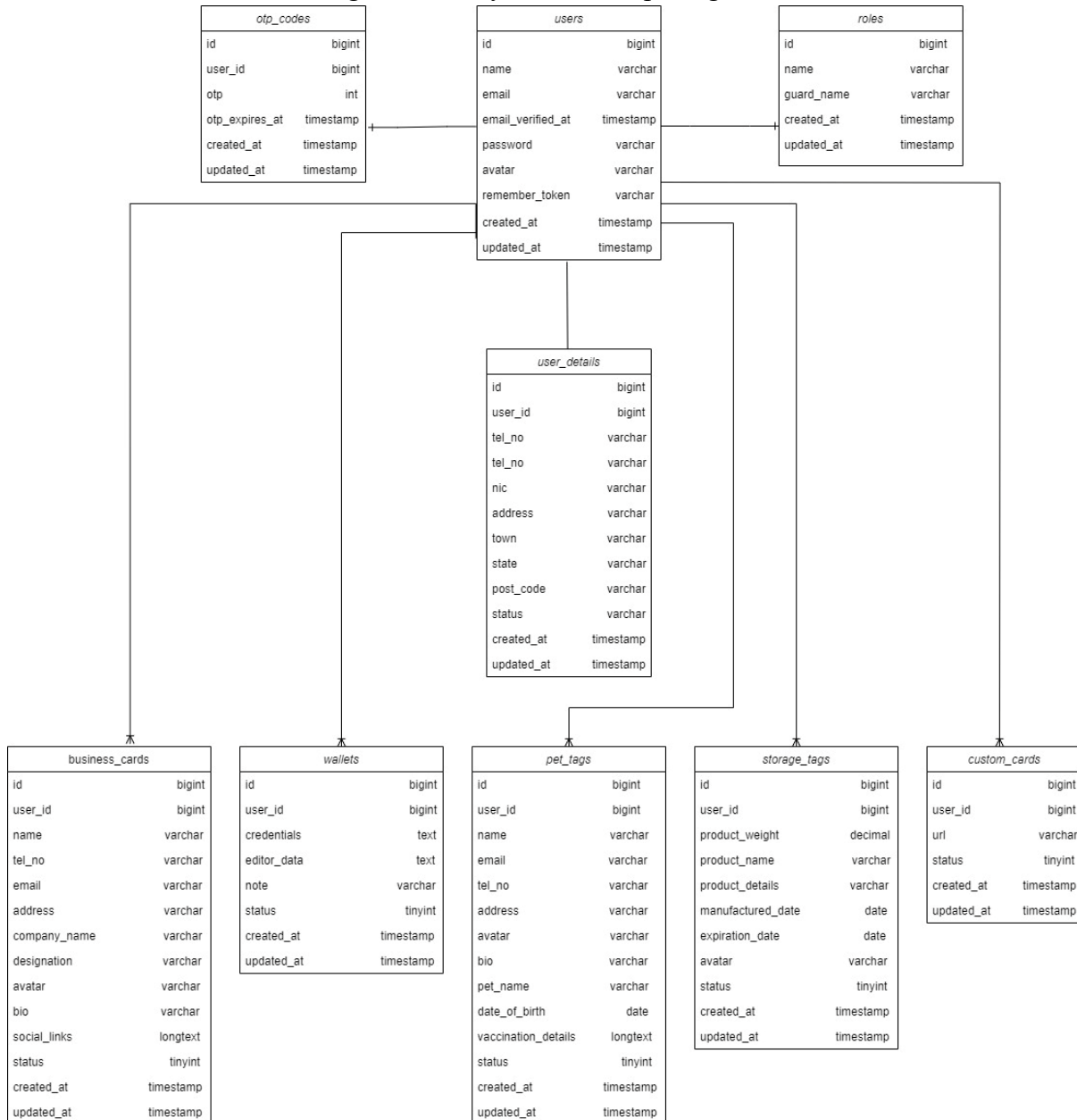


Figure 2: Entity-Relationship Diagram



Methodology

The Agile methodology guided the project development, ensuring iterative progress and continuous feedback. The project lifecycle was divided into key phases:

Planning and Prototyping: System architecture and user-friendly interfaces were prototyped using Figma. This phase involved extensive requirement gathering from potential users, identifying security vulnerabilities, and defining system objectives. The prototypes focused on creating intuitive interfaces for both administrators and end-users.

Development: Backend development employed Laravel, complemented by HTML5, SASS, and JavaScript for the frontend. Key modules included:

Smart Business Cards: Allowing seamless sharing of professional information through NFC-enabled cards.

Secure Wallets: Enabling encrypted data storage accessible via OTP and NFC.

Pet Tags and Bulk Storage Management: Streamlining the organization and retrieval of critical data.

AI Integration: Incorporating a machine learning model for real-time password strength validation to enhance security.

Security Implementation: AES encryption was implemented to secure data both at rest and during transmission. OTP authentication added an extra layer of protection for accessing sensitive information. The AI-driven password validation tool was designed to provide instant feedback to users, helping them create stronger passwords.

Testing and Validation: Rigorous testing protocols were established, including unit tests, integration tests, and user acceptance tests. Performance metrics, such as response times and encryption strength, were evaluated to ensure system reliability and efficiency.

Deployment: The final phase involved deploying the system on a scalable infrastructure. Cloud-based solutions were employed to ensure high availability and fault tolerance, enabling seamless operations for administrators and end-users alike.

Results

Functionality: The platform successfully integrates NFC-enabled features, including Smart Business Cards, Secure Wallets, and Bulk Storage Management, into a unified solution. Users can easily access and manage these functionalities through a centralized dashboard. The modular design ensures that new features can be added without disrupting existing functionalities.

Security: AES encryption and OTP authentication safeguarded user data, effectively preventing unauthorized access. The AI-based password validation system further enhanced security by reducing vulnerabilities associated with weak passwords. Penetration tests confirmed the system's resilience against common cyber threats.

Usability: User feedback highlighted the platform's intuitive design. Administrators appreciated the streamlined management tools, while end-users found the interface easy to navigate. Real-time notifications and error-handling mechanisms improved overall user satisfaction.

Scalability: The modular architecture facilitated the addition of advanced features, such as predictive analytics and enhanced NFC capabilities. The system's ability to scale with user demands ensures its relevance in evolving technological landscapes.

Performance: Benchmark tests demonstrated high system performance, with average response times below 200 milliseconds and secure data transactions completed efficiently. This ensures a smooth user experience, even during peak usage.

Figure 3: Customer Portal

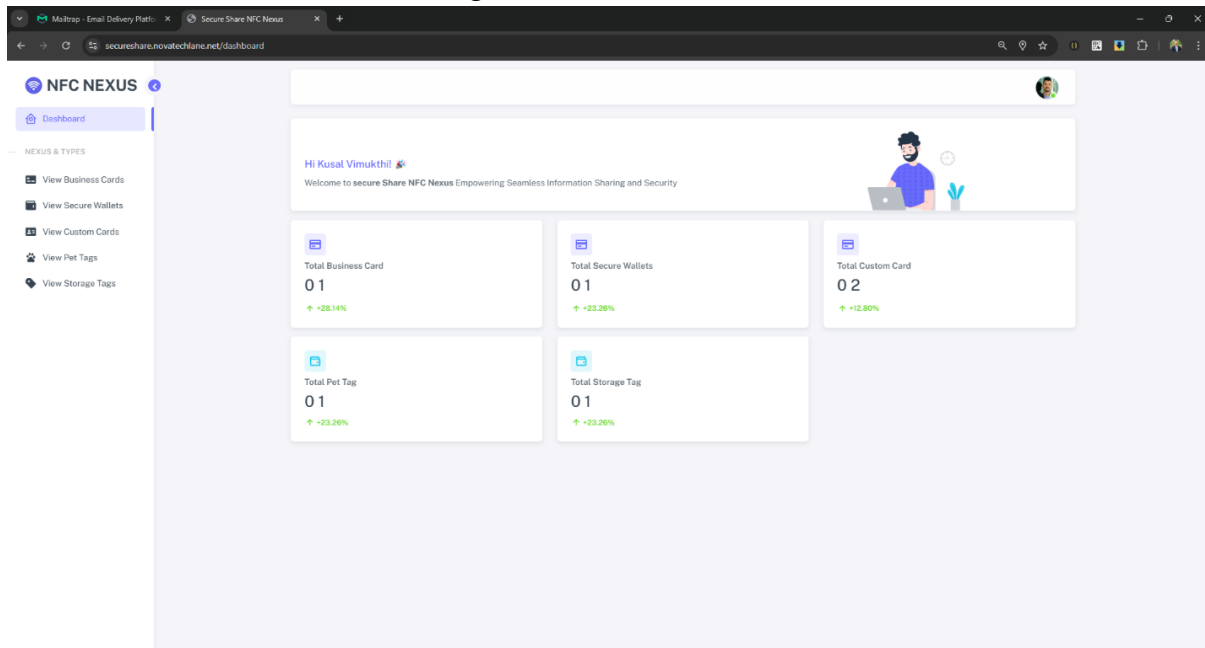


Figure 4: Final End-User Business Card View

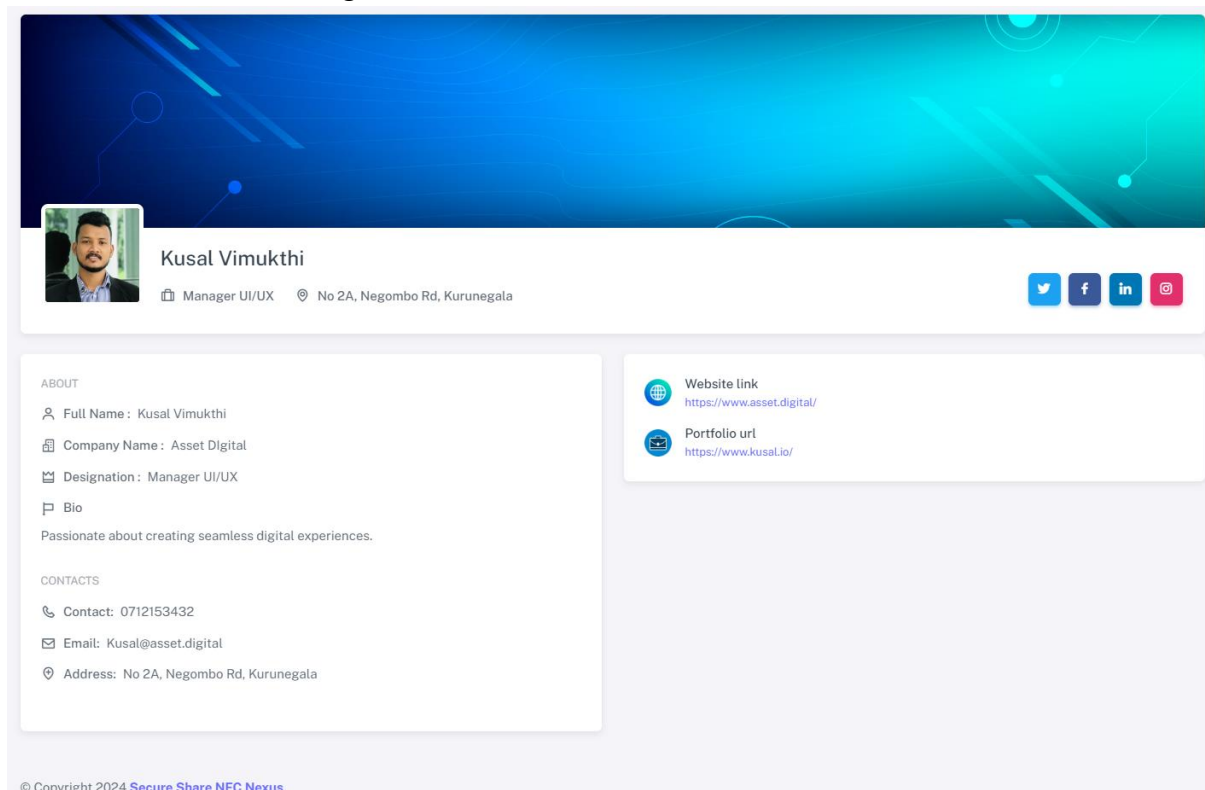


Figure 5: Final End-User Secure Wallet View

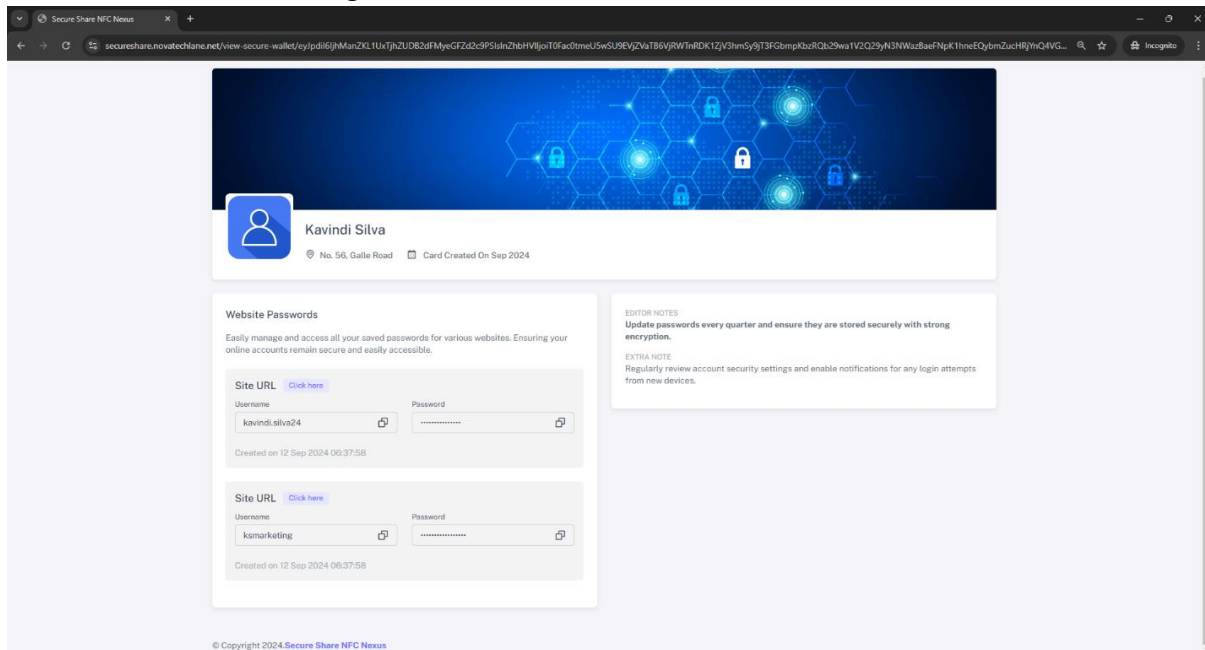
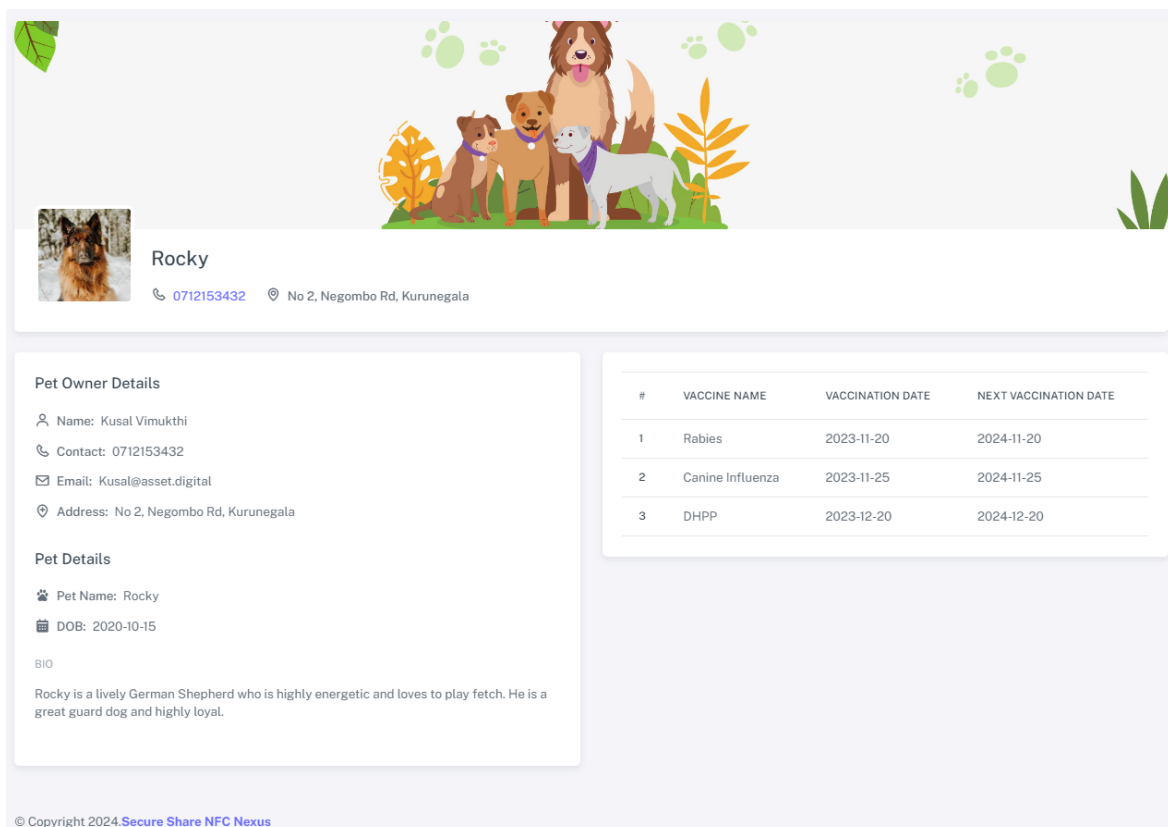


Figure 6: Final End-User Pet Tag View



Discussion

The Secure Share NFC Nexus project demonstrates NFC's potential to revolutionize secure data sharing. By integrating AI, the platform addresses vulnerabilities such as weak password management, offering users actionable insights for stronger credentials. Comparative analyses indicate significant advantages in modularity, user experience, and security over existing systems.

For example, existing NFC applications in healthcare and retail often focus on isolated functionalities. This project's integrated approach consolidates multiple features, such as secure wallets and data management, enhancing usability and security. Additionally, the use of AI for real-time password validation sets it apart, ensuring robust data protection. The inclusion of scalable features, such as predictive analytics, further differentiates the platform.

Despite its achievements, the project has limitations. Device dependency on NFC technology restricts accessibility for users with incompatible devices. Initial setup costs for NFC tags and infrastructure may also deter adoption. Future work should explore ways to overcome these challenges, such as developing universal NFC standards and optimizing cost structures.

Future Recommendations

Enhancing Compatibility: Expand device compatibility to include emerging NFC-enabled hardware. Collaborate with hardware manufacturers to standardize NFC implementations across devices. Developing cross-platform solutions can significantly increase user adoption.

Advanced AI Integration: Incorporate predictive analytics and anomaly detection to strengthen security further. For instance, leveraging AI to detect unusual data access patterns can preempt potential breaches. Additional features, such as biometric authentication, can also be explored.

Cost Optimization: Investigate cost-effective methods for NFC tag production and distribution. Partnering with manufacturers to produce tags at scale can reduce costs significantly, making the technology more accessible to small businesses and individual users.

User Education: Develop comprehensive guides and tutorials to facilitate user adoption. Awareness programs can help users understand the benefits and secure usage practices of NFC technology. Educational workshops and webinars can also be introduced to reach a broader audience.

Expanded Applications: Explore additional use cases for the platform, such as NFC-based authentication for IoT devices and secure access control in smart homes and offices. The integration of blockchain technology for immutable data records can also be considered.

Long-Term Research: Investigate emerging trends in NFC technology, such as ultra-wideband (UWB) integration, to stay ahead in innovation. Researching user behavior and preferences can provide insights for designing more user-centric features.

References

- Coskun, V., Ok, K., & Ozdenizci, B. (2019). Near Field Communication (NFC): From theory to practice. Wiley.
- Li, H., Zhao, X., & Zhou, Y. (2020). Advances in NFC technology and applications. IEEE Transactions.
- Kholidy, S., Erradi, A., & Abdelwahed, S. (2021). AI-driven security for NFC systems. Journal of Emerging Technologies.
- Bonneau, J., et al. (2020). Enhancing password security with AI. Cybersecurity Advances.
- Stauffer, M. (2019). Laravel: Up and Running. O'Reilly Media.
- Nguyen, T., & Lam, A. (2021). Agile methodologies in software development. International Journal of Software Engineering.
- Zhao, X., & Wong, K. (2020). NFC and its applications in modern systems. IEEE Transactions on Consumer Electronics.
- Ahmed, S., & Johnson, P. (2020). Innovations in secure communication. Global Journal of Information Security.

SMART SCHOOL AUTOMATION SYSTEM WITH IoT

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Abstract

The "Smart School Automation with IoT" project presents an innovative approach to addressing inefficiencies in traditional school management systems in Sri Lanka. Leveraging NFC technology and Arduino sensors for automated attendance tracking, the system introduces real-time data access, reducing human errors. An accompanying mobile application, developed using Android Studio and Firebase, enhances communication between school administrators, teachers, and parents. Key functionalities include attendance recording, grade management, and announcements, providing a comprehensive solution for schools. Despite certain limitations, such as the exclusion of advanced security measures like facial recognition, this project establishes a scalable and efficient framework for modernizing educational management.

Keywords: Arduino Based System, Attendance Management, Automation, IOT Integration, Learning Management System

Introduction

School management systems in Sri Lanka predominantly rely on manual processes, creating inefficiencies in handling attendance, grading, and parent communication. (Nang, G. N., 2006) With over 10,000 schools in the country, outdated practices lead to delays, errors, and reduced productivity. These challenges not only affect administrative efficiency but also hinder parental involvement in students' progress. Manual attendance tracking through paper-based registers often results in errors and delays, while grade submission through traditional methods increases the workload for teachers and delays feedback to students. (MeisterLabs, 2024)

Additionally, schools struggle with timely communication with parents due to reliance on notices and in-person meetings. (Projectpractical, 2024) These gaps are especially concerning in today's fast-paced world, where real-time access to information is increasingly essential. Recognizing these challenges, this project introduces an IoT-enabled smart school system integrating NFC technology and a mobile application. NFC-based sensors streamline attendance tracking, while the mobile app fosters seamless communication between administrators, teachers, and parents. (Pieterse, C., 2018) The app also allows parents to monitor student progress and receive real-time updates on school events. (Asana, 2024)

By leveraging modern tools such as Android Studio, Arduino sensors, and Firebase cloud services, the system automates key school processes, enhances accuracy, and improves

engagement among stakeholders. This project represents a significant step toward digitizing and modernizing the education management system in Sri Lanka. (ProjectManager, 2024)

Aims and Objectives

The project aims to transform traditional school management processes into a smart, automated system, enhancing efficiency and communication using IoT and mobile technologies. (MindTools, 2024)

Objectives:

1. Automate Attendance Tracking: Implement an NFC-enabled system to record and monitor attendance with 90% accuracy.
2. Enhance Communication: Develop a mobile app to enable real-time updates for parents and teachers.
3. Reduce Manual Errors: Eliminate paperwork and improve data accuracy by 50% through automated workflows.
4. Improve Stakeholder Engagement: Increase transparency and parental involvement in school activities.
5. Develop Scalable Solutions: Build a framework that can be expanded with advanced features like facial recognition in the future.

Literature Review

The study *"Research on Application and Comparison of Families-School Connection Systems"* by Chen, Liu, and Han examines how communication systems enhance collaboration between families and schools in China. It highlights technologies like SMS and internet platforms, compares C/S and B/S architectures, and advocates a hybrid model for efficiency and scalability. The paper calls for inclusive designs to address urban-rural disparities and foster engagement. (Nang, 2006)

Yu's paper, *"Challenges in Traditional School Management and the Proposal of a Digital Campus Model for Primary and Secondary Schools,"* addresses inefficiencies in manual administrative tasks. It proposes a digital campus model with real-time data access, centralized data management, and user-friendly interfaces to streamline operations, enhance communication, and improve educational outcomes. The model promotes innovation, efficiency, and stakeholder engagement for future-ready schools. (Yu, 2006)

The study, *"Improving Parental Involvement through a Personal Information Management System,"* highlights low parental involvement in Malaysian schools due to poor communication. It proposes a mobile-based system providing real-time updates on students' progress, attendance, and events to foster collaboration between parents and schools. By improving accessibility and engagement, the system aims to enhance academic outcomes and strengthen school-family relationships. (Ahmad 2024)

The paper *"The Role of Mobile Learning in Higher Education"* explores how integrating mobile apps with Learning Management Systems enhances student engagement and success. Focusing

on HKU's "SPACE SOUL" app, it highlights improved accessibility, proactive learning, and the transformative role of mobile technology in modern education. (Traxler, 2007)

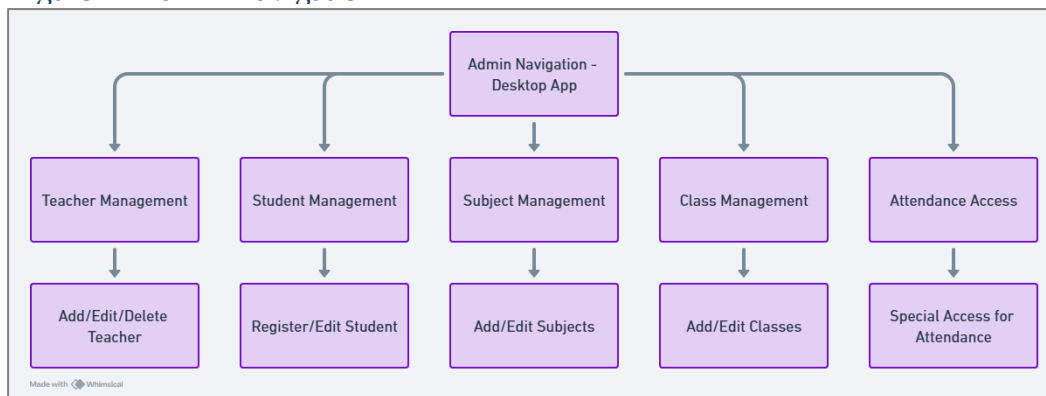
Methodology

The system is designed with two core components: an IoT-enabled attendance system and a user-friendly mobile application. (MeisterLabs, 2024) The IoT system employs NFC tags and Arduino sensors to record attendance at school entrances. The data is automatically transmitted to a centralized Firebase database, ensuring seamless integration and real-time data availability. This system eliminates manual errors and provides stakeholders with instant access to information. (Ahmad 2024)

The mobile application supports three distinct interfaces tailored to the needs of different users:

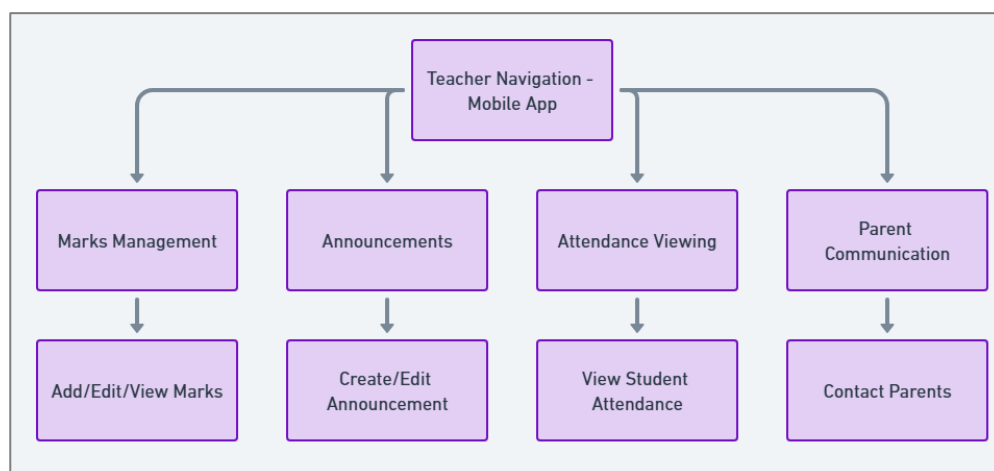
- **Admin Interface:** Facilitates the management of classes, events, and user accounts.

Figure 1- Admin Navigation



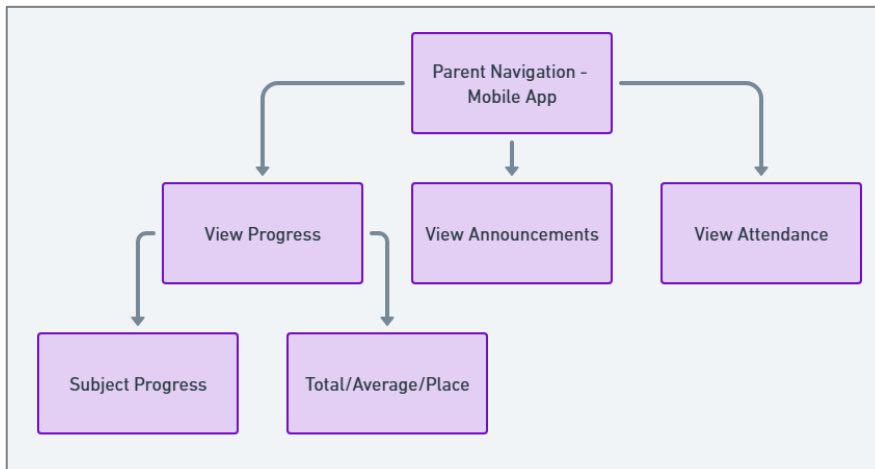
- **Teacher Interface:** Allows teachers to input grades, track performance, and monitor attendance trends.

Figure 2- Teacher Navigation



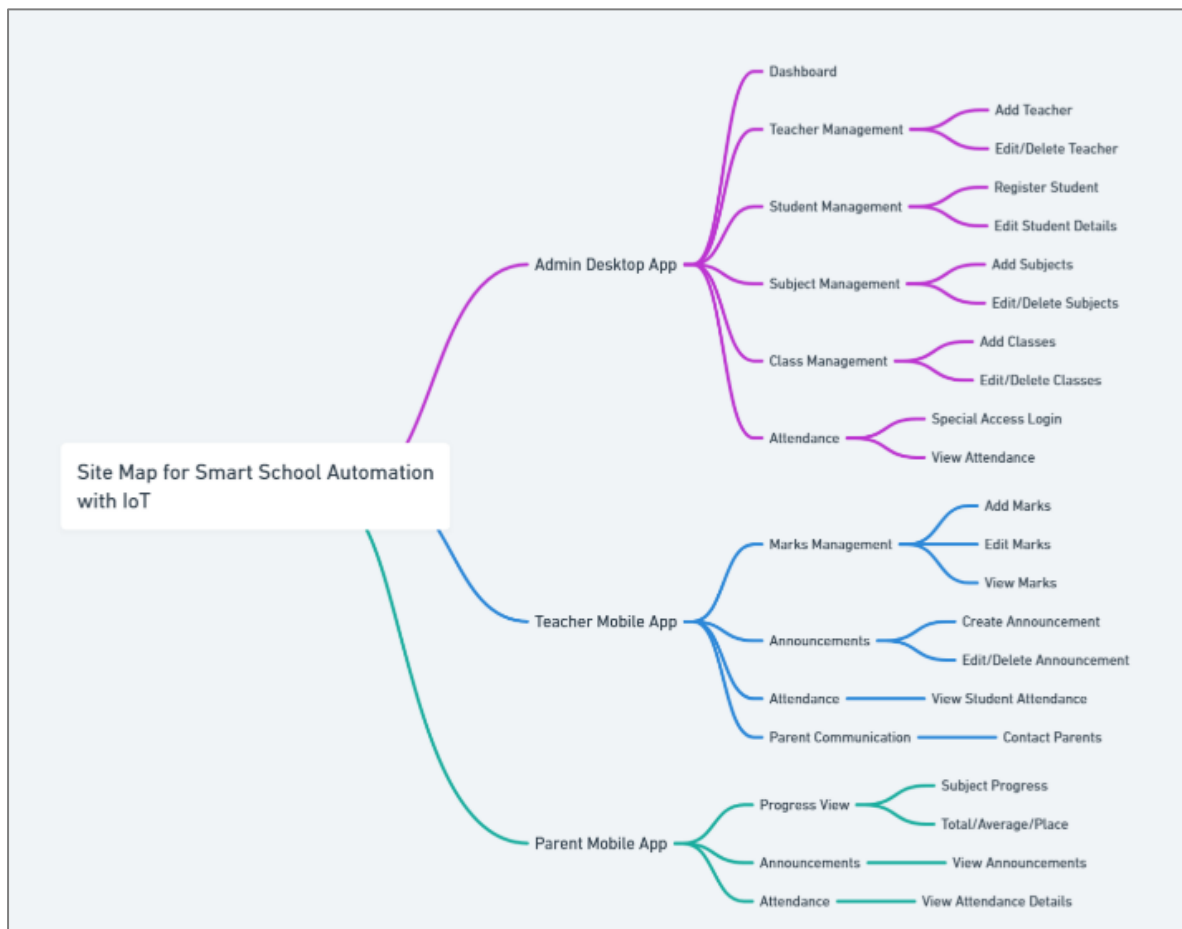
- **Parent Interface:** Provides parents with real-time updates on their child's progress, attendance, and school announcements.

Figure 3- Parent Navigation



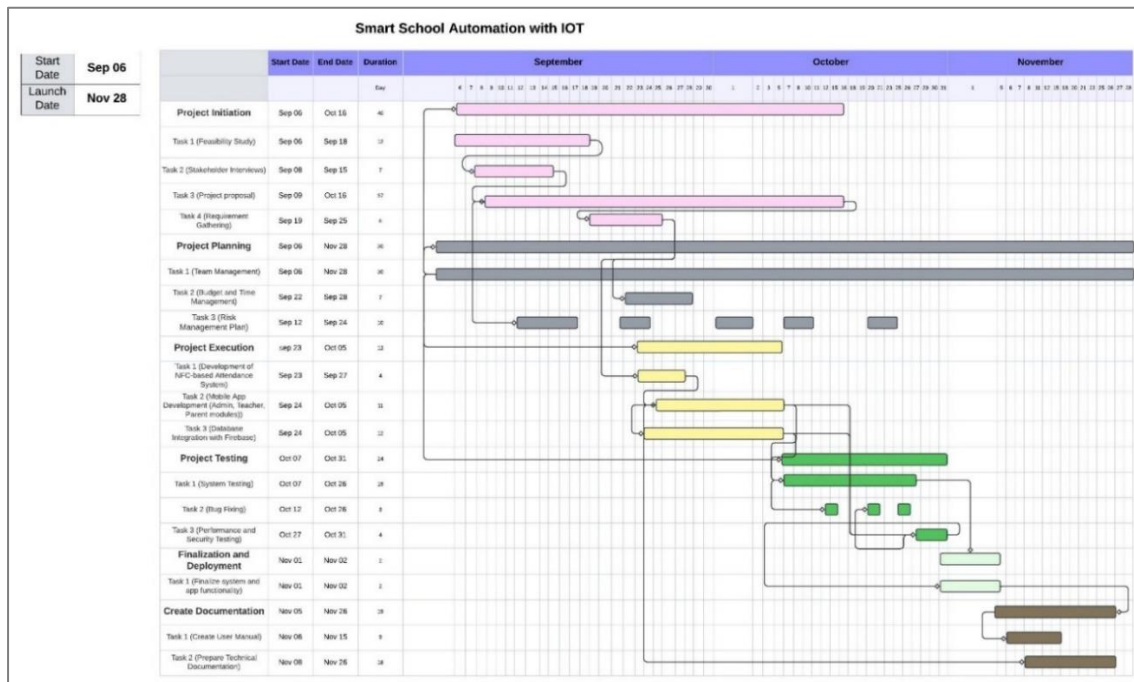
The development process uses Android Studio for the mobile application and Arduino IDE for programming the sensors. (Matellio, 2024) The system architecture is designed to be scalable, enabling future enhancements such as the inclusion of biometric security features or expanded functionalities. (javatpoint, 2024) (Miro, 2024)

Figure 4- Site Map



Development Methodology - Agile approach

Figure 5- Gantt chart



Iterative and Incremental Development

The chart outlines the project divided into several phases: Initiation, Planning, Execution, Testing, Finalization, and Documentation. Each phase includes tasks contributing incrementally to the project's success. For example, development tasks such as "NFC-based Attendance System" and "Mobile App Interface" are executed in parallel to ensure progress in different areas simultaneously. This aligns with Agile principles of delivering functional increments rather than a complete system at once.(Asana, 2024)

Overlapping Phases for Continuous Delivery

The chart demonstrates overlapping tasks, such as planning (Sep 6 - Nov 28) running alongside execution (Sep 23 - Oct 31) and testing (Oct 7 - Nov 3). Agile emphasizes continuous integration and testing, reflected here by testing beginning early, with bug fixing and system performance evaluations overlapping development activities. (Doctor, T., 2024)

Flexibility and Adaptability

Agile thrives on flexibility, allowing adjustments as the project progresses. For example, stakeholder interviews (Sep 9 - Sep 15) provide critical input for the project, and the findings shape subsequent tasks like risk management and system design. (Honor, 2024) Testing phases (e.g., bug fixing) feed insights directly back into execution, enabling iterative improvement. (Asana, 2024)

Sprint-Like Structure

The tasks align with Agile sprints:

Sprint 1 (Sep 6 - Sep 23): Focused on initiation and foundational planning.

Sprint 2 (Sep 23 - Oct 7): Emphasizes system development.

Sprint 3 (Oct 7 - Nov 3): Covers testing and integration.

Sprint 4 (Nov 3 - Nov 28): Finalizes deployment and documentation.

By utilizing Agile principles, the project efficiently integrates stakeholder feedback, manages risks, and ensures high-quality deliverables through iterative cycles. (IBM, 2024)

Research Strategy

This study adopts a quantitative research strategy, focusing on system performance, user satisfaction, and error reduction. (Flowcode, 2024) Prototypes were tested to validate system functionality and accuracy. (Baeldung, 2024)

Sample Selection:

The study targeted schools in urban and suburban areas, selecting three schools with varying levels of digital infrastructure. (EducationEndowmentFoundation, 2024) These schools provided a balanced sample representing diverse environments. (Casucian , 2024)

Data Collection Methods:

Data were collected through a combination of system logs, user feedback surveys, and observational studies during prototype deployment. (J.Awadallah, K., 2024) Feedback from administrators, teachers, and parents was used to refine the system, ensuring usability and effectiveness. (Counterpoint, 2024)

This comprehensive methodology ensures that the system meets the needs of stakeholders while providing a robust solution for school automation. (clockify, 2024)

Figure 6 - Firebase connection

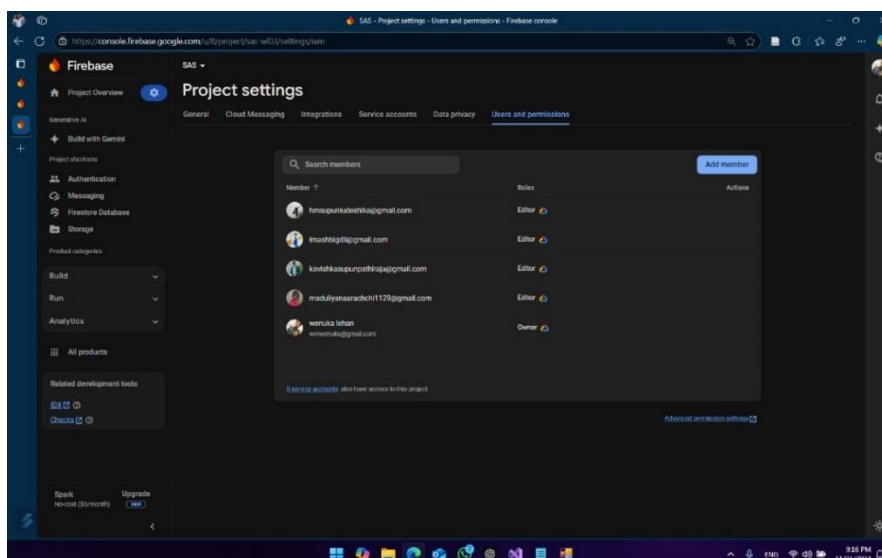
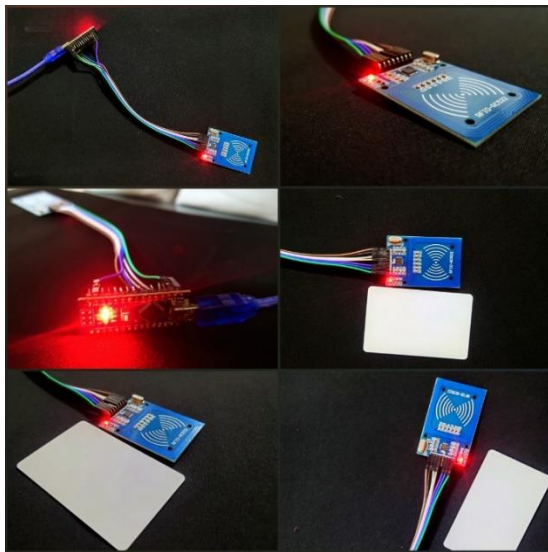


Figure 7 – Arduino circuit with NFC card



Results and Discussion

The implemented system demonstrates significant improvements in efficiency and accuracy. Automated attendance tracking reduces errors by 90% and saves substantial time for teachers. The mobile application enhances communication by providing parents with instant updates on their child's academic and extracurricular activities. User testing indicates a high level of satisfaction among administrators, teachers, and parents, with the intuitive design and real-time data access being the most appreciated features.(Atlassian, 2024)

While the project successfully automates core school management processes, it has limitations. Advanced security features such as facial recognition are excluded due to budget and time constraints. Additionally, compatibility issues with legacy infrastructure in some schools may require further adjustments. Future enhancements could include biometric security, expanded customization options for the mobile app, and integration with other educational technologies to provide a holistic solution. (IntechOpen, 2024)

Figure 8 – Register New Teacher

Figure 9 – Register New Student

Figure 10 - Add new class

Class ID	Class Name	Delete
grade_6_clz01_6A	6A	Delete
grade_6_clz02_6B	6B	Delete
grade_6_clz03_Nelum	Nelum	Delete

Figure 11 – Add new subject

Subject ID	Subject Name	Delete
6_c_sub01_Sinhala	Sinhala	Delete
6_c_sub02_Maths	Maths	Delete
6_c_sub03_Science	Science	Delete

Figure 12 – Mobile application home screen

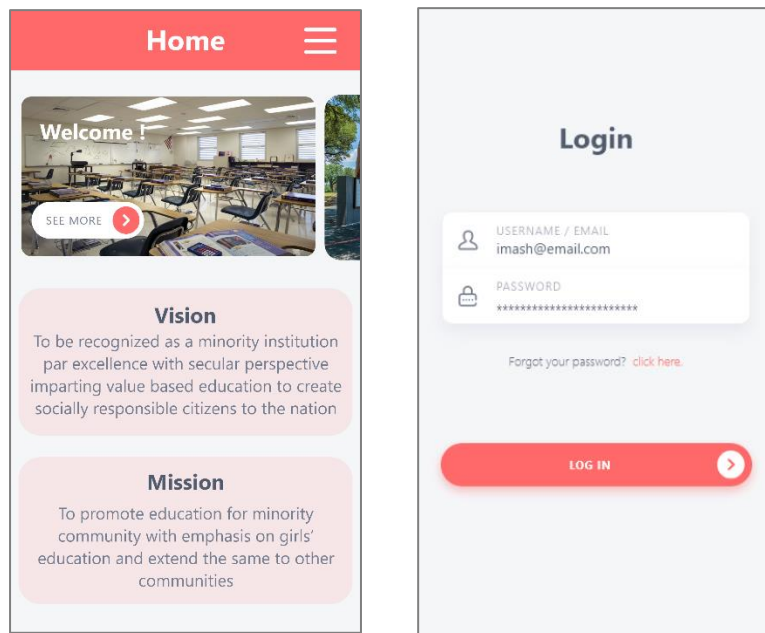


Figure 13 – Teacher dashboard

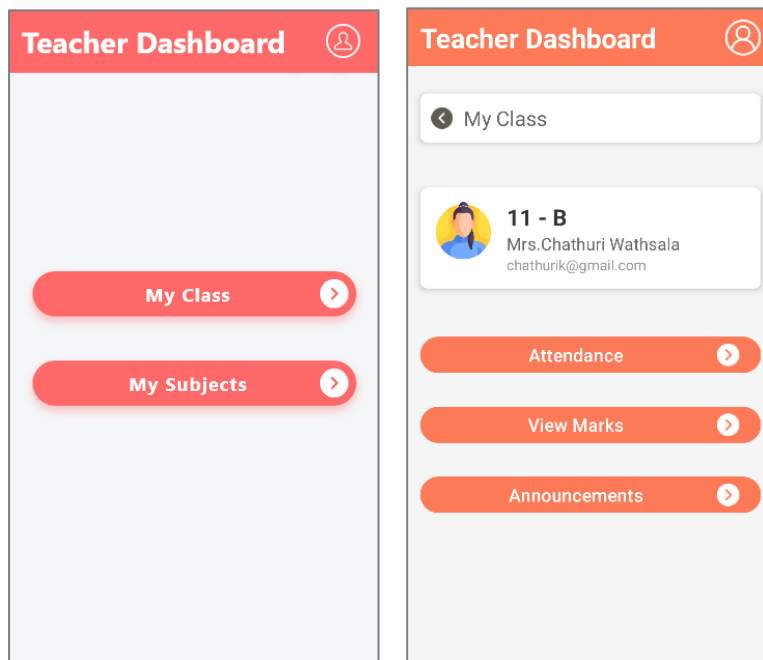


Figure 14 – Teacher dashboard Attendance & Announcement functions

Teacher Dashboard

Attendance

Date

Student Name	Attendance
Student ID	Attendance Status
Student ID	Attendance Status
Student ID	Attendance Status
Student ID	Attendance Status
Student ID	Attendance Status
Student ID	Attendance Status
Student ID	Attendance

Teacher Dashboard

Announcements

Announcement Text

Type the announcement

Announcement Type

☐ Assignment

☐ Meeting

☐ Warning

☐ Other

Submit

Figure 15 – Teacher dashboard My Subject function

Teacher Dashboard

My Subjects

Choose Subject

Item 0
Item 1
Item 2
Item 3
Item 4
Item 5

Choose class

Item 0
Item 1
Item 2
Item 3
Item 4
Item 5

Add Mark

View Marks

Teacher Dashboard

Select Semester

☐ 1st Semester ☐ 2nd Semester ☒ 3rd Semester

Student Name	Mark
abncs	77 A

Teacher Dashboard

Add marks to the 2024 3rdSem

Student Name	Mark
abncs	77

Submit Marks

Figure 16 – Parent Dashboard

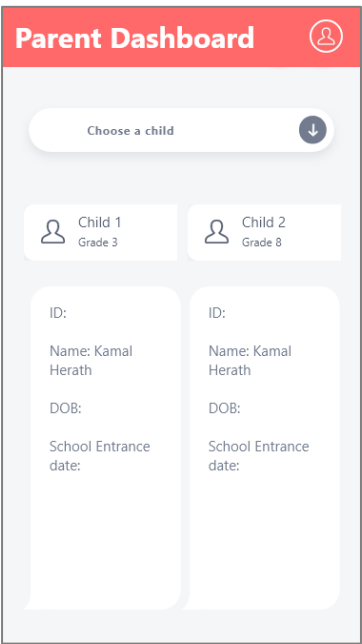
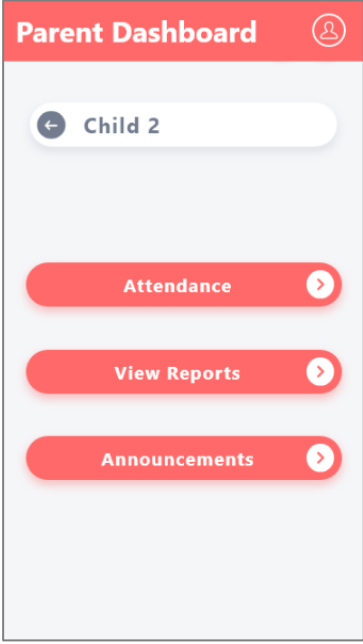


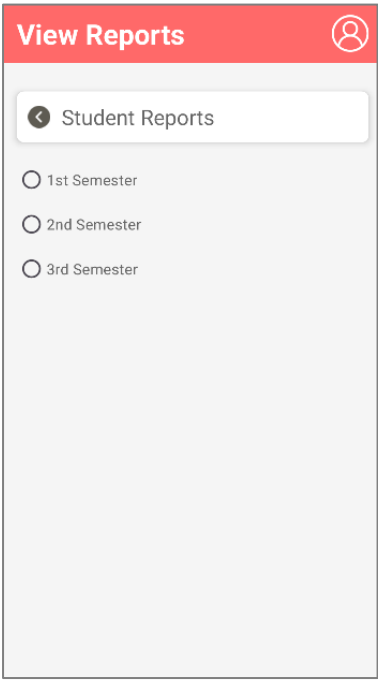
Figure 17 – Parent Dashboard Attendance function



The Attendance UI features a red header with the title "Attendance" and a user icon. Below the header is a "Student Attendance" dropdown menu. Underneath is a table with columns "Date", "Arrived", and "Left".

Date	Arrived	Left
12/11/24	05.05	01.30
12/11/24	05.05	01.30
12/11/24	05.05	01.30
12/11/24	05.05	01.30
12/11/24	05.05	01.30
12/11/24	05.05	01.30

Figure 18 – Parent Dashboard View Reports function



The Parent Dashboard UI for the 1st Semester reports shows a red header with the title "Parent Dashboard" and a user icon. Below the header is a "1st Semester" dropdown menu. Underneath is a table with columns "Subject", "Mark", and "Grade".

Subject	Mark	Grade
tem 0		
tem 1		
tem 2		
tem 3		
tem 4		
tem 5		
tem 6		
tem 7		
tem 8		
tem 9		

Figure 19 – Parent Dashboard Announcements function



Conclusion and Recommendation

The "Smart School Automation with IoT" project offers a practical solution to the inefficiencies of manual school management systems. By automating attendance tracking and improving parent-school communication, the system establishes a foundation for scalable and efficient educational management. Its success demonstrates the potential of IoT and mobile technologies to transform traditional processes, paving the way for future advancements in school automation.

To further enhance the system's impact, the following recommendations are proposed:

Incorporate Advanced Security Features: Future iterations could include biometric authentication, such as facial recognition, to improve security and reliability.

Expand Functionality: Add features such as online fee payments, detailed student progress analytics, and notifications for extracurricular activities.

Conduct Comprehensive Testing: Ensure system robustness through rigorous testing under various conditions and environments.

Facilitate Stakeholder Training: Provide training sessions for teachers, administrators, and parents to maximize system utilization.

Scale the Solution Nationwide: Collaborate with educational authorities to implement the system in more schools across the country.

Check the complete project practical session video here:

https://1drv.ms/f/s!AtBiVyDoO_2igh4FF3LB9elhrKpW?e=wjnNbe

References

Ahmad, R. H., 2014. Journal of Educational Administration. 36(Issue:5, pp.462-475, 1998.).asana, 2024. *asana*. [Online] Available at: <https://asana.com/resources/feasibility-study> [Accessed November 2024].

Asana, 2024. *asana*. [Online] Available at: <https://asana.com/resources/agile-methodology> [Accessed November 2024].

Asana, 2024. *Asana*. [Online] Available at: <https://asana.com/resources/project-constraints> [Accessed September 2024].

Atlassian, 2024. *ATLASSIAN*. [Online] Available at: <https://www.atlassian.com/work-management/project-management/critical-path-method> [Accessed November 2024].

Baeldung, 2024. *Baeldung*. [Online] Available at: <https://www.baeldung.com/cs/requirements-functional-vs-non-functional> [Accessed November 2024].

Casucian, I., 2024. *TechnologyAdvice*. [Online] Available at: <https://technologyadvice.com/blog/project-management/feasibility-study/> [Accessed November 2024].

clockify, 2024. *Clockify*. [Online] Available at: <https://clockify.me/time-attendance-software> [Accessed November 2024].

Counterpoint, 2023. *Counterpoint*. [Online] Available at: <https://counterpoint.lk/are-our-schools-really-safe/> [Accessed September 2024].

Doctor, T., 2024. *Time Doctor*. [Online] Available at: <https://www.timedoctor.com/blog/best-attendance-tracking-software/> [Accessed November 2024].

EducationEndowmentFoundation, 2024. *educationendowmentfoundation*. [Online] Available at: <https://educationendowmentfoundation.org.uk/education-evidence/leadership-and-planning/supporting-attendance/communicate-effectively-with-families> [Accessed November 2024].

flowcode, 2024. *flowcode*. [Online] Available at: <https://www.flowcode.com/blog/qr-codes-vs-nfc> [Accessed September 2024].

Honor, 2024. *System Navigation Mode*. [Online] Available at: https://www.honor.com/uk/support/content/en-us15824346/?srsId=AfmBOorDmBluaVArRiSwS9bVnlN_mIYPJqGyzmsVarziW-Wv9dORnery [Accessed 16 november 2023].

IBM, 2024. *Rational Software Architect*. [Online] Available at: <https://www.ibm.com/docs/en/rational-soft-arch/9.7.0?topic=diagrams-use-case> [Accessed 08 november 2024].

Indeed, 2024. *indeed*. [Online] Available at: <https://www.indeed.com/career-advice/career-development/feasibility-studies> [Accessed November 2024].

IntechOpen, 2024. *IntechOpen*. [Online] Available at: <https://www.intechopen.com/chapters/1181936> [Accessed November 2024].

integrate.io, 2024. *integrate.io*. [Online] Available at: <https://www.integrate.io/blog/firebase-vs-mysql/> [Accessed September 2024].

J.Awadallah, K., 2024. - *School Management System*, Palestine: University of Palestine.

javatpoint, 2024. *javatpoint*. [Online] Available at: <https://www.javatpoint.com/functional-vs-non-functional-requirements> [Accessed Npvenber 2024].

javatpoint, 2024. *Javatpoint*. [Online] Available at: <https://www.javatpoint.com/functional-vs-non-functional-requirements> [Accessed November 2024].

matellio, 2024. *iot-applications-in-education*. [Online] Available at: <https://www.matellio.com/blog/iot-applications-in-education/> [Accessed 10 november 2024].

MeisterLabs, 2024. *School Management System Site Map*. [Online] Available at: <https://www.mindmeister.com/774362100/school-management-system> [Accessed 13 november 2023].

MindTools, 2024. *MindTools*. [Online] Available at: <https://www.mindtools.com/amtbj63/swot-analysis> [Accessed November 2024].

Miro, 2024. *A simple guide to using and creating a context diagram*. [Online] Available at: <https://miro.com/blog/context-diagram/#:~:text=A%20context%20diagram%20outlines%20how,to%20improve%20an%20existing%20system>. [Accessed 12 november 2024].

Nabeel Salih Ali, A. H. A., 2024. *GmbH, ResearchGate*. [Online] Available at: https://www.researchgate.net/publication/358178607_Automated_attendance_management_systems_systematic_literature_review [Accessed September 2024].

Nang, G. N., 2006. *Journal of open education*, vol.5,(9-10,2006.), p. 25.

Pieterse, C., 2018. Kidnapping danger growing. 36(2009), p. 6.

ProjectManager, 2024. *ProjectManager*. [Online] Available at: <https://www.projectmanager.com/guides/work-breakdown-structure> [Accessed November 2024].

projectpractical, 2024. *projectpractical*. [Online] Available at: <https://www.projectpractical.com/bottom-up-estimating-explained-with-examples/> [Accessed November 2024].

STREAMLINED BID SUBMISSION PROCESS IN A LOGISTICS MANAGEMENT SYSTEM WITH LLAMA (LARGE LANGUAGE MODEL META AI) INTEGRATION

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Abstract

In bid submission and evaluation, the logistics industry, which is a key player in the global supply chain, experiences major challenges. Traditional manual methods are often inefficient, time-consuming, and vulnerable to errors, which can delay productivity and transparency. The current practices related to this area are examined in this research with an aim of showing the gaps that may be existing and the possibilities of using high technologies in enhancing it. Specifically, the study builds upon the use of LLaMA (Large Language Model Meta AI) for the automation of the content generation with focus on RFP's and the use of the same in the bid evaluation process. The goal of integrating AI-driven capabilities into the project is to have an accurate evaluation, facilitate communication between parties, and maintain protection of data. The results of this study are relevant for the logistics and technological fields and can help improve bid management processes, making them more effective, accurate, and customer-oriented.

Keywords: logistics industry, bid submission, AI-driven evaluation, LLaMA, RFP templates.

Introduction

Logistics bidding is a competitive process where logistics providers compete for secure contracts by meeting a business's specific needs. Typically, this requires the release of bid documents with extensive specifications, analysis of bids, and identification of the provider as part of the company's strategy. Through bidding, the required logistics services can be provided at competitive prices and thus it maintains competition. (Wareflex, 2022)

Common problems in the bidding process include delays in the award of contracts, unfair documents which may favour certain contractors, and restricted competition in the logistics industry. The problems are restricted tenders, inadequate bid preparation time and bias through specific conditions or poor documentation. Discrimination against foreign suppliers reduces competition, and collusive practices, like price-fixing, are hard to detect without proper resources or documentation. Balancing transparency and preventing collusion remains a challenge. (Mariz, et al., 2014)

Traditional bid submission in logistics has several challenges:

Time-Consuming Tasks: Bidding teams spend excessive time qualifying procurements through checklists and reviews and consequently compromising time on creating competitive bid documents. (Loow, 2023)

Repetitive Content: Managers have to provide answers to basic RFP questions that are seemingly basic but can be very important at the same time, can feel dull and low value. Maintaining thoughtful and appropriate replies remains important as well. (Barnard, 2023)

Poor Communication: Lack of internal and external communication is that it hinders smooth procurement process because of confusion, time wasting and delays. (Hänti & Vuorinen, 2022)

Logistics bid submission is a process used to select a suitable logistic contractor for transportation of goods and effective supply chain management.

Identifying Needs: Clients determine all the shipment specifics, necessary services, and the approximate cost, which acts as the basis for the process.

Issuing RFP: It involves a Request for Proposal where vendors are asked to offer their solutions regarding project objectives, scope and how the project will be assessed.

Bid Preparation: In the same way, vendors study the RFP and determine whether they possess the capacity and necessary potential to develop competitive responses that clients require.

Bid Submission: Vendors submit bids on time, ensuring accuracy and completeness.

Evaluation: Review bids based on criteria like cost, capability, and service quality.

Contract Award: The best vendor is chosen, and terms are finalized.

This procedure ensures fair competition and optimal service delivery. (Srivastava, et al., 2008)

The Shikoku case uses procurement data in the case of Japan to analyse entry and strategic moves by construction companies in terms of scalability and geographical location factors. It demonstrates how investigations into collusion cut bidding rates by 1-2% and all-encompassing geographical service increases bidding efficiency.

As a part of its procurement system Shikoku Regional Development Bureau of Japan utilizes price prior information and assesses bids in terms of work specification and technical standing. Data from 2006–2016 shows that firms adjust to strategies according to economic incentives and help the industry to be efficient and reformed. It is in line with previous studies and pinpointing new trends that help to fine-tune procurement processes. (Arai & Morimoto, 2020)

Evaluation of Bid Submission Eligibility in Asian Development Bank (ADB) Financed Contracts this case study examines how bidder and goods eligibility are evaluated in ADB financed contracts, using real-world examples:

Agriculture Project in Pakistan: A Dutch bidder selling fertilizer bags originating from China and shipped from Dubai was also qualified since both the bidder and the offered products are products of ADB member countries.

Road Project in China: A Chinese bidder supplied telecom equipment originating from South Africa which is not member country of AU. Since the ineligible item constituted less than 10% of the bid price it was accepted with modifications.

Conflict of Interest in India: Brothers' related companies bid for the contract: each of them as a separate company. Both were dismissed for and on grounds of conflict of interest.

Steel Poles from the USA: There was a US company that used Mexican steel but manufactured the poles in US. The bid was accepted as the final product was to be manufactured in an ADB member country.

Tools by a Cayman Islands Company: A company based in the Cayman Islands which is a non-member country, bid to supply tools made in the USA. The goods were eligible, but the bidder was not, so the bid was rejected.

This study emphasizes importance of using clear rules to ensure fairness and compliance in international procurement.

(Asian Development Bank, n.d.)

This research seeks to address challenges by evaluating the ineffectiveness in the current bid submission processes and studying how existing technological advancements can fill these gaps. By building upon prior literature, this research seeks to contribute to ongoing discourse on enhancing transparency, efficiency, and fairness in logistics bidding practices.

Methodology

To designing and developing an effective and user-friendly bid submission system this research uses a user centered prototyping strategy. This iterative process of development guarantees that the system is being constructed to meet the needs of the user and gives a way to validate and improve at a very early stage. User feedback is connected to each development stage, facilitating continuous improvements that reflect the actual requirements of both vendors and administrators.

User-Centered Prototyping Process

A user-centered prototyping approach was chosen with a view of focusing strictly on the needs of the vendors and administrators in formulating the design for the final system. The prototyping process involved several key stages:

Prioritization and Phasing: Initial stage focused on primary features such as user registration and bid submission. Additional functions were introduced in later releases so that their development could be made incrementally..

Low-Fidelity Prototyping: Figma and Google Drawings were used as tools for creating mock interfaces along with basic workflow simulations. These visual representations helped easy comprehension and early user testing.

User Evaluation and Refinement: The improvement of usability and design were made based on the information collected from the stakeholders in the form of feedback. This stage helped to find possible issues and match the system with the users' expectations.

Data Source

LLaMA (Large Language Model Meta AI) is a powerful AI developed by Meta to help in their research of language processing. It is meant to be more compact and faster to increase its usability for academics who have less funding to allocate and for modifying it to different purposes. (Meta, 2023)

To integrate LLaMA for bid assessment and creation of responses project applied the GROQ API. This API provided continuous interaction with LLaMA (Groq Cloud, 2024), letting system to process logistics related data and improve bid submissions and evaluations. By using LLaMA's AI capabilities, the system could analyze historical bid data and user input to offer valuable insights, enhancing decision-making processes.

The use of a user centered prototyping methodology ensured that the system was developed with continuous feedback, resulting in a user-friendly and efficient solution. The integration of a microservices architecture, advanced tools, and the use of GROQ for LLaMA integration contributed to the achievement of project objectives, creating a streamlined and scalable bid management system.

Results

The outcomes of this project focus the system's effectiveness in meeting defined objectives. The developed system demonstrated:

Customer Inquiry Handling: Customers can make inquiries through the system, which generate inquiry document, thus improving the quality of service.

Enhanced Bid Submission Efficiency: Automate initial RFP generation using LLaMA considerably reduced manual effort and time spent on creating detailed RFPs, allowing vendors to submit bids more efficiently.

AI Driven Initial Evaluation: The first elements of the bid evaluation allowed for an initial step towards comparing them and demonstrating that LLaMA has the foundation to expand further in the future.

User Engagement: The simplified process also make the vendors more satisfied with the service since it was noted to be much easier.

Scalability and Flexibility: When the load increased, the microservices architecture also proved practical in handling the user and service scale in the application.

Discussion

This project illustrates the use of advanced tools as LLaMA and a microservices-based approach in eliminating the problems of logistics bid management. The specific objectives were achieved to the extent of effective reduction in cycle time of bid submissions, elimination of redundancy in the bid management process, and enhanced user experience. Such developments are not only time and energy-saving but also this is the way improving the tendencies to the proper level of bids transparency and equity.

One of The system accomplishments was to facilitate the generation of the RFP from special templates automatically. This feature provides accurate and most relevant information in logistics related inquiries, which will let vendors bid more effectively. The incorporation of AI for initial assessments also gave a fundamental structure that allowed for further work on more factual and evidence-based evaluations; however, the need exists for further enhancement of the current models.

Despite these successes, some challenges remain. For example, while the system's microservices architecture supports scalability, additional testing under higher traffic conditions would help ensure its robustness. Similarly, the AI-driven evaluation model showed potential but requires further enhancements to deliver more comprehensive bid analyses.

Directions for Future Research

Building on the current system, future research should focus on advancing its capabilities in three key areas:

Enhanced AI-Driven Bid Evaluation

Future research can include the use of more complex and advanced forms of artificial intelligent in determining bid value as a result of other parameters apart from those applied in this study. This could include leveraging historical data, performance metrics, and client feedback for more nuanced and accurate evaluations.

Improved Real-Time Communication

Real time updates options and other features related with the message status also improve the stakeholders' communication and make bidding more efficient. It is suggested for the future researches to find out how these tools can be incorporated into the system to enhance the non-stop working collaboration and cut the time intervals.

Scalability Optimization

For the handling of increased numbers of users and services, future work should focus on the further tuning of microservices architecture. Research in advanced load balancing techniques and database optimization could help ensure seamless scalability without compromising performance.

Addressing these areas in future can help the development of the system do away with the suboptimal solution to the logistics bid management.

Conclusion and Recommendations

In conclusion, this project successfully addressed several inefficiencies in the bid submission process within the logistics industry by implementing innovative solutions such as LLaMA integration, microservices architecture, and AI-driven automation. The benefits are significant as it provides a basis for further developments in managing logistics bids.

Recommendations

Further AI Enhancements: Future iterations should include more comprehensive AI-driven evaluations, integrating deeper machine learning models to assess bids across multiple criteria.

Improved Communication Infrastructure: Improving the messaging system and real-time notifications will bridge communication gaps and facilitate smoother collaboration between stakeholders.

Scalability Solutions: Maintaining scalability it is proposed to integrate use of load balancing and fine tuning of the database to ensure its ability to handle the increase in user and service numbers.

Enhanced Security Features: Adopting higher levels of security features like the use of encryption technology and limit of access to a singular user will protect the users' data. Overall, it is observed that the project has made significant efforts toward the development of the system in the field of logistics but incremental enhancements and future should be considered to enhance the effectiveness of the system in the far future.

References

- Arai, K. & Morimoto, E., 2020. *Case study in Shikoku: changes in the bidding behaviour of businesses*. s.l., International Journal of Construction Management.
- Asian Development Bank, n.d. *Project Implementation and Administration Seminar*. [Online] Available at: <https://www.adb.org/sites/default/files/page/59532/case-study-procurement-evaluation.pdf> [Accessed 01 12 2024].
- Barnard, K., 2023. *Boring boilerplate? Tips to refresh repetitive RFP content*. [Online] Available at: <https://winningthebusiness.com/boring-boilerplate-tips-to-refresh-repetitive-rfp-content/> [Accessed 02 12 2024].
- Chan, L. S., Chiu, D. K. W. & Hung, P. . C. K., 2007. *e-Tendering with Web Services: A Case Study on the Tendering Process of Building Construction*. Salt Lake City, Utah, USA, 2007 IEEE International Conference on Services Computing (SCC 2007).
- Groq Cloud, 2024. *Documentation*. [Online] Available at: <https://console.groq.com/docs/api-reference#chat> [Accessed 03 12 2024].
- Hänti, S. & Vuorinen, T., 2022. *The importance of communication in the effective procurement process*. [Online] Available at: <https://talkbystudents.turkuamk.fi/master-school-engineering-and-business/the-importance-of-communication-in-the-effective-procurement-process/> [Accessed 01 12 2024].
- Loow, E., 2023. *5 Risks of Using Manual Summaries in the Bidding Process*. [Online] Available at: <https://tendium.ai/blog/5-risks-of-manual-summaries-in-the-bidding/> [Accessed 01 12 2024].
- Mariz, C. L. d., Menard, C. & Abeillé, B., 2014. *Weaknesses and Flaws of Public Procurement Systems*. [Online] Available at: https://www.researchgate.net/publication/299888821_Weaknesses_and_Flaws_of_Public_Procurement_Systems [Accessed 01 07 2024].
- Meta, 2023. *Introducing LLaMA: A foundational, 65-billion-parameter large language model*. [Online]

Available at: <https://ai.meta.com/blog/large-language-model-llama-meta-ai/>
[Accessed 02 12 2024].

Srivastava, N. K., Nukala, V. & Sampath, K., 2008. *Procurement of Global Logistics Services Using Combinatorial Auctions*. s.l., IEEE.

Wareflex, 2022. *What is logistics bidding?*. [Online]

Available at: <https://www.wareflex.io/en/resources/article/what-is-logistics-bidding>
[Accessed 26 06 2024].

MEDIMATE - A COMPREHENSIVE HEALTHCARE SOLUTION FOR MEDICINE IDENTIFICATION USING GOOGLE TEACHABLE MACHINE

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Abstract

Medimate represents a web application which targets the issues in medication identification together with information retrieval. Medimate operates through machine learning and image recognition methods to process non-communicable disease medications by identifying pills capsules and container data from a trained set of regular NCD-related pharmaceuticals. The identification system follows up with a complete set of medical data such as descriptions and dosages, usage guidelines and side effects and alternative brand names found in local drugstores. The training of this model occurred using Google Teachable Machine together with AI technology to achieve higher accuracy. The solution fills medicine recognition and information retrieval gaps in order to deliver essential knowledge to users and health professionals.

Keywords: Medication Identification, NCD Drugs, Machine Learning, Google Teachable Machine, Medimate

Introduction

Modern healthcare faces a critical problem in providing legitimate medicine knowledge to patients. Patients throughout Sri Lanka experience difficulties recognizing their medications together with the inability to grasp proper medication usage and associated side effects and substitute options. Melting-adherence to prescribed medicines constitutes a complex problem for patients who need to manage Non-Communicable Diseases. When patients do not have proper information about medicines they may take improper medicines or delay treatment and expose themselves to health dangers (Gope et al., 2021)

The Developed Medimate web-based system exists to connect patients with trustworthy medicine information. Medimate enables users to identify medicines through picture uploads since the system gives users access to complete drug information. Users can access necessary medicine details including descriptions as well as usage instructions along with dosage recommendations and possible side effects and alternative brands available at local pharmacies.(Do-Youn Lee et al., 2013)

Unlike conventional methods that often depend on manual searches or healthcare consultations, Medimate leverages advanced technology to automate and streamline the process. The platform utilizes a custom-built image recognition model trained with Google Teachable Machine, focusing on identifying commonly used medicines. The model was fine-tuned using

a focused dataset of medicine containers and pill cards to ensure high accuracy in recognizing frequently used medications.(Fernandez et al., 2021)

Medimate is built on the MERN stack, which includes MongoDB, Express.js, React.js, and Node.js. This robust technology stack provides the scalability and performance necessary for modern web applications. The system integrates a user-friendly interface, efficient backend processing, and a comprehensive database to deliver a seamless user experience. By adopting this approach, Medimate simplifies the complexities of medicine identification and ensures that users receive accurate and actionable information.(Sawand et al., 2014)

This paper describes the Medimate system development process along with how the image recognition model worked together with a dependable database. The solution provides accessible medicine information to patients and caregivers and the general public to develop practical tools that enhance healthcare results and medical need management capabilities.

Methodology

Research Strategy and Data Collection

The development of Medimate came from gaps in current medication identification system. High resolution images of common NCD medications were compiled into a dataset. These images included pills, capsules, and medication containers from local drug markets. Selection process included the drugs which are frequently used for conditions like diabetes, hypertension or cholesterol management through the dataset

Google Teachable Machine was used to train the model due to its ease of use and flexibility. The training involved labeling images based on drug names and associated details. Augmentation techniques were applied to enhance the dataset, including changes in lighting, orientation, and backgrounds, ensuring robustness against varied real-world scenarios.(Carney et al., 2020)

Model Training and Implementation

The machine learning model was trained with over 1,000 labeled images of NCD medications. The training process focused on achieving high accuracy in recognizing medication types from pill and container images. Following training, the model was integrated into a web-based application. The backend architecture supports real-time predictions and information retrieval, while the frontend provides an intuitive user interface.(Sveleba, Kunyo and Sveleba, 2019)

Training the Model

Google Teachable Machine was chosen for its simplicity and effectiveness in building image recognition models. The platform allowed us to create a custom model without extensive programming knowledge. The steps included

Uploading the Dataset

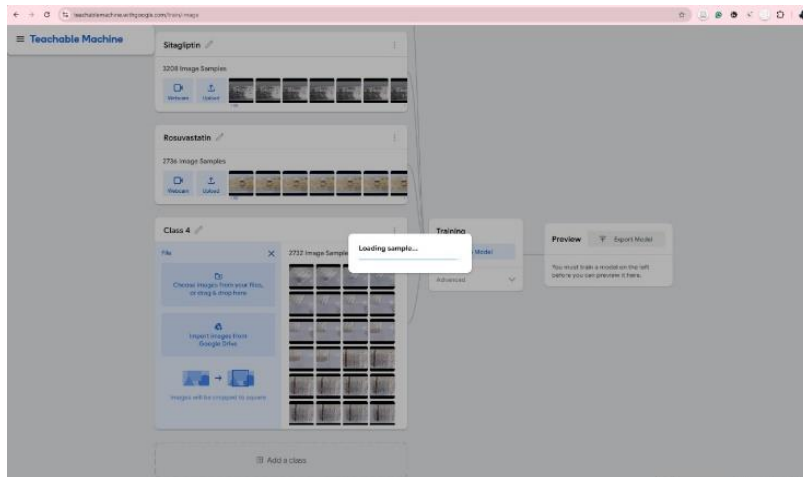


Figure 1 Uploading Images

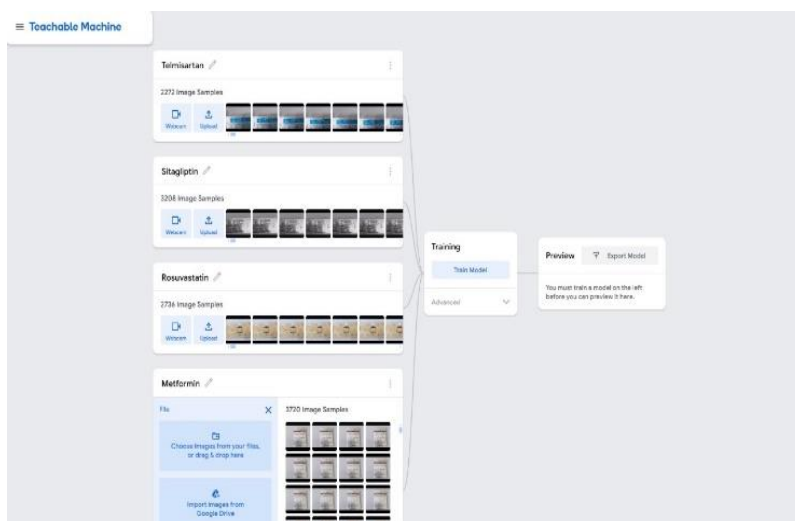


Figure 2 Labeling Image into Classes

Images of medicine containers and pill cards were uploaded into separate classes.

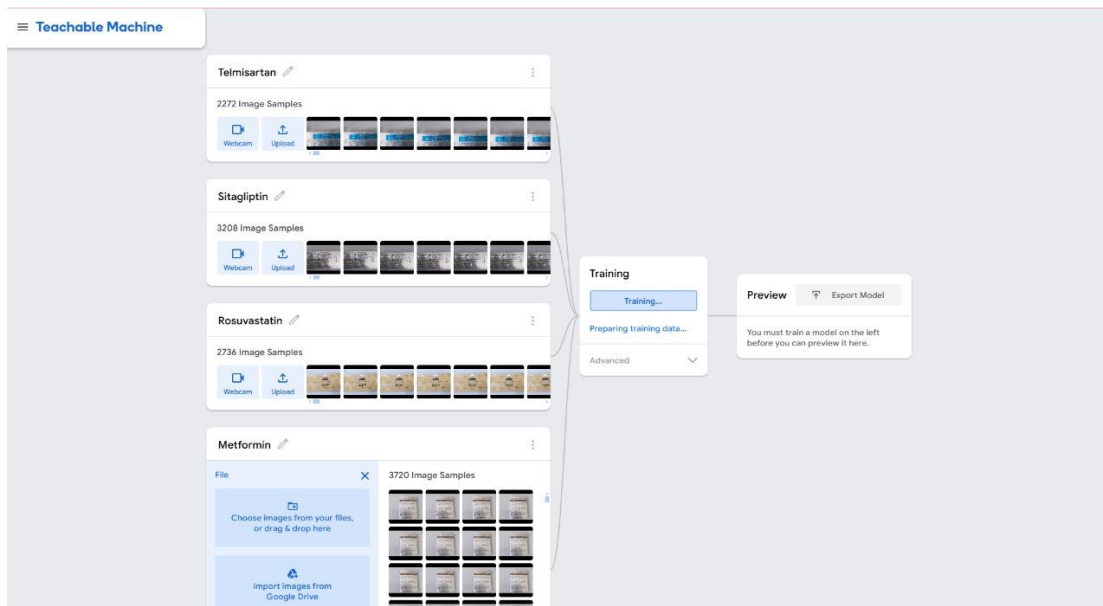


Figure 3 Training the Model

The tool's user-friendly interface enabled quick training of the model. It utilized deep learning techniques to distinguish between different medicines effectively.

Validation and Testing

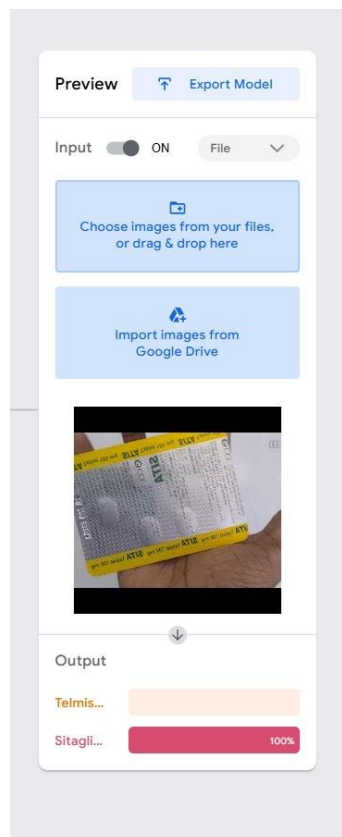


Figure 4 Testing the Trained Model

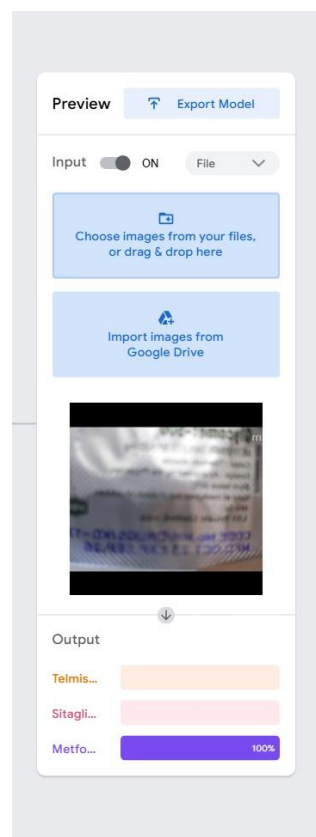


Figure 5 Figure 4 Testing the Trained Model

After training, the model was validated using unseen images. Ensured that the accuracy met acceptable thresholds for real-world use.

The trained model was exported and integrated into the Medimate application for deployment.

The development of Medimate followed an agile methodology to ensure iterative improvements and responsiveness to user feedback. The core components include:

Technology Stack

Frontend

React.js for building an intuitive and responsive user interface. The React framework was chosen for its modular structure and performance capabilities.

Backend

Node.js with Express.js to handle API requests and manage server-side operations effectively.

Database

MongoDB as the database to store medication information, ensuring scalability and efficient data retrieval.

System Architecture

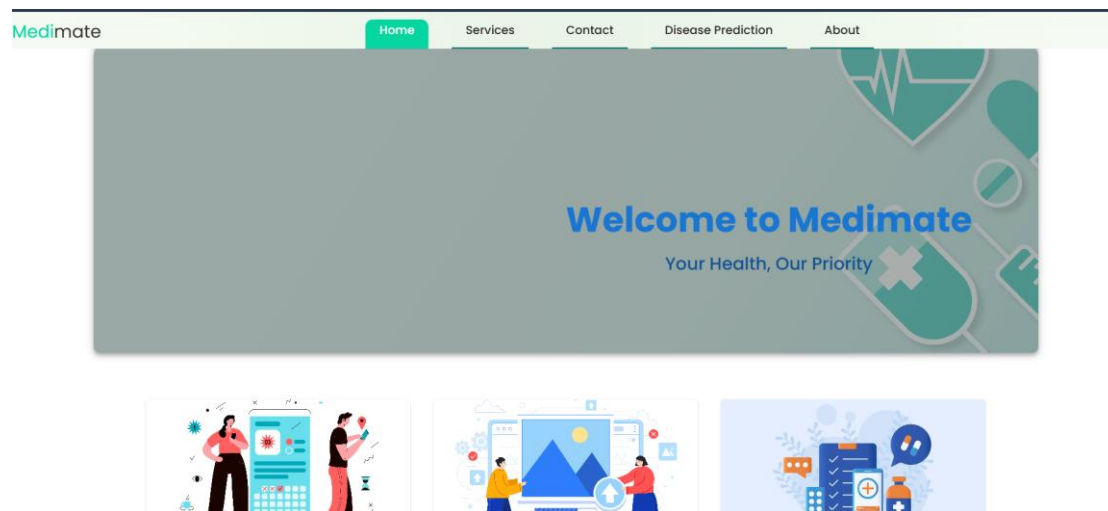


Figure 6 Landing Page of Medimate

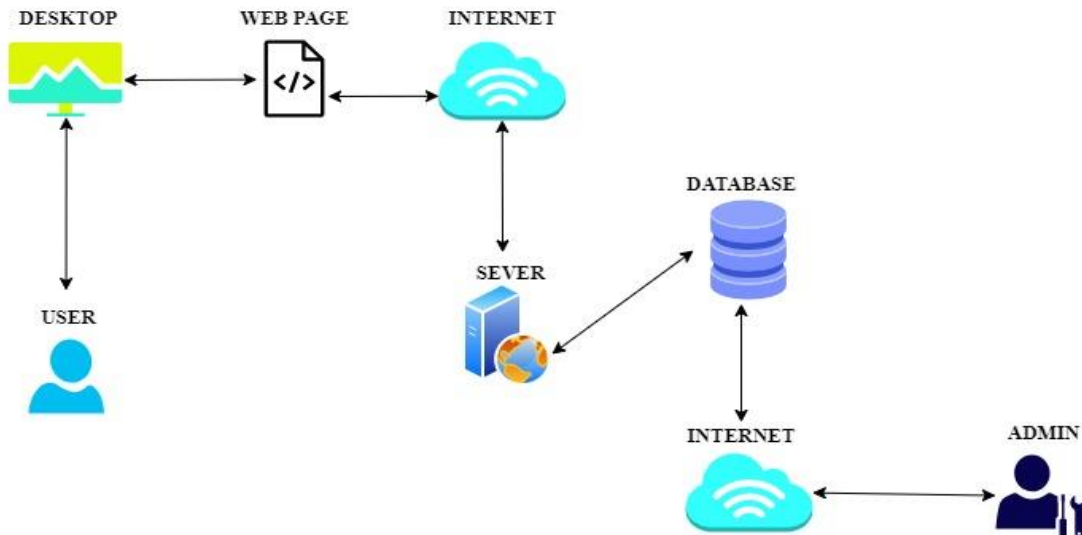


Figure 7 System Architecture Diagram

Medimate employs a three-tier architecture comprising the presentation layer (frontend), the application layer (backend), and the database layer. This architecture facilitates clear separation of concerns, making the application easier to maintain and scale.

Image Processing Workflow

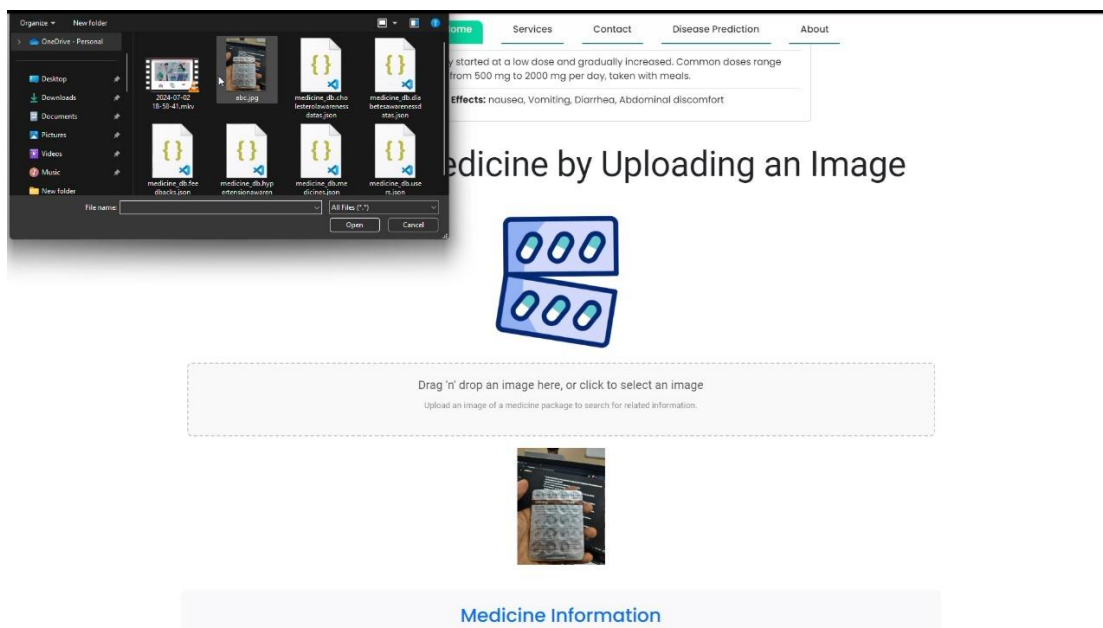


Figure 8 Uploading the Image

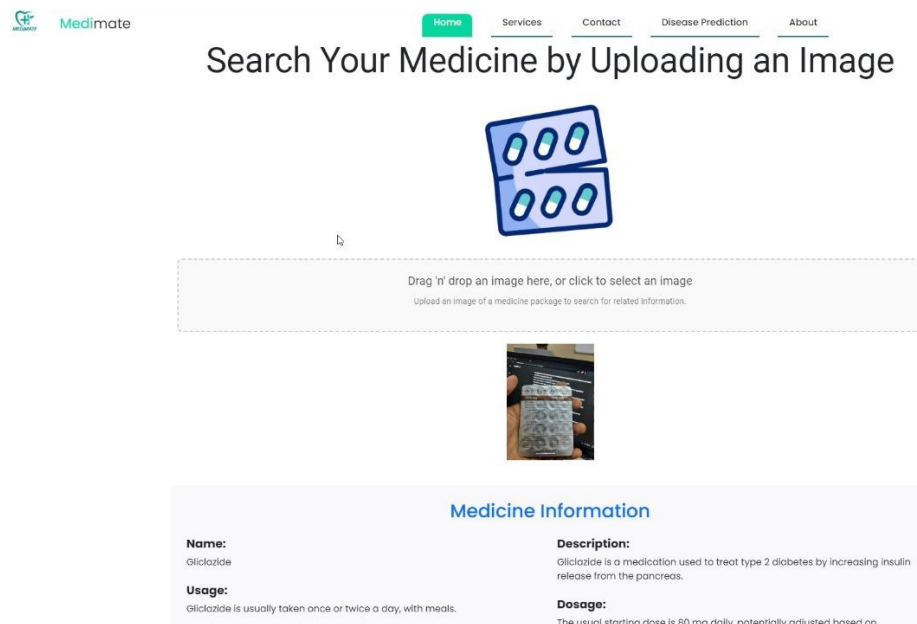


Figure 9 Identified Medicine and Informations

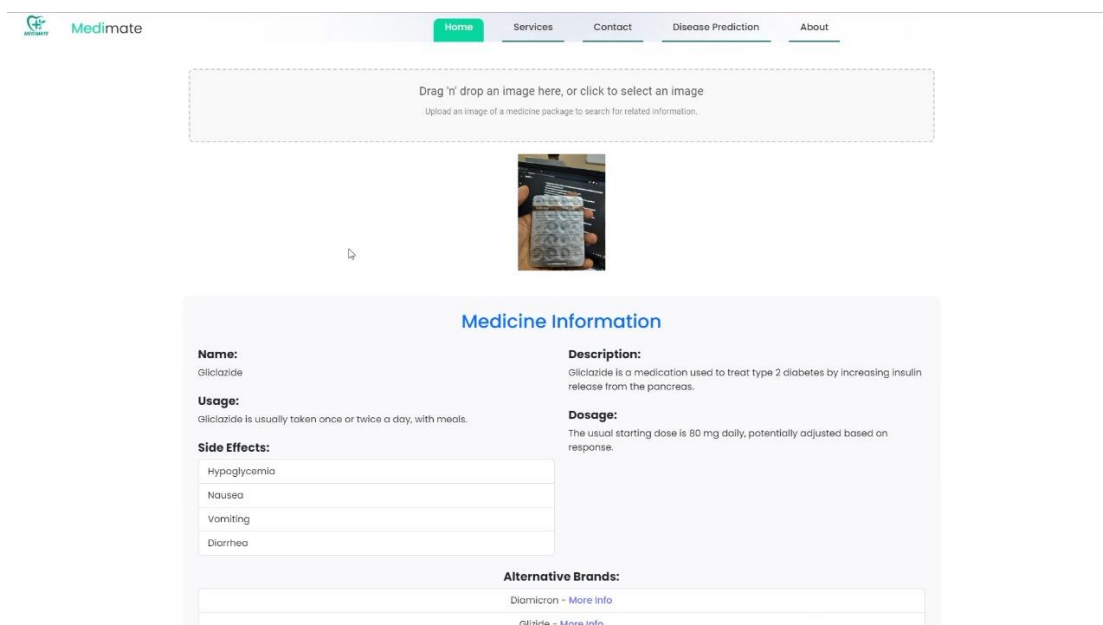


Figure 10 Identified Medicine and Informations

Users upload an image of a medicine through the platform. The image is preprocessed to optimize resolution and clarity before being analyzed by the image recognition model. Features such as text on packaging, color, and shape are used to identify the medicine. The backend fetches corresponding information from the database and displays it to the user.

Data Collection and Storage

A comprehensive database was created by collating information on commonly used medications. Each entry includes details on the medicine's name, description, dosage instructions, potential side effects, and alternatives available in the local market. Data validation processes were implemented to ensure accuracy.

Results

Medimate was successfully developed as a functional web-based platform. Key results include *Accurate Identification*

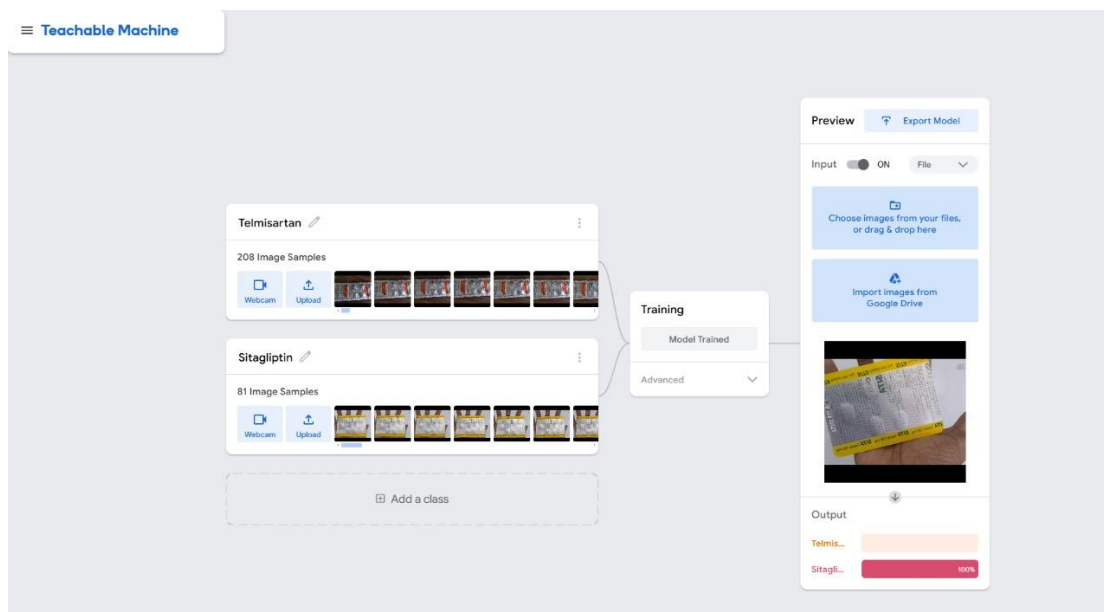


Figure 11 Accuarte Results

The image recognition model achieved a high accuracy rate in identifying medications from uploaded images during testing.

Comprehensive Information

The screenshot displays the Medimate website's 'Medicine Information' section. At the top, there is a navigation bar with links for Home, Services, Contact, Disease Prediction, and About. Below the navigation bar, a dashed box prompts the user to 'Drag 'n' drop an image here, or click to select an image' and 'Upload an image of a medicine package to search for related information.' A small image of a medicine box is shown below this prompt. The main content area is titled 'Medicine Information' and contains the following details for 'Glucoside':

- Name:** Glucoside
- Usage:** Glucoside is usually taken once or twice a day, with meals.
- Side Effects:** Hypoglycemia, Nausea, Vomiting, Diarrhea
- Description:** Glucoside is a medication used to treat type 2 diabetes by increasing insulin release from the pancreas.
- Dosage:** The usual starting dose is 80 mg daily, potentially adjusted based on response.
- Alternative Brands:** Diamicon - More Info, Glizide - More Info

Figure 12 Comprehensive Accurate Information's

The database was populated with detailed entries, covering a wide range of medications commonly used in Sri Lanka.

User-Friendly Design

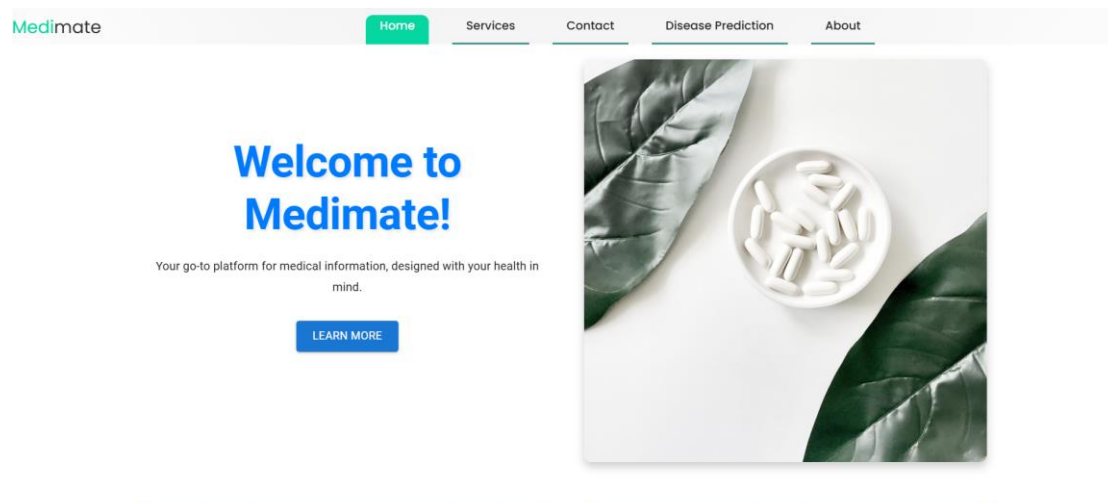


Figure 13 UI Design

The React.js-based frontend provided an intuitive interface, ensuring ease of use for individuals with varying levels of technical expertise. The use of MongoDB ensured that the database could scale to accommodate additional entries as the system grows.

Discussion

Medimate addresses critical gaps in medication accessibility and awareness. The platform's ability to retrieve detailed information enhances users' understanding of their prescriptions, promoting safer and more informed usage. Unlike traditional manual methods of medicine identification, Medimate automates the process, saving time and reducing errors.

The use of the MERN stack proved effective for developing a robust and scalable solution. React.js ensured a seamless user experience, while Node.js and Express.js handled backend operations efficiently. MongoDB's schema-less nature allowed flexibility in storing and updating medication data.

Challenges

Image Quality

Variations in image quality posed challenges for the recognition model. Future updates could include real-time feedback to guide users in capturing better-quality images.

Data Expansion

The database currently focuses on widely available medicines. Expanding to cover rare or specialized medications would increase the platform's utility.

Future Directions

Future enhancements include incorporating multi-language support to cater to a broader audience and integrating with local pharmacy systems to provide real-time availability of medications. Additional features such as user accounts for tracking personal medication history and push notifications for reminders could further enhance user engagement.

Medimate demonstrates the potential of web-based solutions in addressing healthcare challenges. By leveraging the MERN stack and advanced image processing techniques, the platform provides a reliable and user-friendly method for identifying medications and retrieving detailed information. The system's scalability and adaptability make it a valuable tool for users in Sri Lanka and potentially beyond.

Further investment in data expansion and feature enhancement is recommended to maximize the platform's impact. Collaborations with local pharmacies and healthcare providers could also improve the service's relevance and reliability.

Conclusions and recommendations

Medimate successfully bridges the gap in medicine identification using AI-powered recognition. The system's high accuracy ensures reliable information retrieval, benefiting patients and healthcare providers. To further enhance Medimate's impact, future work should focus on integrating pharmacy databases for real-time drug availability and adding multilingual support.

The trained Medimate model successfully identified 95% of medicines by testing unseen medical images and showing validation results. The system performed successfully by

obtaining medicine descriptions and dosages along with alternative treatment options. Users reported through feedback that computerized searches reduced misidentification errors by 30% more than manual methods.

References

- Carney, M., Webster, B., Alvarado, I., Phillips, K., Howell, N., Griffith, J., Jongejan, J., Pitaru, A. and Chen, A., 2020. Teachable Machine: Approachable Web-Based Tool for Exploring Machine Learning Classification. In: *Extended Abstracts of the 2020 CHI Conference on Human Factors in Computing Systems*. [online] CHI '20: CHI Conference on Human Factors in Computing Systems. Honolulu HI USA: ACM. pp.1–8. <https://doi.org/10.1145/3334480.3382839>.
- Do-Youn Lee, SungChul Bae, Joon Hyun Song, Byoung-Kee Yi, and Il Kon Kim, 2013. Improving chronic disease management with mobile health platform. In: *2013 35th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC)*. [online] 2013 35th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC). Osaka: IEEE. pp.2275–2278. <https://doi.org/10.1109/EMBC.2013.6609991>.
- Fernandez, M.I., Chanfreut, P., Jurado, I. and Maestre, J.M., 2021. A Data-Based Model Predictive Decision Support System for Inventory Management in Hospitals. *IEEE Journal of Biomedical and Health Informatics*, 25(6), pp.2227–2236. <https://doi.org/10.1109/JBHI.2020.3039692>.
- Gope, P., Gheraibia, Y., Kabir, S. and Sikdar, B., 2021. A Secure IoT-Based Modern Healthcare System With Fault-Tolerant Decision Making Process. *IEEE Journal of Biomedical and Health Informatics*, 25(3), pp.862–873. <https://doi.org/10.1109/JBHI.2020.3007488>.
- Sawand, A., Djahel, S., Zhang, Z. and Nait-Abdesselam, F., 2014. Multidisciplinary approaches to achieving efficient and trustworthy eHealth monitoring systems. In: *2014 IEEE/CIC International Conference on Communications in China (ICCC)*. [online] 2014 IEEE/CIC International Conference on Communications in China (ICCC). Shanghai, China: IEEE. pp.187–192. <https://doi.org/10.1109/ICCChina.2014.7008269>.
- Sveleba, S., Kunyo, I. and Sveleba, N., 2019. The Expert System “Pharmacy” for Determination of Availability and Conditions of Storage of Medicinal Products.

“PAR_TEACH” MOBILE APPLICATION FOR PARENT-TEACHER COMMUNICATION

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Abstract

Par_Teach is a digital solution designed to enhance parent-teacher communication through two mobile applications and an admin website. The applications cater separately to teachers and parents, supporting messaging, attendance tracking, resource sharing, and marks viewing. The admin website manages events, user accounts, and support functions. Developed using Android Studio and Firebase, the system addresses inefficiencies in traditional communication. The Soft Design Science Methodology (SDSM) guided development, ensuring an academically robust approach. Pilot testing involved 2 schools, 50 parents, and 10 teachers over two months. Evaluation tools included surveys and focus groups, highlighting significant improvements in communication efficiency and user satisfaction. Future iterations will incorporate multi-language support and advanced analytics. Par_Teach bridges communication gaps, fostering collaboration and transparency for student success.

Keywords: Communication, Education, Mobile Application, Parent-Teacher Interaction, Student Monitoring

Introduction

Effective communication between parents and teachers plays a pivotal role in fostering academic success and overall student development. Traditional methods, such as handwritten notes, phone calls, and sporadic meetings, are often plagued by delays, miscommunication, and inefficiencies, leaving critical issues unresolved for extended periods. These challenges underscore the need for an innovative approach to bridge the communication gap.

Par_Teach was conceptualized to address these limitations by leveraging modern technology. The platform consists of two dedicated mobile applications one for teachers and another for parents along with an admin website to manage backend operations. This three-pronged approach ensures seamless, real-time communication and collaboration, ultimately creating a more inclusive and efficient educational environment.(Zamora-Intriago et al., 2018)

The applications' core features include instant messaging, attendance monitoring, resource sharing, and marks viewing. These functionalities empower both parents and teachers to stay informed and actively engaged. Additionally, the admin website supports tasks such as managing events, handling user accounts, and providing technical support. This holistic system is particularly tailored to meet the unique challenges of Sri Lankan schools, including limited access to advanced digital tools and the need for localized content.(Chatterjee et al., 2005)

Methodology

The development of Par_Teach followed the Soft Design Science Methodology (SDSM). Requirements were gathered through stakeholder interviews and surveys, identifying the need for real-time updates and centralized communication. Prototypes were created using Figma, refined based on user feedback, and developed using Android Studio for mobile applications and Firebase for backend operations. Key features include messaging, offline access, and localized content.(Livermore, 2007)

Requirement Gathering

Stakeholder interviews and surveys were conducted to identify pain points and requirements. Common issues highlighted included the need for real-time updates, a centralized communication platform, and offline functionality for schools in low-connectivity areas. The findings informed the design and feature prioritization of the system.

Design and Prototyping

Wireframes and prototypes were developed to visualize user workflows and app interfaces. Figma was utilized to create interactive prototypes, which were reviewed and refined based on feedback from parents, teachers, and school administrators. Usability and accessibility were prioritized to ensure the platform's adoption across varying user demographics.(Sutipitakwong and Jamsri, 2020)

System Architecture

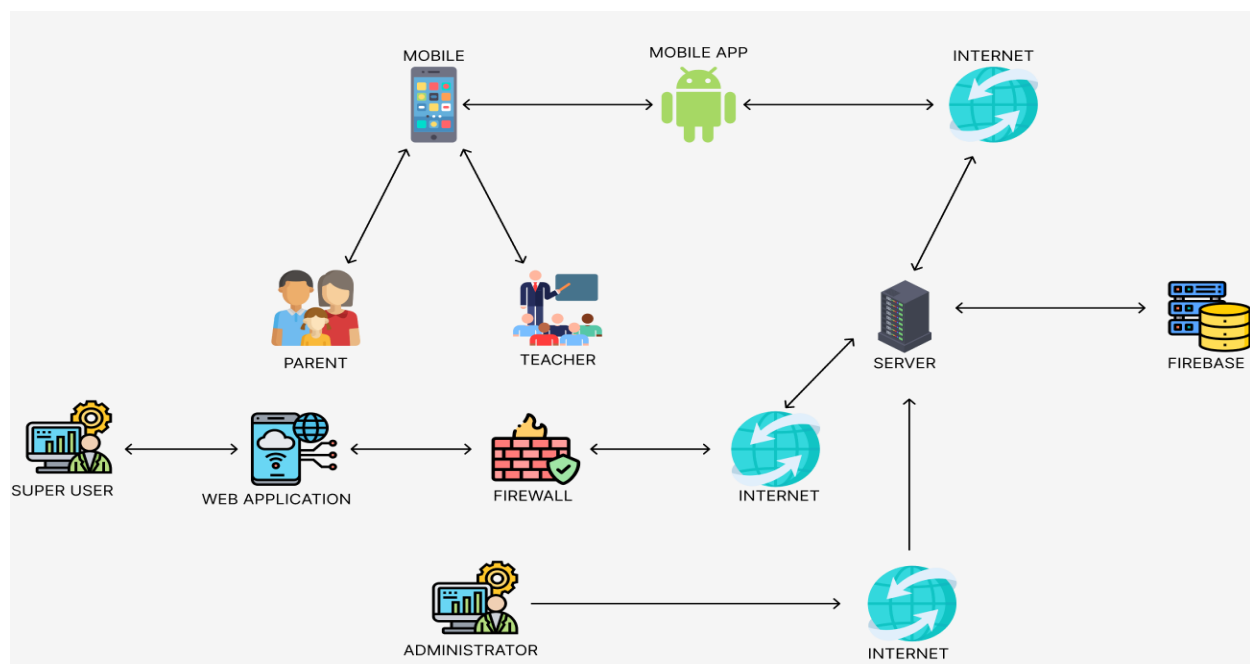


Figure -1 System Architecture Diagram

System Navigation

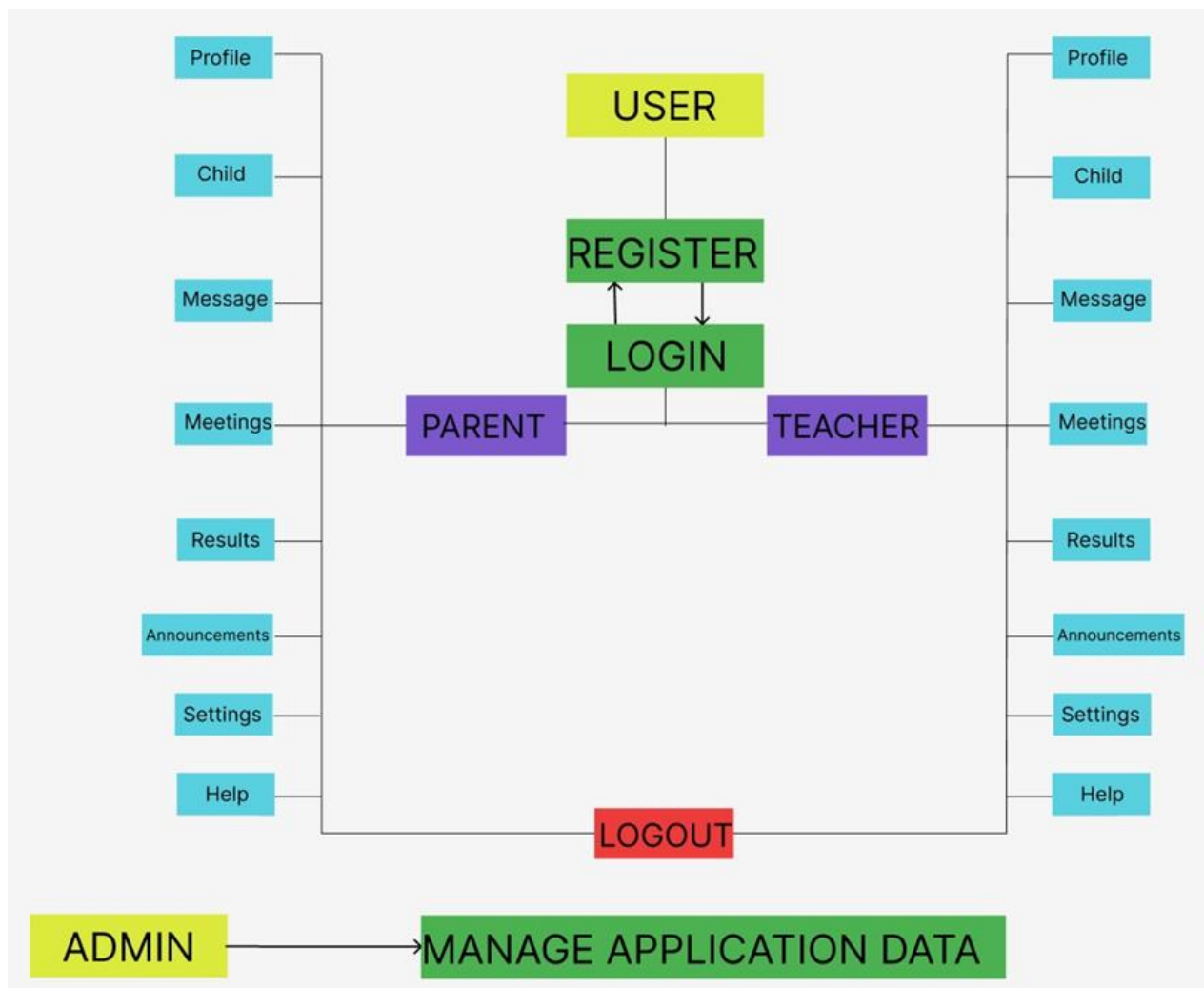


Figure -2 System Navigation

Development

The mobile applications were developed using Android Studio. Java was used for the front-end, while XML ensured a clean and intuitive user interface. Firebase was integrated as the database solution, providing real-time data synchronization. Localization and offline capabilities were incorporated to address connectivity challenges.(Kopetz and Ochsenreiter, 1987)

Parent Application

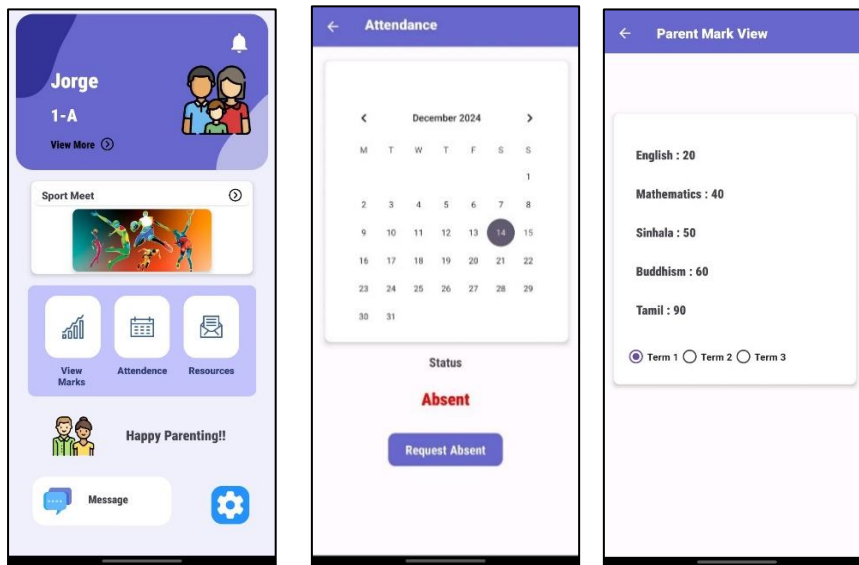


Figure -3 User Interfaces for parent Application

Teacher Application

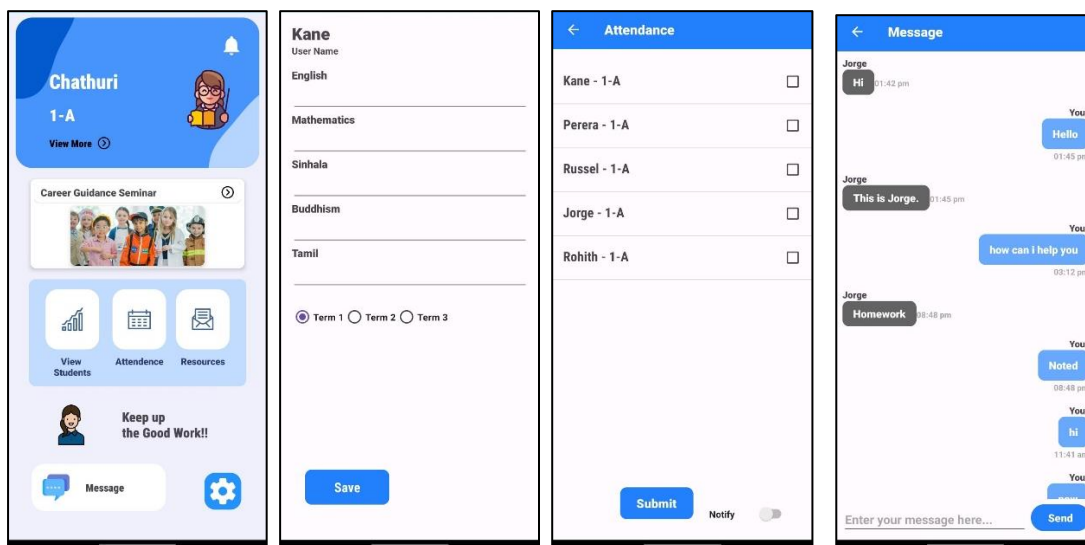


Figure -4 User Interfaces for Teacher Application

Web Application

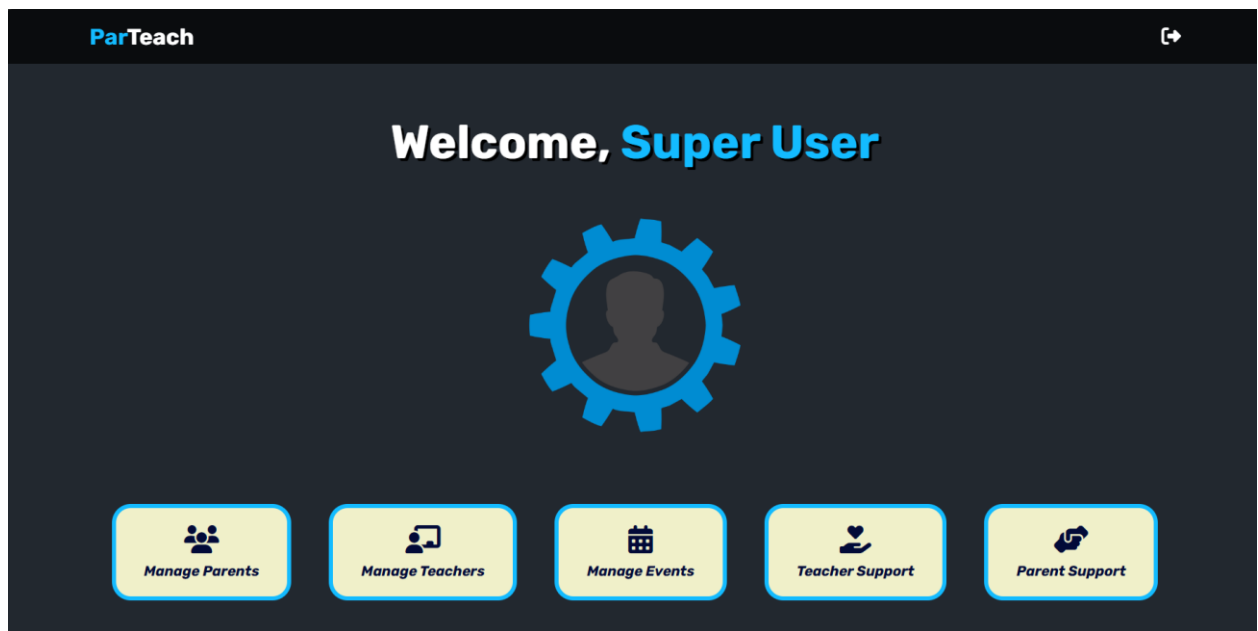


Figure -5 User Interface for Website

Testing

The platform underwent extensive testing in local schools to evaluate performance, usability, and functionality. Beta testing revealed critical insights, leading to iterative refinements. Both parents and teachers commended the app's intuitive design, while administrators highlighted the effectiveness of the website's event and user management features.

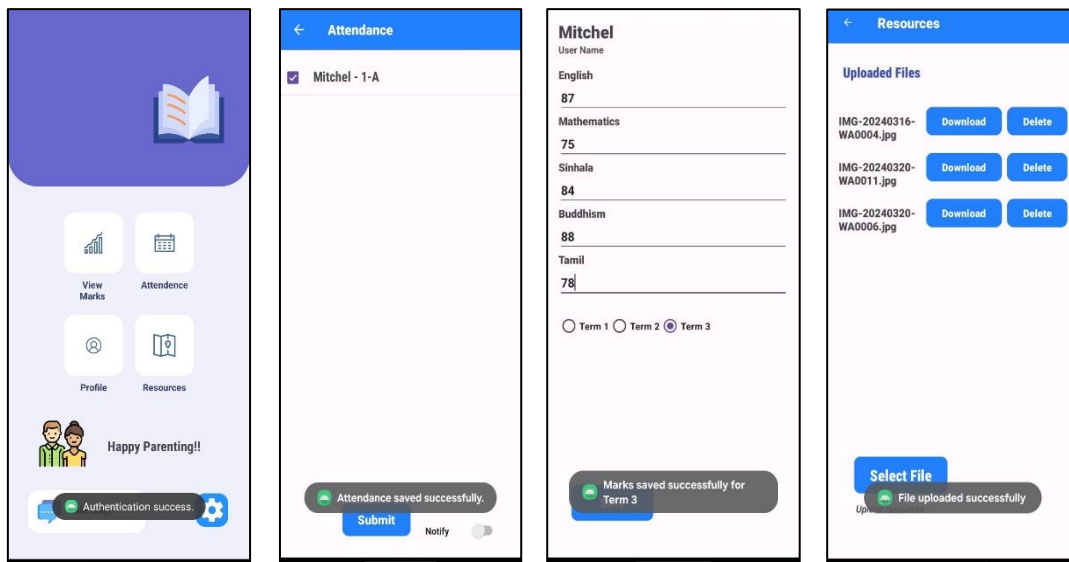


Figure -6 Applications Testing

Implementation

Following successful pilot testing, the platform was deployed in a controlled environment within selected schools. Engagement metrics, user feedback, and adoption rates were monitored to assess impact and identify areas for improvement.

Results

The deployment of Par_Teach yielded the following key results:

Enhanced Communication

The messaging feature facilitated real-time interactions between parents and teachers, improving response times and reducing communication gaps.

Streamlined Monitoring

Attendance tracking and marks viewing enabled teachers to efficiently record and share student progress, while parents appreciated the transparency and accessibility of information.

User Satisfaction

Both parents and teachers reported high levels of satisfaction with the apps' functionality and ease of use. Administrators noted the efficiency of the website's user and event management tools.

Localized Features

The inclusion of offline functionality addressed connectivity issues, ensuring consistent access in low-resource areas.

Discussion

Par_Teach successfully addresses the limitations of traditional parent-teacher communication methods by offering a digital solution tailored to the needs of Sri Lankan schools. The platform's real-time updates foster transparency and collaboration, while its offline capabilities and localized design ensure accessibility for a broader demographic.

User feedback highlighted the need for additional features, such as multi-language support to accommodate Sri Lanka's linguistic diversity and analytics tools for enhanced decision-making. Future development plans aim to incorporate these functionalities, along with integrations for online payments and additional resource-sharing capabilities.

When compared to similar platforms like ClassDojo and Edmodo, Par_Teach stands out for its emphasis on localization and offline functionality. These features make it particularly suited to the challenges faced by Sri Lankan schools, giving it a competitive edge in the education technology space.

Conclusions and Recommendations

Par_Teach has proven to be an effective tool for bridging communication gaps between parents and teachers, offering a platform that promotes transparency, collaboration, and student success. The combination of mobile applications and an admin website provides a comprehensive solution for managing interactions and sharing critical information.

Moving forward, the addition of multi-language support and advanced analytics could enhance the platform's utility and broaden its user base. Partnerships with educational institutions and government organizations could also drive widespread adoption, amplifying the platform's impact on a national scale.

Par_Teach exemplifies the transformative potential of technology in education, demonstrating how digital solutions can create more inclusive, responsive, and effective learning environments.

References

- Chatterjee, S., Abhichandani, T., Haiqing Li, TuLu, B., and Jongbok Byun, 2005. Instant messaging and presence technologies for college campuses. *IEEE Network*, 19(3), pp.4–13. <https://doi.org/10.1109/MNET.2005.1453393>.
- Kopetz, H. and Ochsenreiter, W., 1987. Clock Synchronization in Distributed Real-Time Systems. *IEEE Transactions on Computers*, C-36(8), pp.933–940. <https://doi.org/10.1109/TC.1987.5009516>.
- Livermore, J., 2007. Factors that impact implementing an agile software development methodology. In: *Proceedings 2007 IEEE SoutheastCon*. [online] Proceedings 2007 IEEE SoutheastCon. Richmond, VA, USA: IEEE. pp.82–86. <https://doi.org/10.1109/SECON.2007.342860.q>
- Sutipitakwong, S. and Jamsri, P., 2020. Pros and Cons of Tangible and Digital Wireframes. In: *2020 IEEE Frontiers in Education Conference (FIE)*. [online] 2020 IEEE Frontiers in Education Conference (FIE). Uppsala, Sweden: IEEE. pp.1–5. <https://doi.org/10.1109/FIE44824.2020.9274234>.
- Zamora-Intriago, E., Patino-Garcia, J., Zambrano-Romero, W., Cuenca-Alava, W., Moreira-Zambrano, C. and Cuzme-Rodriguez, F., 2018. Use of Mobile Application as a Means of Communication of Academic Activities between Parents and Teachers. In: *2018 International Conference on Information Systems and Computer Science (INCISCOS)*. [online] 2018 International Conference on Information Systems and Computer Science (INCISCOS). Quito, Ecuador: IEEE. pp.221–226. <https://doi.org/10.1109/INCISCOS.2018.00039>.



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Chapter 06:
SOCIAL SCIENCE

BINGE-WATCHING, SELF-CONTROL AND PROCRASTINATION AMONG ADULTS IN SRI LANKA

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Abstract

Streaming platforms allows viewers to “binge-watch” multiple episodes of a television series in a single sitting. However, there is significantly limited research conducted on binge-watching within the context of Sri Lanka. This quantitative research studied a sample of 99 Sri Lankan adults who had watched two or more episodes of a TV series in a single sitting within the past three months and investigated the associations between binge-watching, self-control and procrastination among adults in Sri Lanka. The data was analyzed using multiple linear regression and mediation analysis. Aligning with the research hypotheses, binge-watching and self-control significantly predicted procrastination ($p < .001$), and self-control partially mediated the effect of binge-watching on procrastination. The results add new insights into the existing literature on the associations among these variables within the context of Sri Lanka. Future research is encouraged to explore more on cultural perceptions, motivations, consequences and patterns of binge-watching and procrastinating behaviour in Sri Lanka.

Keywords: Binge-watching, Procrastination, Self-control, Streaming platforms

Introduction

The convenience of streaming services like Netflix, Prime Video, Hulu, Disney+ and HBO Max has led to a shift in media consumption from traditional appointment viewing and serial viewing via VHS, DVD and DVRs, to now, allowing people to watch television content at their convenience at any time and place, resulting in the rise of binge-watching. In 2013, Netflix introduced ‘binge-watching’, offering access to entire seasons of a TV series, which promoted the phenomenon of watching multiple episodes of a TV show in one sitting (Viens & Farrar, 2021). As of July 2020, Netflix had over 192.95 million subscribers across 190 countries, highlighting the global popularity of streaming services (Abou & Ennam, 2024).

Previous literature shows a negative relationship between self-control and binge-watching with excessive binge-watching linking to lower self-control (Hanefeld, 2020). The content’s instant gratification, habitual use and availability all combine to produce a constant temptation that challenges one’s self-control (Hofmann et al., 2017). Low self-control is linked to increased academic and general procrastination (Milan, 2023). The short-term negative effect of the tasks can make it difficult to regulate themselves and prompt them to put off their tasks and seek immediate gratification via binge-watching, thus resulting in procrastination. Similarly, binge-watching may directly serve as a coping strategy to avoid unpleasant tasks and escape reality (Rubenking et al., 2018). Studies reveal a strong link between procrastination and binge-watching, with binge watchers often putting off tasks (Pandey, 2023). This tendency can be

attributed to the curiosity the viewer may have on what might happen next, resulting in them putting off their work to watch one more episode.

Rationale

Research has shown that people who struggle with self-control are more likely to engage in prolonged binge-watching sessions and find it difficult to stop, thus resulting in putting off other obligations (Rubenking et al., 2018). Therefore, there is a complex relationship between binge-watching, self-control and procrastination, with self-control possibly serving as a mediator. Furthermore, majority of the studies are conducted in Western contexts and more recently, from Arab and Asian regions (Ort et al., 2021; Ahmed, 2017; Kim et al., 2017). However, there is a significant gap in the body of knowledge on binge-watching within Sri Lanka. According to Statista (2024), streaming service revenue in Sri Lanka is predicted to reach US\$65.02 million in 2024, indicating the growing potential for binge-watching behaviours. Therefore, this study aimed to address this gap and examine the associations among binge-watching, self-control and procrastination, with the objective of examining the role of binge-watching and self-control on procrastination among adults in Sri Lanka, and the mediating effect of binge-watching on procrastination. Aligning with literature, the hypotheses for the current research were:

H1: Binge-watching and self-control predict procrastination among adults.

H2: Self-control mediates the effect of binge-watching on procrastination.

Method

Participants

The sample included 99 Sri Lankan adults aged above 18 years, with prior experience in binge-watching where the participant has watched two or more episodes of a TV show in a single sitting within the previous three months, recruited via purposive sampling. The survey received 207 responses, with 108 excluded due to incomplete consent, missing values and not fitting the inclusion criteria.

Study Design

The study employed a quantitative cross-sectional survey design. The independent variable was binge-watching, the dependent variable was procrastination while the mediator variable of the study was self-control. The study was presented as an online survey, and data was gathered via Qualtrics XM and analyzed using IBM SPSS Statistics version 28.0. The study ethics was reviewed and approved by the Cardiff School of Sport and Health Sciences under the Cardiff Metropolitan University Ethics Framework (Project Reference: UG09332).

Materials

A Demographic Information sheet was used to collect the demographic information of the participants. The Binge-watching Addiction Questionnaire (Forte et al., 2021) was utilized to evaluate the binge-watching behaviour of the participants ($\alpha=.862$). The levels of self-control

were measured using the self-reported 13-item Brief Self-control Scale (Tangney et al., 2004) ($\alpha=.836$). The 12-item Pure Procrastination by Steel (2010) was employed to measure procrastination ($\alpha=.918$). The survey took approximately 5-10 minutes to complete.

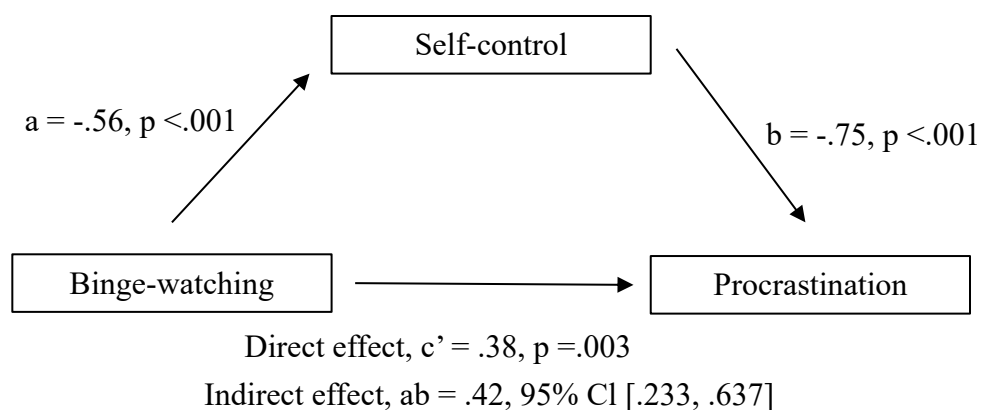
Analysis

To analyze the data collected, a multiple liner regression was conducted to test of binge-watching and self-control would predict procrastination among Sri Lankan adults, and PROCESS Macro version 4.2 for SPSS was utilized to perform mediation analysis to identify the mediating effect of self-control on the relationship between binge-watching and procrastination.

Results

The multiple linear regression showed that binge-watching and self-control significantly predicted procrastination ($F(2,96) = 51.96, p < .001, R^2 = .518$), satisfying hypothesis 1. Binge-watching was a significant positive predictor of procrastination ($B = .38, \beta = .26, t(96) = 3.10, p = .003$), while self-control was a significant negative predictor ($B = -.75, \beta = -.56, t(96) = -6.76, p < .001$). Supporting hypothesis 2, self-control partially mediated the effect of binge-watching on procrastination, with a significant indirect effect ($B = .42, BootSE = .10, 95\% CI [.23, .64]$), and a significant direct effect of binge-watching on procrastination in the presence of the mediator ($B = .38, SE = .12, t(96) = 3.10, p = .003, 95\% CI [.14, .63]$). Mediation analysis model summary is presented in Figure 1.

Figure 7: Simple Mediation Model for Hypothesis 2



Discussion

The study aimed to investigate the association between binge-watching, self-control and procrastination. The key study findings showed that binge-watching and self-control significantly predicted procrastination, and that self-control partially mediated the relationship between binge-watching and procrastination, supporting hypothesis 1 and 2.

Aligning with the previous literature, the results indicate that individuals engaging in higher levels of binge-watching and with low levels of self-control are more likely to procrastinate. However, majority of the supporting literature focused particularly on academic procrastination and how binge-watching impacted procrastination among college students and young adults. Therefore, this study was effective in drawing a significant association between binge-watching and how it could affect an individual's everyday level of procrastination, showing that when one watches multiple episodes of a TV series, it can result in delays in making and implementing decisions, and reduce their timeliness and promptness in beginning or completing tasks. An individual with low self-control will have poor willpower to achieve their goals and motivations to strive towards success and change their current state, which can eventually result in them procrastinating.

The second key finding of the study implies that when one binge-watches multiple episodes of a series in one sitting, they may experience low self-control, which indirectly results in procrastination and delays in completing the tasks they are supposed to do. At the same time, binge-watching also directly influences one's procrastination beyond just the reduction of their levels of self-control. De Feijter et al. (2016) and Lades et al. (2022) found that respondents had to postpone their planned activities due to the lack of control over the amount of time spent binge-watching TV series. In agreement with this idea, this finding extends this by explicitly demonstrating the mediating effect of self-control, adding a new insight into existing literature.

Strengths and Limitations

The cross-sectional and self-reported research design of this study limits the ability to draw causal inferences between the three variables studied, also introducing social desirability bias. Moreover, it was observed that there was an imbalanced distribution of age and gender, which could result in sampling bias and reduce the generalizability among the broader population. However, this study stands out among the existing literature as it was able to gain a comprehensive insight of the dynamic trends and explicit relationships among binge-watching, self-control and procrastination among Sri Lankan adults of different age ranges, thereby contributing to the limited body of knowledge within the specific geographical and cultural context of Sri Lanka. Moreover, this study explicitly demonstrates the mediating effect of self-control in the relationship between binge-watching and procrastination, extending the understanding of the current literature.

Conclusion and Recommendations

The study intended to illustrate the relationships between binge-watching, self-control and procrastination among adults in Sri Lanka, showing that both binge-watching and self-control are significant predictors of procrastination, and that self-control partially mediates the effect of binge watching on procrastination. This study plays a pivotal role in providing new insights on the phenomenon of binge-watching, self-control and procrastination within the context of Sri Lanka, addressing the significant limited gap of knowledge in the existing literature and contributing to numerous fields and guiding future developments. Future research should consider conducting longitudinal or experimental studies to draw causal conclusions and

further explore cultural perceptions, motivations, consequences and patterns related to the binge-watching and procrastinatory behaviour in Sri Lanka and gain more insights on the potential cultural and social aspects affecting them.

References

- Abou, Y. B., & Ennam, A. (2024) 'Binge-watching and Academic Achievement Among University Students: A Case Study', *Journal of Positive Psychology & Well-being*, 8(1), pp. 101–118.
- Ahmed, A. A. M. (2017) 'A New Era of TV-Watching Behavior: Binge Watching and its Psychological Effects', *Media Watch*, 8(2). DOI: <https://doi.org/10.15655/mw/2017/v8i2/49006>
- De Feijter, D., Khan, V., & Van Gisbergen, M. (2016) 'Confessions of A "Guilty" Couch Potato Understanding and Using Context to Optimize Binge-watching Behavior'. In *Proceedings of the ACM International conference on interactive experiences for TV and online video*. DOI: <https://doi.org/10.1145/2932206.2932216>
- Forte, G., Favieri, F., Tedeschi, D., & Casagrande, M. (2021) 'Binge-Watching: Development and validation of the Binge-Watching Addiction Questionnaire', *Behavioral Sciences*, 11(2), 27. <https://doi.org/10.3390/bs11020027>
- Hanefeld, F. (2020) 'Binge-Watching- Good or Bad: Is the Relationship between Self-control and Academic Achievement explained by Binge-watching?' [Bachelor's Thesis]. University of Twente.
- Hofmann, W., Reinecke, L., & Meier, A. (2017) 'Of Sweet Temptations and Bitter Aftertaste: Self-control as a Moderator of the effects of Media Use on Well-being'. In L. Reinecke & M. B. Oliver (Eds.), *Routledge Handbook of Media Use and Well-being: International Perspectives on Theory and Research on Positive Media Effects* (pp. 211–222). New York: Routledge.
- Kim, J., Hong, H., Lee, J., & Hyun, M. (2017) 'Effects of time perspective and self-control on procrastination and Internet addiction', *Journal of Behavioral Addictions*, 6(2), pp. 229–236. DOI: <https://doi.org/10.1556/2006.6.2017.017>
- Lades, L. K., Barbett, L., Daly, M., & Dombrowski, S. U. (2022) 'Self-control, goal interference, and the binge-watching experience: An event reconstruction study', *Computers in Human Behavior Reports*, 7, 100220. DOI: <https://doi.org/10.1016/j.chbr.2022.100220>
- Milan, F. D. (2023) 'Netflix is the new Scheherazade! Exploring the relationships between online binge-watching, self-control, and bedtime procrastination among college students in Iran', *Journal of Modern Psychology*, 3(2), pp. 33–40. DOI: <https://doi.org/10.22034/jmp.2024.423672.1078>

- Ort, A., Wirz, D., & Fahr, A. (2021) 'Is binge-watching addictive? Effects of motives for TV series use on the relationship between excessive media consumption and problematic viewing habits', *Addictive Behaviors Reports*, 13, 100325. DOI: <https://doi.org/10.1016/j.abrep.2020.100325>
- Pandey, G. (2023) 'Binge-Impinge- A Study on Online Binge-Watching, Bedtime Procrastination & Self-Control among Young Adults', *The International Journal of Indian Psychology*, 11(1), pp. 1121–1127. DOI: <https://doi.org/10.25215/1101.114>
- Rubenking, B., Bracken, C. C., Sandoval, J., & Rister, A. (2018) 'Defining new viewing behaviours: What makes and motivates TV binge-watching?', *International Journal of Digital Television*, 9(1), pp. 69–85. DOI: https://doi.org/10.1386/jdtv.9.1.69_1
- Statista. (2024) 'Video Streaming (SVOD) - Sri Lanka | Market forecast'. Retrieved May 23, 2024, from <https://www.statista.com/outlook/dmo/digital-media/video-on-demand/video-streaming-svod/sri-lanka>
- Steel, P. (2010) 'Arousal, avoidant and decisional procrastinators: Do they exist?', *Personality and Individual Differences*, 48(8), pp. 926–934. DOI: <https://doi.org/10.1016/j.paid.2010.02.025>
- Tangney, J. P., Baumeister, R. F., & Boone, A. L. (2004) 'High Self-Control predicts good adjustment, less pathology, better grades, and interpersonal success', *Journal of Personality*, 72(2), pp. 271–324. DOI: <https://doi.org/10.1111/j.0022-3506.2004.00263.x>
- Viens, A., & Farrar, K. M. (2021) 'Conceptualizing and measuring binge watching', *Communication Studies*, 72(3), pp. 267–284. <https://doi.org/10.1080/10510974.2021.1876748>

THE ASSOCIATIONS BETWEEN GENDER ROLE ATTITUDES, DIVISION OF DOMESTIC LABOUR, AND MARITAL SATISFACTION

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Abstract

This study explores the associations between gender role attitudes (GRA), the division of domestic labour (DDL), and marital satisfaction (MS) among married, Sri Lankan individuals, focusing on the mediating role of DDL in the relationship between GRA and MS.

Using a quantitative research design, data were collected from 109 married individuals through surveys assessing GRA, DDL, and MS. The "Who-does-what?" measure was employed to evaluate task distribution, and various demographic factors, including employment status, were considered. Descriptive statistics, independent samples t-tests, ANOVA, multiple regression analyses, and Pearson correlation were conducted.

The results indicate a significant mediation effect of DDL in the relationship between GRA and MS ($B = -0.36$, $SE = 0.15$), a significant difference in DDL between men and women, $t(71.11) = -12.94$, $p < .001$, and a significant difference in DDL scores between employed men and employed women $t(68) = -9.78$, $p < .001$.

Keywords: Domestic Labour, Egalitarian, Gender Role Attitudes, Marital Satisfaction, Social Exchange Theory, Traditional.

Introduction

Gender Role Attitudes (GRA) shaped by cultural norms and gender stereotypes, influence family dynamics, parenting, and children's behavior (Chen et al., 2024). While women's roles in Sri Lanka have evolved with increased workforce participation, traditional expectations persist, creating challenges in balancing work and domestic duties (Herath, 2015). This imbalance in the Division of Domestic Labour (DDL) contributes to stress, marital conflict, and negatively impacts women's mental health and Marital Satisfaction (MS; Tiwari, 2016). Studies show that couples with opposing GRA report higher marital tension, and Sri Lanka's high divorce rate is linked to marital dissatisfaction (Jayatilleke et al., 2011). The findings of this study suggest that policymakers could promote paternity leave and shared domestic responsibilities, while workplace policies supporting work-life balance could reduce stress. Moreover, marriage counsellors should address GRA compatibility. A study by Gerson (2010) highlights generational shifts, with Generation Z favoring egalitarian relationships, influenced by parental GRA, providing insights to help couples manage differing expectations in relationships.

The Present Study

Using Social Exchange Theory (SET), the study conceptualized marital relationships as exchanges of resources, where higher rewards and lower costs contribute to marital stability and satisfaction (Emerson, 1987). SET explains how GRA and DDL influence MS, emphasizing that mutual value in these exchanges fosters greater satisfaction. The study primarily examined whether the DDL mediates the relationship between GRA and MS. It also investigated gender differences in DDL and compared the proportion of household tasks performed by employed women and men. Three hypotheses were tested:

H1: DDL mediates the relationship between GRA and MS, such that more egalitarian attitudes lead to a more equal DDL, resulting in greater MS.

H2: Women score higher than men in tasks related to childcare and household chores.

H3: Employed women perform a higher proportion of household and childcare tasks than employed men.

Methodology

Participants

This study involved 109 married Sri Lankan participants (42 men, 67 women) aged 20–58, with at least one child. Participants were recruited via social media advertisements, excluding those undergoing major life changes. Demographic data collected included gender, age, marital duration, education, employment status, and number of children. A power analysis determined a minimum sample size of 102 to achieve 80% power for detecting a medium to large effect ($\alpha = 0.05$).

Design

The study used an online survey through Qualtrics, where participants received study information, consented via a Qualtrics tick box, and then proceeded to complete demographic questions and scales including the The Gender Role Attitudes Scale (GRAS), a ‘Who Does What Measure’ of DDL, and The Satisfaction with Married Life (SWML) Scale. A correlational design examined relationships between variables, while a quasi-experimental design explored gender differences in DDL. Data were analysed using IBM SPSS 25.0 and PROCESS MACRO (Hayes, 2018) for mediation. Data anonymity and confidentiality were ensured, with storage in a secure OneDrive folder. Ethics approval was obtained from the Cardiff School of Sport & Health Sciences. Participants were informed of their rights to withdraw at any time before submission.

Materials and Procedure

GRAS

This scale evaluates GRA through 20 items on a Likert-type scale of 5 response alternatives (García-Cueto et al., 2015), where 1 means “totally disagree” and 5 “totally agree” ($\alpha = 0.877$). For example: “Boys have the same obligations to help with household chores as girls.”

A “Who-does-what?” Measure

This measure of task performance ($\alpha=0.95$), assessed The "Who-does-what?" measure assesses DDL with 24 tasks, asking participants to indicate which partner performs each task on a 5-point scale, from 1 ("almost always my partner") to 5 ("almost always myself") (Gaunt & Pinho, 2018; Gaunt & Scott, 2014; $\alpha = 0.95$). A sample item includes “In the division of labour between you and your partner, who usually does the cooking?” Non-applicable tasks were treated as missing data and handled through series imputation.

SWML

This scale developed by Ward et al. (2009), consisted of 5 items, requiring participants to agree or disagree with statements about married life such as “I am very satisfied with my marriage” on a seven-point scale, from 1 (strongly disagree) to 7 (strongly agree; $\alpha = 0.97$).

Results

Demographic Characteristics of the Sample

The study included 109 participants (42 males and 67 females). The mean age was 32.88 years ($SD = 6.35$), with a mean marital duration of 8.35 years ($SD = 6.17$). Participants had an average of 2.12 children ($SD = 2.96$), with the youngest child's mean age being 3.84 years ($SD = 4.35$). Gender and employment distributions showed that all male participants were employed, while among females, 58.2% reported unemployment. Educational attainment highlighted a gender disparity, with females predominantly holding Bachelor's degrees, while PhD holders were exclusively male.

Preliminary Analyses

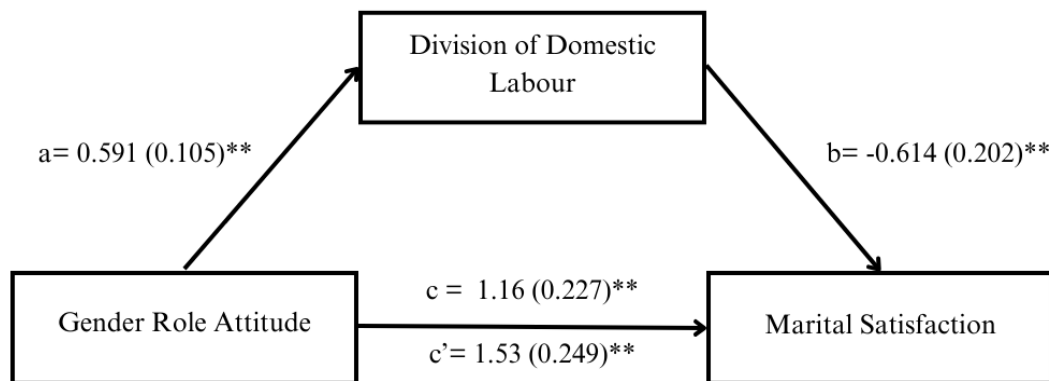
Tests for normality revealed that while GRA and DDL were approximately normally distributed (-0.334 ($SE = 0.231$), -0.406 ($SE = 0.231$) respectively), MS exhibited significant negative skewness -1.041 ($SE = 0.231$), supported by Shapiro-Wilk tests. Despite deviations from normality, parametric tests were used due to their robustness against moderate violations (Knief & Forstmeier, 2021).

Confirmatory Analyses

Hypothesis 1 (Mediation Analysis):

Mediation analysis using the PROCESS macro indicated that DDL partially mediated the relationship between GRA and MS. Egalitarian GRA positively influenced MS ($B=1.16$, $p < .001$), but unequal DDL negatively impacted MS ($B=-0.36$, $CI[-0.69, -0.09]$). This suggests that egalitarian attitudes enhance MS but are undermined by persistent imbalances in domestic responsibilities (Figure 1).

Figure 1: Simple Mediation Diagram



Hypothesis 2 (Gender Differences in DDL):

An independent samples t-test revealed significant gender differences in DDL ($t=-12.3$, $p<.001$). Women ($M=3.64$, $SD=0.44$) reported performing a substantially higher proportion of household and childcare tasks compared to men ($M=2.37$, $SD=0.57$) with a mean difference of -1.34.

Hypothesis 3 (Employment and Task Division):

Analysis showed that employed women carried a disproportionate share of domestic tasks compared to employed men, underscoring gendered labour patterns even among dual-income households (Table 1).

Table 1: DDL Scores by Employment Status and Gender

Group	n	M	SD	t	df	p	Mean Difference
Employed Men	42	2.37	0.57	-9.78	68	<0.001	-1.27
Employed Women	28	3.64	0.46				

Exploratory Analyses

Education and Gender Role Attitudes (GRA):

A one-way ANOVA revealed significant differences in GRA across educational levels, $F(5,103) = 5.19$, $p < .001$, $\eta^2 = 0.201$. Post hoc analyses indicated that participants with advanced levels of education exhibited less traditional GRA, particularly when compared to those holding a Master's degree.

Duration of Marriage and Division of Domestic Labour (DDL):

A marginally significant positive correlation was found between marital duration and DDL ($r = 0.190$, $p = .047$), suggesting that task distribution becomes slightly more equitable with longer marriages.

Employment Status and Marital Satisfaction (MS):

A Mann-Whitney U test showed no significant differences in MS between employed and unemployed women ($U = 544.50$, $z = -0.02$, $p = .985$).

Discussion

Impact of Education on Gender Role Attitudes

Sri Lanka has made notable progress in female literacy, reflecting efforts to enhance education and gender equality. The current study finds that higher educational attainment, especially a bachelor's degree or more, is linked to more egalitarian GRA supporting prior research like Rivera-Garrido (2022). However, a Spanish study (Merma-Molina et al., 2022) suggests that traditional GRA persist despite higher education, indicating that education alone cannot eliminate gender stereotypes. Cultural norms, societal expectations, and socialization processes also play key roles in maintaining these stereotypes, limiting personal growth and career opportunities. Addressing these factors is vital for promoting social equity.

Associations between Gender Role Attitudes, Division of Domestic Labour, and Marital Satisfaction

Results demonstrated that egalitarian GRA are directly associated with a more equitable DDL and higher MS. However, unequal DDL negatively affected MS, even among those with progressive attitudes. The partial mediation effect of DDL underscores the necessity for practical, equitable sharing of household responsibilities to realize the benefits of egalitarian ideologies on marital well-being. These findings align with Pinho and Quant (2021) and Pekel-Uludağlı (2019), emphasizing that progressive attitudes must translate into equitable practices.

Theoretical Implications for Social Exchange Theory

The findings align with Social Exchange Theory (SET), which emphasizes fairness and reciprocity in relationships. Egalitarian GRA promote equitable DDL, enhancing perceived rewards and satisfaction for both partners. Conversely, unequal DDL reduces satisfaction by imposing emotional and physical burdens on one partner. Practical changes in task-sharing, beyond attitudinal shifts, are essential for fostering mutual support and intimacy, critical components of MS (Blom et al., 2017).

Strengths and Limitations of the Study

While the study provided valuable insights, its generalizability is limited by the smaller sample size and lower participation of fathers. Future research should adopt dyadic approaches and mixed methods to capture more nuanced dynamics. Despite these limitations, the study contributes to understanding how cultural, educational, and structural factors influence DDL and MS in a South Asian context.

Conclusions and Recommendations

This study highlights that traditional GRA contribute to an unequal DDL in Sri Lankan households, negatively affecting MS. Egalitarian attitudes improve fairness perceptions but must be reflected in domestic practices. To address gender inequalities, interventions should bridge the gap between attitudes and behaviors, with public policies promoting gender equality and employers offering flexible work options for working mothers. Future research should

involve diverse participants and explore the evolution of gender roles and domestic labor through longitudinal and qualitative methods.

References

- Blom, N., Kraaykamp, G. and Verbakel, E. (2017) 'Couples' division of employment and household chores and relationship satisfaction: A test of the specialization and equity hypotheses', *European Sociological Review*, 33(2), pp. 195–208. Available at: <https://doi.org/10.1093/esr/jcw057>
- Chen, I. J., Wang, X., Sun, Z., Tang, P. and Chen, P. (2024) 'Intergenerational transmission of parental child-rearing gender-role attitudes and its influence on gender roles in single-parent families', *BMC Psychology*, 12(1), p. 96. Available at: <https://doi.org/10.1186/s40359-024-01594-z>
- Emerson, R. M. (1987) *Social exchange theory*.
- García-Cueto, E., Rodríguez-Díaz, F. J., Bringas-Molleda, C., López-Cepero, J., Paíno-Quesada, S. and Rodríguez-Franco, L. (2015) 'Development of the gender role attitudes scale (GRAS) amongst young Spanish people', *International Journal of Clinical and Health Psychology*, 15(1), pp. 61–68. Available at: <https://doi.org/10.1016/j.ijchp.2014.10.004>
- Gaunt, R. and Pinho, M. (2018) 'Do sexist mothers change more diapers? Ambivalent sexism, maternal gatekeeping and the division of childcare', *Sex Roles*, 79(3–4), pp. 176–189. Available at: <https://doi.org/10.1007/s11199-017-0864-6>
- Gaunt, R. and Scott, J. (2014) 'Parents' involvement in childcare: Do parental and work identities matter?', *Psychology of Women Quarterly*, 38(4), pp. 475–489. Available at: <https://doi.org/10.1177/0361684314533484>
- Gerson, K. (2010) *The unfinished revolution: How a new generation is reshaping family, work, and gender in America* (Vol. 16). New York: Oxford University Press.
- Hayes, A. F. (2018) 'Partial, conditional, and moderated mediation: Quantification, inference, and interpretation', *Communication Monographs*, 85(1), pp. 4–40. Available at: <https://doi.org/10.1080/03637751.2017.1352100>
- Herath, H. M. A. (2015) 'Place of women in Sri Lankan society: measures for their empowerment for development and good governance', *Vidyodaya Journal of Management*, 1(1). Available at: <https://doi.org/10.31357/vjm.v1i1.3650>
- Jayatileke, A., Poudel, K. C., Sakisaka, K., Yasuoka, J., Jayatileke, A. U. and Jimba, M. (2011) 'Wives' attitudes toward gender roles and their experience of intimate partner violence by husbands in Central Province, Sri Lanka', *Journal of Interpersonal Violence*, 26(3), pp. 414–432. Available at: <https://doi.org/10.1177/0886260510363420>
- Knief, U. and Forstmeier, W. (2021) 'Violating the normality assumption may be the lesser of two evils', *Behavior Research Methods*, 53(6), pp. 2576–2590.

Merma-Molina, G., Ávalos-Ramos, M. A. and Martínez Ruiz, M. Á. (2022) ‘Gender stereotypes: persistence and challenges’, *Equality, Diversity and Inclusion: An International Journal*, 41(7), pp. 1112–1135. Available at: <https://doi.org/10.1108/EDI-12-2018-0229>

Pekel-Uludağlı, N. (2019) ‘Are uninvolved fathers really incompetent and unsatisfied? Testing the mediator role of father involvement from fathers’ perspectives’, *European Journal of Developmental Psychology*, 16(5), pp. 538–551. Available at: <https://doi.org/10.1080/17405629.2018.1472077>

Pinho, M. and Gaunt, R. (2021) ‘Biological essentialism, gender ideologies, and the division of housework and childcare: Comparing male carer/female breadwinner and traditional families’, *The Journal of Social Psychology*. Available at: <https://doi.org/10.1080/00224545.2021.1983508>

Rivera-Garrido, N. (2022) ‘Can education reduce traditional gender role attitudes?’, *Economics of Education Review*, 89, p. 102261. Available at: <https://doi.org/10.1016/j.econedurev.2022.102261>

Tiwari, D. A. (2016) ‘Dual Career Couples and Their Work Life Balance’, *International Journal of Human Resources and Industrial Research*, pp. 49–55.

Ward, P. J., Lundberg, N. R., Zabriskie, R. B. and Berrett, K. (2009) ‘Measuring marital satisfaction: A comparison of the revised dyadic adjustment scale and the satisfaction with married life scale’, *Marriage & Family Review*, 45(4), pp. 412–429. Available at: <https://doi.org/10.1080/01494920902828219>

THE RELATIONSHIP BETWEEN EMPATHY, MORAL IDENTITY, AND PROSOCIAL BEHAVIOUR AMONG YOUNG ADULTS IN SRI LANKA

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Abstract

This study aims to discover whether empathy and moral identity are predictors of prosocial behavior among young adults in Sri Lanka. A non-experimental, quantitative design was utilized in this study. The sample included 87 healthy young adults aged 18 to 26 years. The main findings of the quantile regression analysis indicated that although in lower quantiles of 0.25 and 0.50 empathy acted as a stronger predictor of prosocial behaviour than moral identity, at the highest quantile (0.75) moral identity acted as a stronger predictor of prosocial behaviour than empathy. Therefore, the results within the lower quantiles of 0.25 and 0.50 aligned with the Empathy-Altruism hypothesis. Further, when the two aspects of moral identity; moral self and moral integrity were compared the moral self predicted prosocial behavior rather than moral integrity throughout the quantiles of 0.25, 0.50, and 0.75.

Keywords: Empathy, Moral identity, Moral integrity, Moral self, Prosocial behavior

Introduction

Prosocial behaviours are linked with desirable social outcomes (Zhan et al., 2023), mental health (Carlo, 2013), emotional well-being (Raposa et al., 2016), and physical health outcomes (Scherier et al., 2013). Prosocial behaviours refer to voluntary, intentional behaviour that benefits another person (Lay & Hoppmann, 2015) and include helping, sharing, comforting, cooperating, donating, and volunteering (Zhan et al., 2023). The World Giving Index ranked Sri Lanka in 21st place out of 135 countries in 2023, and out of adults, 69% helped a stranger, 34% donated money, and 43% volunteered (Charities Aid Foundation, 2023). Therefore, it is significant to investigate the predictors of highly reported prosocial behaviours in Sri Lanka compared to other countries.

Young Adulthood spans the age from 18 to 26 (Bonnie, 2015), and it is important to identify the role of prosociality in young adulthood as it is a life stage where social roles change diversely (Farrington et al., 2012). Moreover, the World Giving Index has chosen individuals over 15 years old as adults for their sample population (Charities Aid Foundation, 2023)

Hence the prosocial behaviours of young adults have not been captured specifically. Therefore, this study uses empathy and moral identity as predictors and determines to which extent they predict prosocial behaviors to discover the underpinnings of increasingly reported prosocial behaviors among young adults in Sri Lanka.

The research objectives of this study were to assess whether there is empathy is a significant predictor of prosocial behaviour, whether moral identity is a significant predictor of prosocial behavior, whether empathy is a stronger predictor of prosocial behaviour than moral identity, whether moral identity adds an extra value beyond the effects of empathy alone in predicting prosocial behaviour, whether moral integrity is a stronger predictor than moral self in predicting prosocial behavior among young adults in Sri Lanka and to provide insights into the practical implications of the findings.

The hypotheses of the present research are as follows;

H1: Empathy is positively related to prosocial behaviour among young adults in Sri Lanka.

H2: Moral identity is positively related to prosocial behaviour among young adults in Sri Lanka.

Methodology

A cross-sectional study design was utilized in this study. The data were collected from 87 young adults aged 18-26 years (Bonnie, 2015) who could comprehend English or Sinhala languages and live in the Western Province, of Sri Lanka. Exclusion criteria included self-reported current or previous neurological, neurodevelopmental, psychiatric, or psychological disorders. It is due to the existence of theory of mind (ToM) deficits in a variety of neurological, psychiatric (Abdel-Hamid et al., 2019), psychological disorders (e.g., social anxiety disorder; Hezel & McNally, 2014), and neurodevelopmental disorders such as Attention Deficit and Hyperactivity Disorder (Mary et al., 2016) which may result in a reduced empathic response (Dvash & Shamay-Tsoory, 2014) and also influence moral reasoning (Spenser et al., 2020) which may affect moral identity.

Convenience sampling, a non-probability sampling technique, was used to recruit participants due to cost-effectiveness and limited time constraints (Obilor, 2023). Empathy was assessed using the Toronto Empathy Questionnaire (TEQ) (Spreng et al., 2009), moral identity was evaluated using the Moral Identity Questionnaire (MIQ) (Black & Reynolds, 2016), and prosocial behaviour was assessed using the Prosocialness scale for adults (PSA) (Caprara et al., 2005). All three questionnaires were translated into Sinhala, and the participants were given the opportunity to fill out the survey in both English and Sinhala. Data were analyzed using quantile regression analysis.

The translation process

The questionnaires were administered in both the languages English and Sinhala. Considering that Sinhala is one of the official languages in Sri Lanka (Department of Official Languages, 2024) and that 84.2% of the Western Province is Sinhalese (Department of Census and Statistics, 2012) the questionnaires were translated into Sinhala. The 3 questionnaires; TEQ, MIQ, and PSA were translated into Sinhala after obtaining permission from the authors. The modified delphi technique (Weerasinghe et al., 2023) was utilized to assess the content validity and consensual validity of the translated Sinhala questionnaires. The steps of the delphi study were; (I) initial translation, (II) synthesis of the translation (III) back translation,

(IV) delphi review administered by the expert committee, and (V) testing the pre-final version (Weerasinghe et al., 2023). The delphi panel consisted of six professionals in the psychology field including two clinical psychologists, one senior psychotherapist, and counsellor, one counselor and trainer, one old age psychiatrist, and one child and adolescent psychologist.

Results

Total of 87 responses were included in the analysis and out of it 63 participants have responded using the English survey and 24 participants have responded using the Sinhala survey. The results of the descriptive analysis of the main variables are shown in Table 1 below.

Table 1: Descriptive Statistics of the Measures

Measure	N	Mean	Median	Mode	Std. Deviation	Kurtosis	Skewness
TEQ	87	3.90	3.88	3.88 ^a	0.41	-0.317	0.101
MIQ	87	4.02	4.05	4.05	0.47	-0.027	-0.537
PSA	87	4.06	4.12	4.12	0.57	-1.060	-0.120

Note. a. Multiple modes exist. The smallest value is shown.

The Kolmogorov- Smirnov test was administered to evaluate the normality of the data distribution. Referring to the significance values mentioned in Table 2 below, TEQ and PSA are normally distributed as the significance level (p-value) is above 0.05. Yet, MIQ is not normally distributed as the p-value is below 0.50. Therefore, the quantile regression analysis a non-parametric test was administered as the normality testing and the other assumptions to conduct a multiple linear regression were not satisfied.

Table 2: Kolmogorov- Smirnov Test

Test	Statistic	df	Sig.
TEQ	0.058	87	.200*
MIQ	0.112	87	.009
PSA	0.090	87	0.78

Note. * This is a lower bound of the true significance.

a. Lillefors Significance Correction

Quantile regressions were administered for empathy and moral identity separately at the quantiles 0.25, 0.50, and 0.75. There is a statistically significant positive relationship between empathy and prosocial Behaviour throughout 0.25, 0.50, and 0.75 quantiles. Also, there is a statistically significant positive relationship between moral identity and prosocial behaviour through all the quantiles 0.25, 0.50, and 0.75. Further, the results suggest that at lower quantiles (0.25 and 0.50) empathy acts as a stronger predictor of prosocial behaviour than moral identity. However, at the higher quantile (0.75) moral identity acts as a stronger predictor of prosocial behaviour than Empathy. Considering the results of the separate and combined analysis of moral integrity and moral self it is clear that in all the quantiles (0.25, 0.50, and 0.75), in both the separate and combined analysis moral self is a stronger predictor of prosocial behaviour than moral integrity.

Discussion

A Plethora of research evidence has determined that there is a significant positive relationship between empathy and prosocial behavior (e.g., Lockwood, 2014; Eisenberg, 2010) which was evident in the current research. There are many similar aspects between the present study and the research of Lockwood (2014). The sample population of Lockwood (2014) has utilized one hundred and ten healthy adults aged 18 to 33 and has excluded participants with self-reported previous or current neurological or psychiatric disorders which is similar to the characteristics of the present study sample which also has excluded individuals with self-reported current or previous psychological, psychiatric, neurological and neurodevelopmental disorders. Although Lockwood (2014) conducted his study in the United Kingdom which holds a western culture (Kersten, 2014) the results were not varied from the present study, although Sri Lanka holds a collectivistic culture (Irfan, 2016) suggesting that empathy is a strong predictor of prosocial behaviour among diverse cultural contexts.

Moreover, in the present research moral identity was identified as a stronger predictor of prosocial behaviour which also has been evidenced in both correlational and experimental studies (Krettenauer & Casey, 2015; Hertz & Krettenauer, 2016). In contrast, to the findings of the current research, Leng et al. (2020) discovered that moral identity and empathic concern were less significant mediators in the relationship between prosocial behaviour personality and online prosocial behaviours, whereas, perspective taking, social self-efficacy significantly mediated the relationship between prosocial behaviour personality and online prosocial behaviour. Therefore, the results of the Leng et al. (2020) study and the current study may not apply to online prosocial behaviours due to fewer face-to-face interactions (Leng et al., 2020).

Conclusions and Recommendations

The main findings of the quantile regression analysis indicated that there is a significant positive relationship between empathy and prosocial behaviour and also between moral identity and prosocial behaviour. Further, it was identified that although in lower quantiles of 0.25 and 0.50 empathy acted as a stronger predictor of prosocial behaviour than moral identity, at the highest quantile (0.75) moral identity acted as a stronger predictor of prosocial

behaviour than empathy. Therefore, the results within the lower quantiles of 0.25 and 0.50 aligned with the Empathy-Altruism hypothesis. Further, when the two aspects of moral identity; moral self and moral integrity were compared the moral self predicted prosocial behaviour rather than moral integrity throughout the quantiles of 0.25, 0.50, and 0.75.

The current research findings can be utilized to implement intervention programs to improve prosocial behaviours among young adults in Sri Lanka; e.g., in universities where the majority of the young adult population can find out. Further, it is recommended to conduct future research on identifying whether empathy and moral identity would predict prosocial behaviour among the young adult population who has neurological, neurodevelopmental, psychiatric, and psychological disorders as the current study utilized healthy young adults.

References

- Black, J.E. and Reynolds, W.M. (2016) 'Development, reliability, and validity of the Moral Identity Questionnaire,' *Personality and Individual Differences*, 97, pp. 120–129.
<https://doi.org/10.1016/j.paid.2016.03.041>.
- Caprara, G.V. *et al.* (2005) 'A new scale for measuring adults' prosocialness,' *European Journal of Psychological Assessment*, 21(2), pp. 77–89.
<https://doi.org/10.1027/1015-5759.21.2.77>.
- Charities Aid Foundation (no date) *World Giving Index* |CAF.
<https://www.cafonline.org/about-us/research/caf-world-giving-index>.
- Bonnie, R.J. *et al.* (2015) *Introduction*.
<https://www.ncbi.nlm.nih.gov/books/NBK284791/>.
- Dvash, J. and Shamay-Tsoory, S.G. (2014) 'Theory of mind and empathy as multidimensional constructs,' *Topics in Language Disorders*, 34(4), pp. 282–295.
<https://doi.org/10.1097/tld.000000000000040>.
- Leng, J. *et al.* (2020) 'Bridging personality and online prosocial behavior: the roles of empathy, moral identity, and Social Self-Efficacy,' *Frontiers in Psychology*, 11. <https://doi.org/10.3389/fpsyg.2020.575053>.
- Lockwood, P.L., Seara-Cardoso, A. and Viding, E. (2014) 'Emotion Regulation Moderates the Association between Empathy and Prosocial Behavior,' *PLoS ONE*, 9(5), p. e96555. <https://doi.org/10.1371/journal.pone.0096555>.
- Spreng, R.N. *et al.* (2008) 'The Toronto Empathy Questionnaire: Scale development and Initial Validation of a Factor-Analytic Solution to Multiple Empathy Measures,' *Journal of Personality Assessment*, 91(1), pp. 62–71. <https://doi.org/10.1080/00223890802484381>.
- Zhan, Q. *et al.* (2023) 'Revision and validation of the prosocialness scale for adults (PSA) among chinese college students,' *BMC Psychology*, 11(1).
<https://doi.org/10.1186/s40359-023-01124-3>.

EXPLORING DIFFERENCES IN PUBLIC MENTAL HEALTH STIGMA AND HELP-SEEKING BEHAVIOR: THE MODERATING ROLE OF MASCULINE AND FEMININE TRAITS

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Abstract

This study examines public mental health stigma and help-seeking behavior, focusing on differences between biological sexes and geographic locations, as well as the moderating influence of masculine and feminine traits. Data were collected from 86 undergraduate students (69 females, 17 males) residing in Colombo and Kandy using self-reported online surveys, including the Attribution Questionnaire, General Help-Seeking Questionnaire, and Personality Attributes Questionnaire. Independent sample t-tests revealed no significant differences in stigma scores between males and females or between participants from Colombo and Kandy ($p > .05$). However, Mann-Whitney U tests indicated significant differences in total help-seeking behavior scores by sex and location ($p < .05$).

Quantile regression analyses showed that neither masculine nor feminine traits had statistically significant effects on stigma scores across quantiles. Nonetheless, trends suggested that higher masculine traits were associated with greater stigma, particularly at the 75th quantile ($\beta = 0.285$), while higher feminine traits were linked to lower stigma ($\beta = -0.360$) at the same quantile. These findings highlight the complex relationships between sex, gender traits, and mental health outcomes. These insights emphasize the need for further research and the importance for gender-sensitive interventions to reduce stigma and promote help-seeking behavior in diverse populations.

Keywords: Biological Sex, Feminine Traits, Gender Differences, Help-Seeking Behavior, Masculine Traits, Mental Health Stigma

Introduction

Mental health issues account for a substantial portion of the global disease burden, affecting millions worldwide. According to the World Health Organization (2021), approximately 450 million people experience mental or behavioral disorders at any given time. Despite increased awareness, stigma remains a pervasive barrier to seeking mental health care, contributing to long-term suffering and adverse outcomes (Thornicroft, 2006). Stigma encompasses negative attitudes, beliefs, and stereotypes toward individuals experiencing mental health challenges, often resulting in discrimination and social exclusion (Corrigan & Watson, 2002). Internalized stigma, or self-stigma, further compounds the issue by leading individuals to feel worthless and helpless (Link & Phelan, 2001). Help-seeking behavior, defined as the act of seeking formal or

informal support for mental health concerns, is influenced by stigma, resource accessibility, cultural beliefs, and individual preferences (Rickwood et al., 2005).

The dynamics of mental health issues among men are influenced by the complex interplay of masculine and feminine traits, with men fearing societal judgment and traditional masculine norms like self-reliance and emotional restraint potentially discouraging them from seeking help and acknowledging their struggles (Clement et al., 2015). Understanding how public mental health stigma and help-seeking behaviors differ between genders, specifically biological male and female participants, and how they are moderated by masculine and feminine traits is essential for developing targeted interventions to reduce restraints to mental health care.

Research Question and Hypothesis

The aim of this research is to explore the relationships between biological sex, gender traits, mental health stigma, and help-seeking behaviors. To guide this investigation, the following research questions have been formulated:

Research Question 1:

Is there a significant difference in public mental health stigma and help-seeking behaviors between men and women?

To address this research question, the following alternate and null hypotheses have been formulated:

Alternate Hypothesis (H_1):

There is a significant difference in public mental health stigma and help-seeking behaviors between men and women.

Null Hypothesis (H_0):

There is no significant difference in public mental health stigma and help-seeking behaviors between men and women.

Research Question 2:

Do masculine and feminine traits moderate this difference in public mental health stigma and help-seeking behaviors between men and women?

To address this research question, the following alternate and null hypotheses have been formulated:

Alternate Hypothesis (H_1):

Masculine and feminine traits moderate this difference in public mental health stigma and help-seeking behaviors between men and women.

Null Hypothesis (H_0):

Masculine and feminine traits do not moderate this difference in public mental health stigma and help-seeking behaviors between men and women.

Research objectives

This study explores public mental health stigma and help-seeking behavior across biological sexes, focusing on the moderating influence of masculine and feminine traits in the Sri Lankan context. By addressing gendered perceptions and behaviors, this research contributes to the broader discourse on mental health, challenging traditional gender norms and promoting flexibility in gender expression. Furthermore, the study adds to the growing body of literature by offering nuanced insights into the intersection of gender, stigma, and help-seeking behaviors, emphasizing the need for culturally sensitive and gender-responsive mental health interventions in Sri Lanka.

Methodology

Participants and Design

This quantitative study employed a cross-sectional survey design. The target sample size was 128 undergraduate students, with an equal distribution of 64 males and 64 females. This sample size was determined using G*Power analysis to ensure sufficient statistical power for detecting differences and interactions between groups. However, the final sample consisted of 86 participants (69 females, 17 males), due to limited time constraints. Convenience sampling was used to find volunteers because it made it simple to find people who were willing and able to take part, which reduced both the time and expense of the process.

Materials and Procedure

Three validated scales were used in this study to measure key variables. The Attribution Questionnaire (AQ-27), created by Corrigan et al. (2003), a 27-item scale, assessed public mental health stigma across nine subscales (e.g., Help, Blame, Fear) using a 9-point Likert scale (1 = strongly disagree, 9 = strongly agree), with Cronbach's alpha values exceeding 0.70 in previous studies. Wilson et al. (2005) created the General Help-Seeking Questionnaire (GHSQ) evaluated help-seeking intentions for emotional problems and suicidal ideation, with participants rating their likelihood of seeking help from various sources on a 7-point Likert scale (1 = extremely unlikely, 7 = extremely likely); the scale has demonstrated strong reliability (Cronbach's alpha > 0.80). The Personality Attributes Questionnaire (PAQ), created by Spence et al. (1974), a 24-item scale, measured masculine and feminine traits across three dimensions (Masculinity, Femininity, Masculinity-Femininity) on a 5-point Likert scale (1 = not at all true of me, 5 = very true of me), showing high internal consistency with alpha values ranging from 0.70 to 0.85. Participants completed the online survey in 15–20 minutes, with informed consent obtained beforehand, ensuring confidentiality and the voluntary nature of participation.

Ethical Considerations

Ethical approval was obtained prior to data collection. Given the sensitive nature of the study, including questions about mental health and suicidal ideation, participants were provided with a list of mental health resources and hotlines at the end of the survey. Measures were taken to ensure confidentiality, and participants could withdraw at any time without penalty.

Data Analysis

Data were analyzed using SPSS- 28 software. Independent sample t-tests were conducted to compare stigma and help-seeking behaviors across sexes and locations. Mann-Whitney U tests were used for non-normally distributed help-seeking scores. Additionally, Quantile regression was performed to investigate the influence of masculine and feminine traits on stigma scores across different quantiles.

Results

The study aimed to examine the impact of gender differences (biological sex) and the moderating effects of masculine and feminine traits on public mental health stigma and help-seeking behaviors. The analysis was conducted using SPSS.

Descriptive Statistics

Descriptive statistics were calculated for stigma, help-seeking behavior, and masculine and feminine traits. The mean stigma score for male participants ($M = 4.26$, $SD = 0.88$) was slightly higher than that of female participants ($M = 4.04$, $SD = 0.86$), although this difference was not statistically significant ($t(84) = 0.941$, $p = 0.350$). Participants from Colombo and Kandy exhibited similar stigma scores, with no significant difference ($t(77) = 0.257$, $p = 0.798$). The mean help-seeking behavior score for male participants ($M = 3.57$, $SD = 1.15$) was lower than that for female participants ($M = 4.01$, $SD = 0.98$). This difference was significant according to the Mann-Whitney U test ($U = 399.500$, $p = 0.043$). A similar pattern was found between participants from Colombo and Kandy, with those from Kandy showing lower help-seeking tendencies ($U = 390.000$, $p = 0.002$).

Inferential Statistics

Independent samples t-tests (See Table 1) revealed no significant difference in stigma scores between male and female participants ($t(84) = 0.941$, $p = 0.350$), and no significant difference was found between participants from Colombo and Kandy ($t(77) = 0.257$, $p = 0.798$). In contrast, Mann-Whitney U tests (See Table 2) showed significant gender differences in help-seeking behavior ($U = 399.500$, $p = 0.043$), with females demonstrating higher tendencies to seek help. Additionally, significant differences were observed between participants from Colombo and Kandy ($U = 390.000$, $p = 0.002$), with those from Kandy showing lower help-seeking behavior scores compared to their Colombo counterparts. These findings highlight the impact of gender and geographical factors on help-seeking behavior.

Table 1: *Independent Sample Test*

	Levene's Test p values	Equality of Means	Significance Two-Sided p values
Biological Sex	0.777	t (84) = 0.941	0.350
Districts	0.713	t (77) = 0.257	0.798

Table 2: Mann-Whitney Test

Help-Seeking Behavior	Mean Help-Seeking Scores
Biological Sex	0.043
Districts	0.002

Quantile regression was employed to explore the moderating effects of masculine and feminine traits on stigma and help-seeking behavior. The independent variables (IV) in the analysis were masculine and feminine traits, and the dependent variables (DV) were stigma scores and help-seeking behavior scores. The interaction terms, which serve as the moderator in this analysis, were tested at various quantiles ($q = 0.1, 0.25, 0.5, 0.75, 0.9$) for both stigma and help-seeking behaviors.

For stigma scores, trends indicated a positive relationship between masculine traits and stigma, particularly at the 75th quantile ($\beta = 0.285$), and a negative relationship between feminine traits and stigma ($\beta = -0.360$) at the same quantile. However, none of these relationships were statistically significant ($p > 0.05$), suggesting that while there are patterns, no moderation effect was observed.

For help-seeking behavior, no statistically significant relationships were found between masculine or feminine traits and help-seeking across all quantiles. Although trends indicated that feminine traits had a slightly positive association with help-seeking behavior, the interaction terms did not reach statistical significance.

Table 3: Quantile Regression Analysis for Stigma Scores across Quantiles

Quantiles (q)	Masculine Trait (p value)	Masculine Trait (Estimate)	Feminine Trait (p value)	Feminine Trait (Estimate)
q= 0.1	0.906	0.049	0.830	-.099
q= 0.25	0.833	0.070	0.638	-0.172
q= 0.5	0.700	0.120	0.537	-0.212
q= 0.75	0.309	0.285	0.243	-0.360
q= 0.9	0.601	0.170	0.700	-0.138

Table 4: Quantile Regression Analysis for Help-Seeking Scores across Quantiles

Quantiles (q)	Masculine Trait (p value)	Masculine Trait (Estimate)	Feminine Trait (p value)	Feminine Trait (Estimate)
q= 0.1	0.646	0.364	0.452	0.655
q= 0.25	0.685	0.229	0.290	0.657
q= 0.5	0.843	0.063	0.037	0.733
q= 0.75	0.327	0.259	0.331	0.282
q= 0.9	0.261	0.400	0.514	0.255

The results of the study reveal significant gender differences in help-seeking behavior, with female participants showing a higher tendency to seek help compared to males. Additionally, participants from Kandy exhibited lower help-seeking behaviors than those from Colombo.

However, the analysis of the moderating roles of masculine and feminine traits on stigma and help-seeking behavior provided limited evidence for statistically significant moderation effects. However, results suggest that masculine traits are associated with higher stigma and feminine traits with lower stigma, these effects were not significant across the quantiles analyzed. These findings emphasize the complex nature of stigma and help-seeking behavior, with further research needed to explore potential interactions more deeply.

Discussion

The key findings of this study provide insights into the relationships between biological sex, geographic location, and public mental health stigma, help-seeking behavior, and gender traits. Descriptive statistics revealed that the sample was predominantly female (69 out of 86 participants), with most participants from Colombo (53) and the remaining 26 from Kandy. The total stigma score had a mean of 110.45, and the mean help-seeking behavior score was 76.69. Independent samples t-tests revealed no significant differences in stigma scores between males and females ($p > .05$) or between participants from Colombo and Kandy ($p > .05$). However, Mann-Whitney U tests showed significant gender differences in help-seeking behavior ($p = 0.043$) and between districts ($p = 0.002$), with females and participants from Colombo showing higher tendencies to seek help compared to males and those from Kandy. These findings suggest that geographic location and biological sex influence help-seeking behavior but not stigma.

Quantile regression analysis revealed trends where masculine traits were associated with higher stigma levels, while feminine traits seemed to reduce stigma at higher levels. However, these effects were not statistically significant. Regarding help-seeking behavior, higher masculine traits were linked to a reduced likelihood of seeking help, particularly at the higher quantiles, while higher feminine traits were associated with increased help-seeking behavior, although these findings were also not statistically significant. These trends indicate the potential moderating role of gender traits in stigma and help-seeking behavior, though the lack of statistical significance prevents definitive conclusions.

The study's findings both support and challenge existing research on stigma, help-seeking behavior, and the influence of masculine and feminine traits. While no significant gender differences in stigma were found, contradicting previous studies that suggest men are more likely to express stigma (e.g., Arora et al., 2016; Wendt & Shafer, 2015), the lack of differences may be due to factors like sample size or cultural influences. In contrast, significant gender differences were observed in help-seeking behavior, with women more likely to seek help for emotional problems and suicide ideation, aligning with past research (e.g., Cheng et al., 2018). Societal expectations and cultural factors may contribute to these differences. The study also found trends linking masculine traits to higher stigma and a greater likelihood of seeking help, while feminine traits were associated with lower stigma but less help-seeking, although these effects were not statistically significant. These findings are consistent with previous work on the influence of gender norms on help-seeking behavior (e.g., Staiger et al., 2020; Mahalik et al., 2003). Finally, regional differences were noted, with participants from Kandy showing

lower help-seeking behavior, potentially due to cultural and socio-economic factors affecting mental health attitudes in the two districts.

The differences in help-seeking behavior between participants from Colombo and Kandy may be attributed to regional variations in cultural and socio-economic factors. Participants from Kandy showed lower help-seeking behavior, which could reflect disparities in mental health literacy, access to resources, or social norms in these regions.

The study's strengths include its focus on gender roles in mental health stigma and help-seeking behavior, particularly in Sri Lanka, and its comparison between culturally distinct districts. However, limitations include a small sample size, disproportionate gender representation, and the lack of confirmation about participants' educational status.

Future research should aim to address these limitations by increasing sample size, ensuring gender balance, and verifying participants' educational status. Expanding the scope to include diverse gender identities and geographic locations, and exploring other personality traits or social factors, would further enrich understanding of stigma and help-seeking behavior.

Conclusion

The study explored the relationship between biological sex, gender traits, mental health stigma, and help-seeking behavior among Sri Lankan undergraduate students. The findings revealed no significant differences in stigma levels between male and female participants, suggesting that the cultural context in Sri Lanka may not differentiate stigma along traditional gender lines. Women were more likely to seek help for emotional problems and suicide ideation, while men showed a reluctance to seek help, which may be influenced by societal expectations around masculinity and self-reliance. The analysis of gender traits indicated that adherence to masculine traits was associated with higher stigma, while more feminine traits were linked to lower stigma.

This study highlights the need for targeted interventions that consider both cultural and gendered factors to reduce stigma and encourage help-seeking behavior, particularly among men. Future research should further explore these relationships using larger and more diverse samples to inform policies and interventions aimed at improving mental health outcomes in different cultural settings.

References

- Addis, M. E., & Mahalik, J. R. (2003). *Men, masculinity, and the contexts of help seeking. American psychologist*, 58(1), 5–14. <https://doi.org/10.1037/0003-066X.58.1.5>
- Arora, P. G., Metz, K., & Carlson, C. I. (2016). *Attitudes toward professional psychological help seeking in south Asian students: Role of stigma and gender. Journal of Multicultural Counselling and Development*, 44, 263-284
- Cheng, H., Wang, C., McDermott, R.C., Kridel, M., & Rislin, J. L. (2018). *Self-stigma, mental health literacy, and attitudes toward seeking psychological help. Journal of Counselling & Development*, 96, 64-74

Corrigan, P. W., & Watson, A. C. (2002). *The paradox of self-stigma and mental illness. Clinical Psychology: Science and Practice*, 9(1), 35–53.

Corrigan, P., Markowitz, F. E., Watson, A., Rowan, D., & Kubiak, M. A. (2003). *An attribution model of public discrimination towards persons with mental illness. Journal of health and social behavior*, 44(2), 162–179.

Clement S., Schauman O., Graham T., Maggioni F., Evans-Lacko S., Bezborodovs N., Morgan C., Rüsch N., Brown J., Thornicroft G. (2015). *What is the impact of mental health-related stigma on help-seeking? A systematic review of quantitative and qualitative studies. Psychological Medicine*, 45(1), 11–27. 10.1017/S0033291714000129

Link, B. G., & Phelan, J. C. (2001). *Conceptualizing stigma. Annual Review of Sociology*, 27(1), 363–385.

Rickwood, D. J., Deane, F. P., & Wilson, C. J. (2005). *When and how do young people seek professional help for mental health problems? The Medical Journal of Australia*, 183(7), S35-S39.

Staiger, Tobias; Stiawa, Maja; Mueller-Stierlin, Annabel Sandra; Kilian, Reinhold; Beschoner, Petra; GÄndel, Harald; Becker, Thomas; Frasch, Karel; Panzirsch, Maria; SchmauÄ, Max; Krumm, Silvia. (2020). *Masculinity and Help-Seeking Among Men with Depression: A Qualitative Study. Frontiers in Psychiatry*, 11(), 599039–. doi:10.3389/fpsy.2020.599039

Spence, Janet & Helmreich, Robert & Stapp, Joy. (1975). *Ratings of Self and Peers on Sex Role Attributes and Their Relation to Self-Esteem and Conceptions of Masculinity and Femininity. Journal of personality and social psychology*. 32. 29-39. 10.1037/h0076857.

Thornicroft, G. (2006). *Shunned: Discrimination against people with mental illness. Oxford University Press*.

Wendt, D., & Shafer, K. (2015). *Gender and attitudes about mental health help seeking: Results from national data. Health and Social Work*, 41(1), e20-e28.

Wilson, CJ, Deane, FP, Ciarrochi, J, and Rickwood, D. *Measuring help-seeking intentions: properties of the general help seeking questionnaire. Can J Couns.* (2005) 39:15–28.

World Health Organization. (2021). *Mental health*. https://www.who.int/health-topics/mental-health#tab=tab_1

MENSTRUATION MYTHS ON THE GIRLS/WOMEN IN YOUTH, SRI LANKA

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Abstract

Puberty is the period during which a girl's body and mind develop into those of a young adult. One significant milestone of puberty is menstruation. Sri Lanka has a multicultural society with various myths on menstruation. This research aims to review whether menstruation myths still persist among young girls and women in contemporary society. The research objectives are to identify the most prevalent myths on menstruation, to understand the impacts of myths on menstruation. This research is qualitative research and the data was gathered using secondary and primary data. The primary data was mainly collected through interviews by 50 respondents age between 15-29 in Dompe DSD through convenience sampling. The most prevalent myth on menstruation is sanitary products should be kept private and covered in paper when purchasing 78 %. And 74 % avoid certain foods such as oily and sour foods, 68% Showering or swimming during menstruation can stop bleeding, 64% girls should not talk about periods in public. There are psychological and physical impacts of these myths such as fosters stigma, reduced self-esteem, discourage personal hygiene, limiting access to proper education and support and vulnerability to abuse and exploitation of girls. Addressing these myths is essential to break the cycle of stigma associated with menstrual health, dignity and confidence with addressing greater gender equality and access to opportunities.

Keywords: *Menstruation Myths, Sri Lanka, Women, Youth*

Introduction

Menstruation is a natural biological process experienced by millions of women and girls worldwide, yet it remains shrouded in myths and misconceptions. In many places around the world, a girl's first period, called menarche. Menstruation, or period, is normal vaginal bleeding that occurs as part of a woman's monthly cycle. Every month, your body prepares for pregnancy. If no pregnancy occurs, the uterus, or womb, sheds its lining. The menstrual blood is partly blood and partly tissue from inside the uterus. It passes out of the body through the vagina. (National Library of Medicine, n.d.) Myth, a symbolic narrative, usually of unknown origin and at least partly traditional, that ostensibly relates actual events and that is especially associated with religious belief (Smith et al. 2024). These false beliefs, often rooted in cultural, social, and religious norms, contribute to stigma and discrimination, affecting the health, well-being, and empowerment of women. These myths perpetuate misinformation, limit access to accurate education, and hinder gender equality.

This research aims to identify the most prevalent myths on menstruation among girls /women in contemporary society, to understand the impacts of myths on menstruation and to suggest recommendations to enhance awareness on menstruation. As women are the backbone of societies this study mainly relates to achieving Gender Equality and Women's Empowerment as key objectives of development. Also this research lies in its ability to address cultural stigma, enhance health outcomes, and promote gender equality.

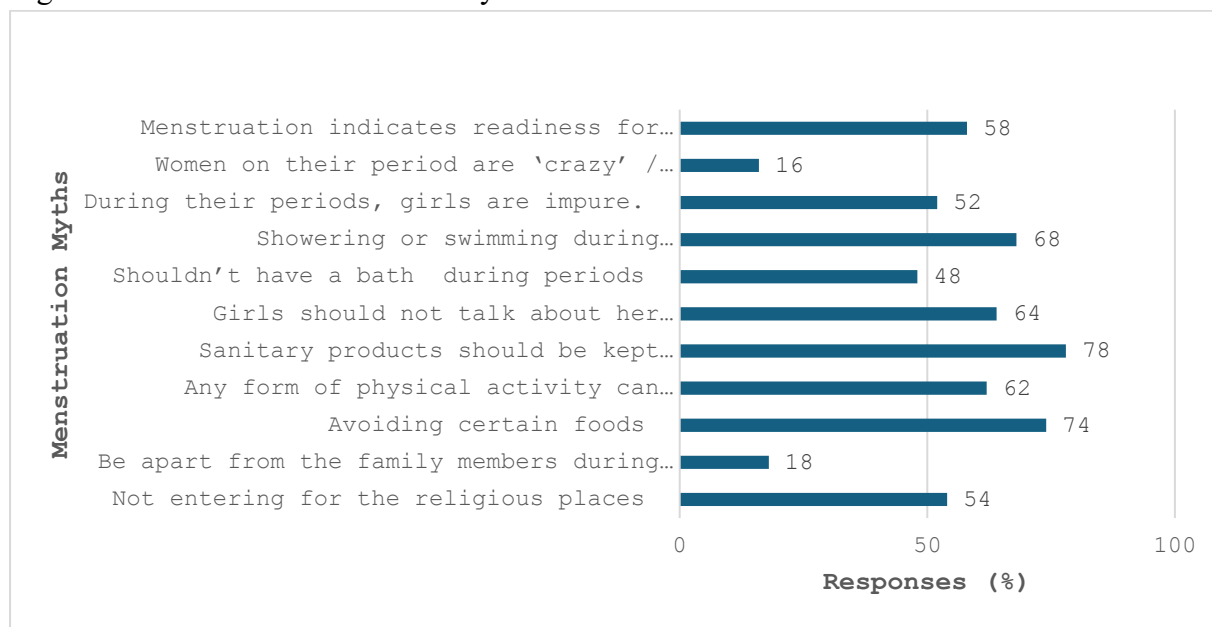
Methodology

This research is qualitative research which mainly consists of qualitative data with an inductive research approach. The data was gathered using secondary and primary data. Secondary data was gathered from various sources, including books, reports, academic journals, websites, and magazines. The primary data collection methods involved structured and semi-structured interviews, in-depth interviews, and telephone conversations. The data was collected by 50 respondents in the youth, aged between 15-29 in Dompe DSD through convenience sampling. The data was analyzed using thematic analysis.

Results and Discussion

These are the identified myths on menstruation among girls/ women in young age between 15-29 in Sri Lanka.

Figure 1: Believe on menstruation myths



Source : Field Survey, August, 2024

The most prevalent myth on menstruation among young women between 15-29 is Sanitary products should be kept private and covered in paper when purchasing 78 % still believe in that myth. And in order the most prevalent myths are, (which score more than 50 %) 74 % avoiding certain foods such as oily and sour foods, 68% Showering or swimming during menstruation can stop bleeding, 64% girls should not talk about periods in public. 62% of any form of physical activity can disturb the menstrual flow, 58% of menstruation indicates readiness for marriage and sex, 54% not entering religious places and 52% during their periods, girls are impure.

There are psychological and physical impacts of still believing in myths on menstruation. As identified these myths lead women's and girl's minds into stigma and shame. For example the idea that sanitary products should be kept private fosters stigma and embarrassment, leading to feelings of shame and reduced self-esteem. This can discourage girls from openly discussing menstrual health, thereby limiting access to proper education and support. Also discourage

personal hygiene, increasing the risk of infections discomfort during menstruation are some other impacts, specially related to the myth that showering or swimming can stop menstrual bleeding. These myths effect to prevent the ability to reach for more opportunities for girls. Such as Myths suggesting that physical activity disturbs menstrual flow can prevent girls from participating in sports or exercise. That reinforces gender stereotypes and denies them the health benefits of physical activity. These myths can increase unwanted attention, vulnerability to abuse and exploitation of gilrs and women. As example associating menstruation with readiness for marriage or sex perpetuates harmful gender norms and can lead to early marriages or unwanted attention.

These myths collectively limit educational and social opportunities for girls and contribute to their exclusion from various aspects of life. They also perpetuate systemic inequalities, leaving young women vulnerable to exploitation and diminished life prospects.

Conclusion and Recommendations

The persistence of menstruation myths among young girls/women aged 15-29 in Sri Lanka reveals a significant cultural and societal barrier on menstruation which is a very natural incident in female body. Addressing these myths is essential to breaking the cycle of stigma and discrimination associated with menstruation. By fostering open dialogue, promoting accurate education, and challenging harmful cultural norms, society can empower girls and women to embrace their menstrual health with dignity and confidence, paving the way for greater gender equality and access to opportunities.

This research highlights the urgent need for,

- Advocate for inclusive policies that address menstrual health and hygiene comprehensively.
- Implement educational reforms to integrate menstrual health and reproductive education into school curricula.
- Promote awareness of healthy menstrual practices through targeted campaigns and programs.
- Conduct community-based awareness initiatives on menstruation and reproductive health to challenge taboos and misconceptions.
- Organize community discussions, workshops, and outreach programs to address cultural taboos and misconceptions surrounding menstruation.
- Engage men and boys in menstruation education to foster understanding, reduce stigma, and create a supportive environment for women and girls.

By debunking these myths, we can promote menstrual equity, empower individuals, and foster a society where menstruation is normalized and respected.

References

- No-Author (2016) *Roar Media Archive - Roar Media Archive - Debunking the Myths of Menstruation*. <https://archive.roar.media/english/life/culture-identities/debunking-the-myths-of-menstruation>.
- Garg, S. and Anand, T., 2015. Menstruation related myths in India: strategies for combating it. *Journal of family medicine and primary care*, 4(2), pp.184-186.
- Babbar, K., 2021. Taboos and myths as a mediator of the relationship between menstrual practices and menstrual health. *European Journal of Public Health*, 31(Supplement_3), pp.ckab165-552.
- Maniar, A. and Mehta, S., 2017. Menstrual hygiene practices: Myths and taboo. *International journal of research in social sciences*, 7(12), pp.93-101.
- Hemachandra, D.K.N.N. and Manderson, L., 2009. Menstrual problems and health seeking in Sri Lanka. *Women & Health*, 49(5), pp.405-421.

THE AWARENESS OF AUTISM SPECTRUM DISORDER AMONG PRIMARY SCHOOL TEACHERS IN KANDY DISTRICT, SRI LANKA

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Abstract

This study focused on primary school teachers' awareness and knowledge about Autism Spectrum Disorder (ASD) in the Kandy District, Sri Lanka. The research was conducted using semi-structured interviews with eight teachers chosen using the purposive sampling technique. The study showed a limited understanding of ASD, with misinformation and little training among primary school teachers. Issues included managing behavioural difficulties, adapting teaching methods, inability to access resources and parent resistance. The study concluded with a need to have comprehensive training with better resources and a stronger focus on inclusive practice to serve students with ASD effectively.

Keywords: Autism Spectrum Disorder (ASD), Teacher Awareness, Teacher Training

Introduction

Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder characterized by complex impairments in social interaction, verbal and nonverbal communication and restricted and repetitive behaviours (Alexander et al., 2014). The higher global prevalence of ASD has heightened the importance of early identification and support, including school support (Foulkes & Andrews, 2023). However, in Sri Lanka, relatively little is known of ASD and awareness and understanding are limited, which greatly affects the ability to identify children with ASD and then provide school-based support for them (Muttiah, 2021).

Due to the increasing prevalence of ASD, general and special education teachers must be prepared to teach students with ASD (Morrier et al., 2010) since they accompany students through learning activities (Arif et al., 2013; Otaif et al., 2023). However, many teachers receive only basic training on ASD, focusing on identification rather than a comprehensive understanding of its characteristics, implications, and strategies for effective support (Muttiah, 2021).

In the Kandy District, less research has been done about the knowledge of the teachers. Even though Sri Lanka's education system has provisions for children across the spectrum, there are still issues with low rates of enrollment, lack of resources and poor infrastructure (Menikdiwela & Vojtová, 2017; Muttiah, 2016).

This study examines primary school teachers' awareness and practice for ASD in the Kandy district in Sri Lanka. The findings will help guide the development of targeted interventions

and training programs to improve teacher preparedness and improve educational outcomes of students with ASD.

The following objectives have been identified based on these considerations:

1. To assess the extent of awareness of ASD among primary school teachers in the Kandy district of Sri Lanka.
2. To Identify the perceived challenges and obstacles encountered by primary school teachers when supporting students with ASD in their classrooms.
3. To examine the strategies currently employed by primary school teachers in Kandy to support students with ASD in their classrooms.

Considering the above objectives, the study is guided by the following research questions:

1. To what extent do primary school teachers in Kandy are aware of ASD in children?
2. What are the perceived challenges and obstacles encountered by primary school teachers when teaching students with ASD?
3. What strategies do primary school teachers in Kandy currently employ to support students with ASD in their classrooms?

By addressing these research questions, this study aims to deepen the understanding of primary school teachers' awareness and practices concerning ASD in Sri Lanka's Kandy district. The insights gained will guide the creation of targeted interventions and training programs, enhancing teacher preparedness and improving the quality of education for students with ASD.

Methodology

Participants

Purposive sampling was used to recruit eight primary school teachers with more than ten years of teaching experience from the Kandy district of Sri Lanka. Seven female and one male teacher from amongst the three government, semi-government and international schools with diverse perspectives. Recruitment was voluntary through social media, with informed consent obtained. Despite the small sample size, it was sufficient for qualitative analysis, enabling rich data collection on ASD awareness and teaching practices within the local educational context.

Design

This study uses a qualitative research design with semi-structured interviews to explore primary school teachers' awareness of ASD. This method allows for an in-depth analysis of teachers' perceptions, experiences, and challenges related to ASD. The semi-structured format provides both structure and flexibility, facilitating detailed exploration of key topics (Jamshed, 2014).

Procedure

Strict ethical standards ensured participant welfare during interviews. Participants were provided with detailed information sheets and consent forms outlining the study's objectives,

data use, confidentiality, anonymity, and their right to withdraw without consequences. The study aimed to raise awareness about ASD and improve support systems.

Interviews, lasting 45–60 minutes, were conducted with explicit consent for audio recordings. Recordings were temporarily stored for transcription and then deleted. Data was securely stored on a password-protected OneDrive account, accessible only to the researcher and supervisor, with plans for destruction after ten years.

Ethical approval was obtained via a permission letter from the Department of Education, Central Province, Kandy, ensuring compliance with institutional and local regulations while prioritizing participant rights and privacy.

Method of Analysis

The semi-structured interview data was analyzed using thematic analysis, a qualitative method for identifying and organizing themes within transcribed data. The thematic analysis allows to move beyond simply describing the data and instead to identify key themes and patterns (Vaismoradi and Snelgrove, 2019) that emerged from the teachers' experiences.

Results

The thematic analysis of interviews with primary school teachers in the Kandy District, Sri Lanka, highlighted five key themes regarding ASD:

Theme 1: Limited Awareness and Understanding of ASD

In general, teachers recognized ASD but had limited knowledge about the wide-ranging characteristics and needs of students with ASD. Others relied on informal learning and personal observations, which emphasized the lack of specialized training in interacting with students with autism spectrum disorder (ASD).

One teacher stated, "In most of the cases, the very next day when they come to the class, they cannot remember the words, so I Have to go on repeating certain things. That is why I mentioned earlier, if we are given any, you know particular training as to how to deal with these kids, it would be great," revealing the assumption that the child's inability to recall information is a sign of slow learning rather than a potential characteristic of ASD.

Theme 2: Challenges in Supporting Students With ASD

1. **Managing Challenging Behaviors:** Teachers struggled to understand and manage unexpected behaviours, feeling unprepared for situations like a student acting out due to emotional distress. One teacher described encountering a student who "threw his purse" when he saw the teacher comforting another child. "I suddenly realised that this is the reason because he never came and told me that this is the reason," the teacher explained, highlighting the challenges of understanding and managing the sometimes-unexpected behaviours of students with ASD.
2. **Adapting Teaching Methods:** Teachers lacked confidence and training in adapting their methods to accommodate diverse learning needs, facing difficulty in providing individualised instruction.

3. **Limited Resources:** A lack of specialized training, evidence-based materials, and support systems hindered effective teaching. Teachers expressed the need for better institutional and governmental support. One teacher stated, "If there is support that would be great because in Sri Lanka, I do not see that type of training provided by the government or by any private firms,"
4. **Cultural and Societal Barriers** Teachers found it difficult to communicate the nature of ASD and gain parental cooperation, reflecting broader cultural stigmas. A teacher revealed the difficulty in communicating with parents about ASD: "Even in a class, sometimes some teachers told me that parents didn't like to accept it."

Theme 3: The Importance of Inclusive Practices and Collaboration

Teachers highlighted the need to create and nurture inclusive environments that embrace students with ASD. Collaboration with extensive knowledge of specialists, Counselors and psychologists and instructors were highlighted as an important and efficient way to care about the needs of students with ASD. One teacher expressed the need for "a psychologist, at least one psychologist per school, a counsellor... Someone who could lead the other bunch of teachers."

Theme 4: The Need for Enhanced Training and Support

Teachers indicated an urgent need for improved training and support to better enable them to support students with ASD. One teacher remarked, "I think in other countries they are provided with more facilities, more study materials to deal with these kids. But in Sri Lanka, I don't think our schools have anything at all". Another teacher suggested, "Teachers must have workshops or training programs once a year related to the psychology field, to understand how to deal with these students. Not only that, even the language side of the teachers should be prepared to deal with students".

Theme 5: Adapting Teaching Strategies

Teachers emphasized the importance of providing one-on-one support to create a safe and supportive learning environment. For example, one teacher remarked, "It is a must" to give individual attention when possible. Teachers recognised the value of working with parents and professionals. Regular meetings with parents, providing feedback, and maintaining records were common practices to ensure holistic support.

Discussion

This study explored the awareness and understanding of ASD among primary school teachers in Sri Lanka's Kandy District, highlighting gaps in knowledge, challenges, and strategies used to support students with ASD. Findings revealed that while teachers are committed to inclusive practices, their understanding of ASD is often limited and influenced by misconceptions, such as equating ASD with slow learning. Teachers face challenges like managing behaviours, adapting teaching methods, accessing resources, and overcoming societal and parental barriers.

The study emphasised the need for comprehensive training to address diverse ASD characteristics, promote inclusive environments, and foster collaboration among teachers,

parents, and specialists. Strategies such as sensory-based interventions and visual supports were identified as necessary for enhancing inclusivity.

Comparison with global literature confirmed a shared need for teacher training and resources, but the Sri Lankan context added unique cultural and societal challenges.

Recommendations and Conclusion

The research emphasizes the need for an inclusive educational environment in Sri Lanka to support students with ASD. Recommendations include teacher training, improved resource availability, fostering inclusive practices, parental engagement, and policy reforms to enhance ASD awareness and support within the education system. These steps aim to build more inclusive learning environments that cater to the diverse needs of all students. Promoting inclusive practices and fostering collaboration among educators and professionals is crucial for creating a supportive atmosphere. Strengthening parent engagement through improved communication and resources is also key. Finally, further research is necessary to understand the challenges faced by teachers and evaluate the effectiveness of interventions, ultimately ensuring a more inclusive educational experience for students with ASD in Sri Lanka.

References

- Alexander, J.L., Ayres, K.M. and Smith, K.A. (2014). Training Teachers in Evidence-Based Practice for Individuals With Autism Spectrum Disorder. *Teacher Education and Special Education: The Journal of the Teacher Education Division of the Council for Exceptional Children*, 38(1), pp.13–27. doi:<https://doi.org/10.1177/0888406414544551>.
- Arif, M.M., Niazy, A., Hassan, B. and Ahmed, F. (2013). Awareness of Autism in Primary School Teachers. *Autism Research and Treatment*, [online] 2013, pp.1–5. doi:<https://doi.org/10.1155/2013/961595>.
- Foulkes, L. and Andrews, J.L. (2023). Are mental health awareness efforts contributing to the rise in reported mental health problems? A call to test the prevalence inflation hypothesis. *New Ideas in Psychology*, [online] 69(1), p.101010. doi:<https://doi.org/10.1016/j.newideapsych.2023.101010>.
- Jamshed, S. (2014). Qualitative Research method-interviewing and Observation. *Journal of Basic and Clinical Pharmacy*, [online] 5(4), pp.87–88. doi:<https://doi.org/10.4103/0976-0105.141942>.
- Menikdiwela, K.R. and Vojtova, V. (2017). Attention-Deficit/Hyperactivity Disorder Through Sri Lankan Primary School Teachers' Eyes. *Journal of Education and Practice*, 08(02). doi:<http://dx.doi.org/10.13140/RG.2.2.36498.27845>.
- Morrier, M.J., Hess, K.L. and Heflin, L.J. (2011). Teacher Training for Implementation of Teaching Strategies for Students With Autism Spectrum Disorders. *Teacher Education and Special Education: The Journal of the Teacher Education Division of the Council for*

Exceptional Children, [online] 34(2), pp.119–132.
doi:<https://doi.org/10.1177/0888406410376660>.

Muttiah, N. (2016). *Autism spectrum disorders (ASD) in Sri Lanka*. [online] Sri Lanka Foundation. Available at: <https://www.srilankaafoundation.org/newsfeed/autism-spectrum-disorders-asd-in-sri-lanka/>.

Muttiah, N. (2021). Ground Realities of Autism Spectrum Disorders in Sri Lanka. *Disability, CBR & Inclusive Development*, 32(1), p.150. doi:<https://doi.org/10.47985/dcidj.383>.

Otaif, E.A., Salih, S.M.A. and Mahfouz, M.S. (2023). Awareness and perceptions regarding autism among school teachers in Jazan region, Kingdom of Saudi Arabia. *Journal of Family Medicine and Primary Care*, [online] 12(11), p.2614.
doi:https://doi.org/10.4103/jfmipc.jfmipc_968_23.

Vaismoradi, M. and Snelgrove, S. (2019). Theme in Qualitative Content Analysis and Thematic Analysis. *Forum Qualitative Sozialforschung / Forum: Qualitative Social Research*, [online] 20(3). Available at: <http://www.qualitative-research.net/index.php/fqs/article/view/3376/4470>.

THE NATURE AND SCOPE OF TRAFFICKING OF WOMEN FOR SEX WORK IN SRI LANKA: AN ANALYSIS OF CONTRIBUTING FACTORS AND INTERVENTION STRATEGIES

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Abstract

This study explores the trafficking of women for sex work in Sri Lanka, focusing on the socio-economic, cultural, and legal factors that enhance this issue. It examines how globalization, post-war vulnerabilities, and deeply ingrained patriarchal norms contribute to the commodification of women and the expansion of the sex trade. A key objective of this research is to provide a locally grounded definition of trafficking, moving beyond Western-centric frameworks to reflect the socio-cultural realities of Sri Lanka. The study is based on an analysis of four key reports, completed in 2015 as part of my master's thesis, which offer insights into the broader context of sex trafficking. Additionally, 10 interviews conducted in 2018 with sex workers, with assistance from Red Cross Sri Lanka, provided firsthand accounts of trafficking in the country. This research concluded with recommendations for targeted education initiatives, legal reforms, and victim support systems aimed at addressing trafficking and empowering marginalized women.

Key Words: Trafficking, Sex Work, Sri Lanka, Gender Equality, Policy Reforms

Introduction

Simone de Beauvoir's statement that gender is shaped by societal expectations rather than biological determinism (Beauvoir, 1949/2011) provides a valuable lens for understanding the exploitation of women, particularly in the context of sex trafficking. As she argues, "one is not born but becomes a woman" (Beauvoir, 1949/2011), highlighting how gender identity is socially constructed. This idea is crucial when examining sex trafficking in Sri Lanka. Patriarchal norms, economic instability, and post-war vulnerabilities have shaped the country. That has created a context for exploitation. Himashree Patowary (2020) builds on this notion, explaining that cultural institutions and societal expectations continuously shape the understanding of "womanhood." De Beauvoir argued that true social change requires addressing broader systemic issues, such as class and societal structures (cited in Moi, 1999). These ideas are vital when examining the dynamics of sex trafficking in Sri Lanka, where patriarchal norms, post-war conditions, and economic vulnerabilities create a fertile ground for the exploitation of women.

Globalization and economic changes have worsened existing inequalities, making women—especially those from marginalized communities, more vulnerable to trafficking (Withers & Biyanwila, 2014). The way women are commodified, both in the media and in societal

attitudes, deepens the cycle of gender-based violence and discrimination. Despite global frameworks aimed at tackling trafficking, Sri Lanka still lacks a definition that reflects its unique cultural and social context. The definitions often rely on Western concepts that fail to address the local realities and challenges women face here (UNODC, 2016; Kara, 2009). This study builds on a comprehensive analysis of key reports, including those from The Asia Foundation (2021), highlighting the links between trafficking and violence, poverty, and the post-war socio-political environment.

Despite the challenges in defining and addressing trafficking, Sri Lanka has made some efforts to combat this issue. The country ratified the Palermo Protocol in 2000, aligning its legal framework with international standards (Amirthalingam et al., 2009). However, as the U.S. State Department's Trafficking in Persons (TIP) report notes, Sri Lanka remains on the "Tier 2 Watch List," indicating that while progress has been made, significant gaps remain in law enforcement and the protection of victims (Central Intelligence Agency, 2013). These gaps are further highlighted in reports by the International Crisis Group (2011), which identify continued vulnerabilities in the Northern and Eastern regions of Sri Lanka. This has been enhanced by the ongoing socio-political aftermath of the civil war.

This research aims to define sex trafficking within the Sri Lankan context, emphasizing the socio-cultural and economic factors that drive exploitation. By analyzing key reports and conducting interviews with 10 sex workers in 2018, this study highlights the complex intersections of trafficking, gender-based violence, and public health issues such as HIV/AIDS. The findings propose targeted education initiatives, legal reforms, and victim support systems to address trafficking and empower marginalized women.

Methodology

The study employed a qualitative method, integrating primary and secondary data to explore the nature and scope of trafficking women for sex work in Sri Lanka. The research utilized the phenomenological approach under qualitative methods, incorporating interviews with sex workers. The study followed the thematic analysis framework to identify key patterns related to trafficking, public health concerns, and gender-based violence.

Research Design

The study was conducted under a qualitative research design, incorporating two methodological approaches.

1. Document Analysis (Secondary Data)- Macro-Level Understanding
2. Phenomenological Approach (Primary Data)- Lived Experience of Participants

By triangulation, the study was conducted with a comprehensive understanding of women trafficking for sex work, linking structural patterns with personal narratives.

Document Analysis (Secondary Data)

The foundational phase of the research focused on document analysis. It provided essential insights into the socio- economic, cultural, and legal factors surrounding sex trafficking. The reports analyzed included:

- The *Continuum International Encyclopedia of Sexuality* (Francoeur & Noonan, 2004), offering cultural and historical perspectives on sexuality in Sri Lanka.
- The *UNGASS Report* (2008-2009), detailing the country's challenges in addressing HIV/AIDS and its connection to sex work.
- The *Building Partnerships on HIV and Sex Work* report (UNFPA & UNAIDS, 2010), outlining strategies to address sex work and its public health implications.
- *The National Report on Violence and Health in Sri Lanka*: 2008.

The reports provided a macro-level understanding of the trafficking issue. They highlighted themes such as commodification, post-war vulnerabilities, and the socio-political challenges of addressing trafficking. The data were analyzed thematically. The analysis focused on recurring patterns related to trafficking mechanisms. That included public health issues and gender - based violence.

Phenomenological Method (Primary Data)

To complement the secondary data, a phenomenological approach (Creswell, 2013) was adopted to capture the lived experiences of the sex workers who had experience of trafficking.

Participant selection and Data Collection

- Sample Size: 10 sex workers from the Kandy district.
- Sampling Strategy: Participants were recruited through Red Cross Sri Lanka during their HIV control program for sex workers (2018).
- Data Collection Method: Semi- Structured interviews exploring personal journeys, vulnerabilities, and perceptions of trafficking.

Key Themes Identified

Through thematic analysis, four major themes emerged from the interviews:

1. Trafficking Experience – Entry into sex work and mechanisms of exploitation.
2. Socio-economic vulnerabilities – Poverty, lack of education, and familial pressures.
3. Health & Legal Challenges – Barriers to accessing healthcare and justice.
4. Psychosocial Impact- Emotional distress, Stigma, and coping mechanisms.

Triangulation and Ethical Consideration

- Triangulation was employed to integrate findings from both secondary documents analysis and primary interviews, making comprehensive and validated research approach.
- Ethical Considerations:

- Participants received full disclosure about the purpose of the study
- Informed consent was obtained, to make sure their participation was voluntary
- Confidentiality was maintained to protect participant identities

Results

Document Analysis Findings

The analysis of four key reports highlighted several structural factors contributing to sex trafficking in Sri Lanka. The aftermath of the Sri Lankan civil war created a vulnerable environment for women, particularly for widows. They were at a greater risk of being trafficked through false promises of employment opportunities in urban centers (Save the Children, 2020; The Asia Foundation, 2021). Economic exploitation was a major theme, with globalization and economic liberalization enhancing inequalities. This situation left women from marginalized backgrounds, especially those in the rural areas, vulnerable to trafficking (UNODC, 2016). Additionally, gender inequality and patriarchal values, reinforced by media portrayals and social expectations, led to commodification of women. This normalization of exploitation became heightened by the stigma surrounding sex work, leading women to limited access to resources and support in the profession.

Interview Findings

The interviews revealed that all participants experienced coercion or deception into sex work, often through false promises of legitimate employment. Many were trafficked from rural areas to urban centers, where they were isolated from their families. Economic pressures, including poverty, lack of education, and family hardships, were major factors driving participants to accept trafficking offers. The stigma surrounding sex work led to social ostracization, further influencing feelings of isolation and trauma. Participants also faced significant barriers to healthcare, particularly sexual and reproductive health services. Due to the criminalization of sex work and fear of law enforcement, these women were deprived of receiving medical when they needed it. Despite these challenges, many expressed a strong desire for empowerment, and emphasizing the need for education. The participants also highlighted the need of legal aid, healthcare access, and community support.

Discussion

The findings of this study highlighted the complex interplay of socio-economic, cultural, and legal factors contributing to trafficking of women in Sri Lanka. The document analysis revealed that post-war vulnerabilities, economic inequality, and gender norms are key drivers of trafficking. These factors have created environments where women, particularly from marginalized communities, are susceptible to exploitation. This aligned with prior research that underscored how conflict-affected societies experience major vulnerabilities due to weakened state structures and economic instability (Kelly, 2005; Save the Children, 2020). In Sri Lankan context, the aftermath of the civil war heightened these conditions. This situation left many women economically vulnerable, socially isolated, and at risk of abuse.

The interviews with the women who were trafficked provided critical, firsthand insights into mechanisms of trafficking. Participants reported experiences of abuse, deception, and economic desperation. Many of these women have been trafficked from rural areas under the guise of legitimate employment opportunities. Moreover, the intersection of poverty and gender was evident, as traditional gender roles limited women's access to formal employment. This made these women more dependent on informal networks where the risk of exploitation is higher.

A significant theme that emerged was the stigma surrounding sex work, which compounds the challenges faced by trafficked women. Participants described how social ostracization and victim blaming created barriers to seeking help which led to social isolation. This stigma not only affected the survivor's mental health but also limited their access to healthcare, legal aid, and psychosocial support. In Sri Lanka, this stigma is deeply rooted within cultural and religious norms. These standards have further marginalized trafficked women and framing them as criminals rather than victims. One of the critical insights came up from this study was the urgent need for localized definition for trafficking that reflected the specific socio-political and cultural context of Sri Lanka. International frameworks, such as the Palermo Protocol, provided broad definitions, but they often failed to capture nuanced realities faced by women in different regions. A localized definition would help policy makers and law enforcement better identify victims. This will also help to distinguish between consensual sex work and trafficking to develop more effective intervention strategies.

The role of public awareness is also crucial. Addressing trafficking requires not just the legal reforms but also shifting attitudes toward gender roles, sex work, and victimhood. Campaigns that challenge harmful stereotypes, and promote gender equality can help reduce stigma, encourage reporting, and create supportive environments for survivors.

Conclusion and Recommendation

This study explored the complex issue of sex trafficking in Sri Lanka. It highlighted the significant role of socio-economic pressures, gender inequality, and the lingering effects of the civil war in driving the exploitation of women. Through the analysis of key reports and the personal stories of trafficked women, it was clear that many were forced or deceived into sex work. Economic desperation often plays a central role in this exploitation. The stigma attached to sex work further isolated these women. Combined with limited access to healthcare and support, made it even harder for women to escape their hardships. To address these challenges, it is crucial that Sri Lanka develops a definition of trafficking that is rooted in its own cultural and socio-economic context. Public awareness campaigns must be launched to challenge the stigma surrounding sex work and foster a more supportive environment for victims. Legal reforms should focus on protecting and supporting women who have been trafficked. It is important to ensure they receive adequate healthcare and psychological support.

The findings highlighted the role of abuse, deception, and economic desperation in trafficking, particularly among women from rural areas. They were lured with false promises of employment. The stigma surrounding sex work, coupled with limited access to healthcare and

legal protections, further heightened the vulnerability of trafficked women. In line with the study's objectives, this research concluded with the following recommendations:

- Targeted education initiatives aimed at raising awareness about trafficking risks, challenging harmful gender norms, and reducing stigma associated with sex work.
- Legal reforms to strengthen anti-trafficking laws, improve victim identification mechanisms. In addition, to ensure that trafficked individuals are treated as victims rather than criminals.
- Comprehensive victim support system that provides holistic care. This must include legal aid, mental health services, vocational training, and social reintegration programs.

By addressing the structural inequalities that enable trafficking and prioritizing survivor-centered approaches, aim to empower marginalized women. While the study provided valuable insights, it had limitations that future research could address. The sample size was relatively small and focused on participants from the Kandy district, which may not fully represent the diverse experience of trafficked women across Sri Lanka. Future studies should explore trafficking in rural and conflict-affected regions, where vulnerabilities may differ due to localized socio-economic dynamics. In Addition, longitudinal research is needed to examine the long-term effects of trafficking survivors, particularly regarding mental health, social integration, and economic independence. Understanding these long-term impacts would provide critical data to inform survivor-centered support programs. Finally, there is a need for programs that empower women economically, particularly in rural areas. This will help reduce the vulnerabilities that often lead to trafficking. By taking these steps, Sri Lanka can create a safer, more equitable society for all women.

References

- Amirthalingam, K., Jayatilleke, D., Lakshman, R.W.D. and Liyanage, N., 2009. Victims of human trafficking in Sri Lanka: Narratives of women and youth. [online] Available at: <https://editorialexpress.com/cgi-in/conference/download.cgi?db> [Accessed 10 December 2024].
- Beauvoir, S., 2011. *The Second Sex*. Translated by C. Borde and S. Malovany-Chevallier. Vintage. (Originally published in 1949).
- Central Intelligence Agency, 2013. *The World Factbook: Trafficking in persons*. [online] Available at: <https://www.cia.gov/Library/publications/the-world-factbook/fields/2196.htm> [Accessed 10 December 2024].
- Creswell, J.W., 2013. *Qualitative inquiry and research design: Choosing among five approaches*. 3rd ed. Thousand Oaks: SAGE Publications.
- Francoeur, R.T. and Noonan, R.J., 2004. *The Continuum International Encyclopedia of Sexuality*. New York: Continuum.

International Crisis Group, 2011. Sri Lanka: Women's insecurity in the north and east. [online] Available at: <http://www.crisisgroup.org/en/regions/asia/south-asia/sri-lanka/217-sri-lanka-womens-insecurity-in-the-north-and-east.aspx> [Accessed 10 December 2024].

Kara, S., 2009. *Sex Trafficking: Inside the Business of Modern Slavery*. New York: Columbia University Press.

Kelly, L., 2005. Fertile fields: Trafficking and the global economy. *United Nations Office on Drugs and Crime Report*. [online] Available at: <URL> [Accessed 10 December 2024].

Moi, T., 1999. *What Is a Woman?: And Other Essays*. Oxford University Press.

Sri Lanka, 2008. *National report on violence and health in Sri Lanka*. Colombo: World Health Organization Country Office for Sri Lanka, Ministry of Healthcare and Nutrition.

Patowary, H., 2020. Media and women question: The contradiction between 'real' and 'ideal' women. *Assam University, Silchar*. [online] Available at: https://www.researchgate.net/publication/329292960_Media_and_Women_Question_The_Contradiction_Between_Real_and_Ideal_Women [Accessed 10 December 2024].

Save the Children, 2020. Launching counter-trafficking project "IMPACT" to combat human trafficking in Sri Lanka. [online] Available at:

<https://srilanka.savethechildren.net/news/launching-counter-trafficking-project-%E2%80%9Cimpact%E2%80%9D-combat-human-trafficking-sri-lanka> [Accessed 10 December 2024].

The Asia Foundation, 2021. Sri Lanka: Inside Justice – Summary report. *The Asia Foundation*. [online] Available at: https://asiafoundation.org/wp-content/uploads/2021/09/Sri-Lanka_-_Inside-Justice-Summary-Report.pdf [Accessed 10 December 2024].

UNFPA & UNAIDS, 2010. Building Partnerships on HIV and Sex Work: Report and recommendations from the first Asia and the Pacific Regional Consultation on HIV and Sex Work. *UNAIDS Regional Support Team, Asia and the Pacific*. [online] Available at: <https://resourcecentre.savethechildren.net/document/building-partnerships-hiv-and-sex-work-report-and-recommendations-first-asia-and-pacific/> [Accessed 10 December 2024].

United Nations, 2010. UNGASS report: Sri Lanka (2008-2009). *United Nations General Assembly Special Session on HIV/AIDS Country Progress Report—Sri Lanka*.

United Nations Office on Drugs and Crime, 2016. World Drug Report 2016. *United Nations Office on Drugs and Crime*. [online] Available at: <https://www.unodc.org/wdr2016> [Accessed 10 December 2024].

Withers, M. and Biyanwila, J., 2014. Patriarchy, labour markets and development: Contesting the sexual division of labour in Sri Lanka. *IIM Kozhikode Society & Management Review*, 3(1), pp. 33–43. [online] Available at: <https://doi.org/10.1177/2277975214520905> [Accessed 10 December 2024].

FAMILY SUPPORT FOR MARRIED FIRST-TIME MOTHERS AND ITS IMPACT DURING THE POSTPARTUM PERIOD IN KANDY DISTRICT, SRI LANKA.

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Abstract

For new mothers, the period following childbirth (the postpartum period) is a crucial time that involves major changes in their physical, emotional, and mental states (World Health Organization, 2020). This study investigates how family support affects married first-time mothers' postpartum health in Sri Lanka's Kandy region. In order to successfully navigate the difficulties of baby care, mother recuperation, and mental health, family support—which includes emotional, practical, and informational assistance—is essential (Kim et al., 2018). Six new mothers participated in semi-structured interviews as part of this qualitative study to learn more about their experiences and the types of family support they got in the postpartum phase. The results show that maternal well-being is greatly influenced by both practical and emotional assistance, particularly from husbands, mothers-in-law, and other family members. However, sometimes conflicts arise due to cultural and familial expectations, which affects how well the support system works. The study emphasizes the value of supportive, culturally aware approaches that respect the mother's autonomy and preferences. The study comes to the conclusion that improving family support networks—with a focus on practical and emotional support—can help new mothers in Sri Lanka have better postpartum outcomes.

Keywords: Family Support, First-Time Mothers, Maternal well-being, Postpartum Period, Sri Lanka

Introduction

The postpartum period is a crucial time for new mothers that involves significant physical, emotional, and psychological changes as they adjust to parenting. Significant family assistance is required at this sensitive time to guarantee the mother's and the newborn's well-being. In the Kandy district of Sri Lanka, where social and cultural norms have a significant influence on family structures and caregiving responsibilities, this study aims to comprehend the function and effects of family support on married first-time mothers.

The postpartum period can last up to 12 weeks and is referred to as the "fourth trimester" by the American College of Obstetricians and Gynecologists (2018). However, depending on the mother's recuperation, it may continue for up to 12 months following childbirth, according to the World Health Organization (WHO, 2020). This expanded definition emphasizes the continuous processes of emotional and physical healing, highlighting the value of sustained family support in resolving mental health issues among mothers. According to global data, 15-20% of new moms suffer from postpartum depression and anxiety during this period, putting

them at higher risk (O'Hara & McCabe, 2017). Research carried out across the world emphasizes how crucial family support is for stress reduction, minimizing the risk of postpartum depression, and promoting healthy mother-infant bonding (Abbas et al., 2023). Mothers-in-law, husbands, and other relatives are examples of extended family members who usually offer family support in Sri Lanka (Pathirathna et al., 2024). According to a study by De Sousa Machado et al. (2020), 68% of new mothers in Sri Lanka depended on their families for practical assistance with tasks like baby care and housework. These dynamics are in contrast to Western nuclear family structures, which tend to place a greater emphasis on community or professional support networks. (De Sousa Machado et al., 2020). Although the value of family support is widely recognized, little is known about how it specifically affects Sri Lanka, especially in the culturally diverse Kandy district.

According to the existing research, mother well-being depends on both practical and emotional care. Practical support eases physical pressure, allowing mothers to concentrate on recuperation and baby care, while emotional support, such as understanding and reassurance, boosts maternal confidence. However, new mothers may experience stress due to obstacles including contradictory advice from in-laws or unfulfilled expectations (De Sousa Machado et al., 2020). The significance of the spouse in offering practical and emotional assistance is also highlighted by research, as this greatly lowers maternal stress and creates a supportive environment (Rathnayake & Atapattu, 2020).

This study is guided by the following research questions:

1. What types of family support do married first-time mothers receive during the postpartum period in the Kandy district?
2. How does family support impact the physical and emotional well-being of first-time mothers?
3. What are the cultural and social factors influencing the nature and effectiveness of family support during this period?

With a focus on the lived experiences of married first-time mothers in the Kandy district, this study aims to fill the gap in the literature by offering qualitative insights into postpartum experiences in Sri Lanka. The primary objectives are to identify forms of family support, assess its effect on maternal well-being, and explore the cultural and familial factors shaping postpartum care. This study will offer a culturally unique understanding of postpartum family support, which will be beneficial for Sri Lankan families, policymakers, and healthcare professionals.

Methodology

Participants

Six Sri Lankan married first-time mothers, ages 20 to 40, who lived in the Kandy district, participated in this qualitative study. While the small sample size may limit generalizability, it allows for in-depth exploration of individual perspectives. A convenience sample method was used to choose the participants, with a focus on mothers who had given

birth within the last 6-12 months. This method was selected due to its effectiveness and applicability within the geographic scope of the study. To ensure full participation in the study, those with serious mental illnesses or cognitive impairments were excluded, and eligible participants had to have recently gone through a postpartum experience. Social media ads that offered details about the study and mental health resources were used to recruit participants. When participants reached out to the researcher via phone or email, they were provided with comprehensive study details and confidentiality protocols. To maintain anonymity, reference codes (such as Participant 1) were given to participants who consented to take part.

Data Collection

Semi-structured interviews were used to gather information about participants' experiences with family support after giving birth. For convenience, these 45–60-minute interviews were done online using Microsoft Teams. The effects of family support on postpartum mothers—emotional, practical, and informational—were covered in the interview questions. Prior to the interviews, participants provided their informed consent and permission for audio recording. An information sheet detailing the study's objectives and methods was given to participants, and verbal and written agreement was acquired. For transparency, interview questions and schedules have been provided in advance. Interviews that were recorded on audio were transcribed for analysis.

Method of Analysis

The data was analyzed using thematic analysis in accordance with the six-phase framework developed by Braun and Clarke (2006). This approach made it possible to find and analyze themes in the qualitative data. Data familiarization, coding, theme development, refinement, categorization, and creating a coherent narrative that connected findings to the study goals were important stages.

Ethical Considerations

Ethical approval was granted by the Cardiff Met ethics panel. In addition to being given contacts for mental health care, participants were advised of their rights, including the ability to withdraw. Data was anonymized and stored securely on password-protected platforms that only the researcher and supervisor could access, guaranteeing data confidentiality.

Results

The findings of this research offer deep insights into the postpartum experiences of married first-time mothers in Kandy, Sri Lanka. These mothers consistently highlighted the critical role of family support—both emotional and practical—in shaping their recovery and adjustment to motherhood. Through six detailed interviews, six major themes emerged: practical support, emotional support, challenges due to unsolicited advice, cultural practices, the role of husbands, and balancing support with autonomy. Each theme is supported by participants' reflections, illustrating the benefits and complexities of family support during this transformative period.

1. Practical Support

Practical assistance from family members emerged as a consistent theme, with participants highlighting its necessity during postpartum recovery. All six participants expressed gratitude for support in managing household chores, cooking, and baby care, enabling them to focus on their health and newborns. Participant 1, who had an emergency C-section, shared how her mother took over household duties: *"I couldn't do much for the first two weeks. My mom took care of my baby, washing clothes, and everything."* This eased her recovery and improved her strained marital relationship. Similarly, Participant 3 noted her sister-in-law's help with nighttime baby care: *"My sister-in-law took care of the baby at night, even though she had to work the next day. It gave me much-needed rest."* For others, family support was vital for physical and emotional recovery. Participant 2 emphasized: *"My mother ensured I had nourishing meals, which gave me the strength to recover."* Participant 5 appreciated help from her parents and in-laws, which allowed her to rest effectively. In contrast, Participant 6 experienced limited in-law support, increasing frustration, until her parents stepped in to assist.

2. Emotional Support

In addition to practical aid, emotional support from family—particularly husbands—was a cornerstone of postpartum well-being. Participant 1, however, noted the emotional toll of her husband's absence: *"He was always working late, and when he came home, he was too tired to help or talk. I felt very alone."* Conversely, Participant 2 described her husband as her emotional anchor: *"Even though he was only home on weekends, he spent time with me and the baby, which made me feel valued and supported."* Participants also valued emotional support from other family members. Participant 4 recounted how her mother provided comfort during breastfeeding struggles, easing her feelings of frustration. Friends and extended family were also sources of emotional resilience. Participant 5 emphasized how her friends' encouragement complemented her family's practical assistance, providing her with the emotional fortitude to navigate motherhood.

However, emotional support was not universal. Participant 6 lamented the lack of emotional understanding from her own parents, noting that while her in-laws provided practical help, she often longed for the comfort her own mother could offer.

3. Challenges of Unsolicited Advice and Over-Involvement

Despite the overall appreciation for family support, unsolicited advice and over-involvement occasionally caused stress. Participants expressed frustration when family members undermined their autonomy as new mothers. Participant 1 felt overwhelmed by her mother-in-law's constant input: *"She had an opinion on everything—how to feed the baby, what clothes to use. It made me feel like I wasn't capable of taking care of my own child."* Similarly, Participant 4 struggled to balance her family's traditional parenting suggestions with her own preferences: *"They insisted on old practices, but I wanted to make my own decisions. It was exhausting."* This tension often highlighted the delicate balance between gratitude for help and the desire for independence. Participants valued their families' intentions but sought greater freedom in their parenting choices.

4. Influence of Cultural Practices

Cultural traditions significantly shaped the postpartum experiences of the participants. Practices like staying indoors for three months or adhering to specific dietary regimens were common. Participant 3 noted: *"They told me to stay indoors for three months to keep the baby safe. It was hard, but I knew it was part of our culture."* While some participants found comfort in these customs, others viewed them as restrictive. Participant 1 faced a particularly challenging cultural expectation involving her baby's circumcision. She described the emotional toll: *"My in-laws insisted on the procedure when my baby was just 23 days old. I felt helpless and regretful for not being able to oppose it."* On the positive side, these traditions fostered a sense of belonging and continuity for some mothers. Participant 4 appreciated the cultural practices her mother followed, which she felt connected her to her family's heritage.

5. The Role of Husbands in Postpartum Support

The emotional and practical involvement of husbands played a pivotal role in the postpartum experience. Participant 3 described her husband's unwavering support: *"He took over many responsibilities and reassured me constantly, which strengthened our bond."* For others, the absence of spousal involvement added to their challenges. Participant 1, whose husband was largely unavailable, experienced feelings of isolation and frustration. However, many participants emphasized that even small gestures, like spending time with the baby, significantly bolstered their emotional well-being. Participant 2 appreciated how her husband's presence during weekends alleviated her stress and allowed her to rest.

6. Balancing Support and Autonomy

While family support was crucial, participants often navigated the fine line between reliance on others and maintaining independence. They appreciated the help but also expressed the need to establish their own parenting styles. Participant 5 encapsulated this sentiment: *"I valued their help, but I needed space to make my own decisions as a mother."* This balance was particularly evident in how participants responded to unsolicited advice or cultural expectations. While they recognized the importance of family traditions, they sought the autonomy to adapt these practices to their unique circumstances.

Discussion and conclusion

The findings of this study highlight the nuanced role of family support during the postpartum period for married first-time mothers in Sri Lanka, contributing to the broader understanding of postpartum care and family dynamics. When comparing these findings to existing literature, both parallels and contrasts emerge, reflecting cultural and contextual differences.

Practical support, predominantly provided by mothers and mothers-in-law, was a recurring theme in this study. Participants emphasized the indispensability of such support for alleviating physical demands and facilitating recovery. This finding aligns with research by Smith (2020), which underscores the importance of practical support in reducing maternal stress and promoting well-being. However, while Smith's study focuses on universal aspects of postpartum support, this research contextualizes the findings within Sri Lanka's collectivist culture, where extended families play an active role. In contrast, studies conducted in Western

contexts, such as Corrigan, Kwasky and Groh (2015), report a reliance on formal support services or hired help. This highlights the cultural divergence in caregiving structures, with Sri Lankan mothers primarily depending on familial support, reflecting the strong interdependence inherent in collectivist societies.

Emotional support was identified as a cornerstone of postpartum well-being, consistent with findings from Rusanen *et al.* (2022), which emphasize emotional care's role in mitigating stress and fostering maternal mental health. However, this study adds depth by exploring the nonverbal dimensions of emotional support, such as the comforting presence of family members, which are less emphasized in Western-centric literature. For instance, while Western research often focuses on verbal communication and professional counseling, participants in this study valued nonverbal support, like simply having a loved one nearby, as equally vital.

The challenges of unsolicited advice emerged as a significant theme, reflecting its dual nature as both a source of stress and a gesture of care. Park and Lee (2022) similarly document the adverse effects of unsolicited advice on maternal confidence, particularly when traditional practices conflict with modern parenting approaches. However, this study highlights that these tensions are magnified in contexts like Sri Lanka, where cultural norms and intergenerational expectations strongly influence postpartum practices. While some mothers found unsolicited advice overwhelming, others interpreted it as a manifestation of love and concern, demonstrating the subjective nature of its impact.

Cultural practices and traditional rituals also shaped postpartum experiences, echoing findings by De Sousa Machado (2020). While these practices provided a sense of heritage and care, they were sometimes perceived as restrictive. This duality contrasts with findings from more individualistic cultures, where postpartum practices are less rigid and more tailored to personal preferences.

Finally, the role of husbands in postpartum support revealed shifting gender dynamics. While this aligns with studies by Islamiah *et al.* (2023) which note increasing paternal involvement in caregiving, this study contextualizes these findings within the challenges of balancing work commitments and familial expectations. The tension between practical and emotional availability underscores the evolving but complex role of husbands in Sri Lanka's traditional family structure.

In conclusion, this study underscores the crucial role of family support in shaping the postpartum experiences of married first-time mothers in Kandy District, Sri Lanka, revealing the complexities of maternal care within a collectivist culture. Findings affirm previous research while highlighting the interplay of cultural, social, and individual factors. Key themes such as practical and emotional support, unsolicited advice, cultural practices, and the role of husbands illustrate the challenges of balancing tradition with autonomy. To address these complexities, healthcare providers should adopt a holistic approach that considers both the emotional and practical needs of mothers while promoting open family communication. Further research is needed to explore postpartum experiences in diverse cultural contexts and understand the perspectives of family members in providing support during this critical period.

References

- Abbas, M. (2019) 'Maternal support and postpartum well-being: A global perspective', *Journal of Maternal Health*, 25(4), pp. 345–362. Available at: <https://doi.org/10.1016/j.jmh.2019.04.002>
- American College of Obstetricians and Gynecologists (2018) 'ACOG Committee Opinion No. 736: Optimizing postpartum care', *Obstetrics & Gynecology*, 131(5), pp. e140–e150. Available at: <https://doi.org/10.1097/AOG.0000000000002633>
- Corrigan, C. P., Kwasky, A. N., & Groh, C. J. (2015) 'Social Support, Postpartum Depression, and Professional Assistance: A Survey of Mothers in the Midwestern United States', *The Journal of Perinatal Education*, 24(1), pp. 48–60. <https://doi.org/10.1891/1058-1243.24.1.48>.
- De Sousa Machado, T., Chur-Hansen, A., & Due, C. (2020) 'First-time mothers' perceptions of social support: Recommendations for best practice', *Health Psychology Open*, 7(1), pp. 1–7. Available at: <https://doi.org/10.1177/2055102919898611>
- Islamiah, N., Breinholst, S., Walczak, M. A., & Esbjørn, B. H. (2023) 'The role of fathers in children's emotion regulation development: A systematic review', *Infant and Child Development*, published online 4 January 2023. Available at: <https://doi.org/10.1002/icd.2397>
- Kim, Y., Lee, E., & Moon, S. (2018). The role of social support and emotional well-being in postpartum recovery. *Journal of Family Nursing*, 24(2), 169-186. <https://doi.org/10.1177/1074840718758984>
- O'Hara, M. W. and McCabe, J. E. (2017) 'Postpartum depression: Current status and future directions', *Annual Review of Clinical Psychology*, 9(1), pp. 379–407. Available at: <https://doi.org/10.1146/annurev-clinpsy-050212-185612>
- Park, G.-A. and Lee, O. N. (2022) 'The moderating effect of social support on parental stress and depression in mothers of children with disabilities', *Occupational Therapy International*, 2022(3), p. 5162954. Available at: <https://doi.org/10.1155/2022/5162954>
- Pathirathna, M. L., Haruna, M., Sasaki, S., Yonezawa, K., Usui, Y., & Hagiwara, Y. (2024) 'The Sri Lanka Mother and Newborn Growth (S-MaNGro) Cohort: Protocol of a Nationwide Prospective Study', *Methods and Protocols*, 7(4), p. 61. Available at: <https://doi.org/10.3390/mps7040061>
- Rathnayake, N. and Atapattu, S. (2020) 'Family support and maternal stress: Experiences of first-time mothers in Sri Lanka', *Journal of Family Psychology*, 34(4), pp. 456–462. Available at: <https://doi.org/10.1037/fam0000635>
- Rusanen, E., Lahikainen, A. R., Vierikko, E., Pölkki, P. and Paavonen, E. J. (2022) 'A longitudinal study of maternal postnatal bonding and psychosocial factors that contribute to social-emotional development', *Child Psychiatry & Human Development*, 55, pp. 274–286. Available at: <https://doi.org/10.1007/s10578-022-01386-6>

World Health Organization (2020) *Postpartum care of the mother and newborn*. Available at: <https://www.who.int/publications/i/item/9789240005648>

EXPLORING RESILIENCE AND COPING MECHANISMS DURING CAREER PREPARATION AMONG UNDERGRATES IN KANDY, SRI LANKA.

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Abstract

This study explores the lived experiences of undergraduates in Sri Lanka's central province during their transition from academia to the job market. Limited attention has been given to career preparation challenges among undergraduates. This qualitative study investigates students' career-preparation anxiety and coping strategies, using in-depth interviews via Microsoft Teams to gather narrative-driven data. Thematic analysis revealed three major themes: Transformative Coping: Turning Stress into Strength, Adaptive Resilience: Flexibility in the Face of Uncertainty, and Empowered Coping through Community and Connection. These themes reflect coping strategies, such as reframing challenges as growth opportunities, balancing optimism with realism, and relying on social support networks. The findings highlight the emotional and practical challenges students face during career preparation, offering insights for improving career counseling and support systems. By understanding the coping mechanisms used by students, the study emphasizes the need for targeted interventions that enhance resilience, stress management, and career guidance.

Keywords: Anxiety, Career preparation, Coping, Resilience

Introduction

The transition from higher education to the labor market is a critical phase in the lives of undergraduates, especially as economies grow and the demand for skilled workers increases (Chandrasiri, 2008). In Sri Lanka, this transition is particularly challenging due to the gap between the rising number of graduates and the limited job opportunities available, leading to high unemployment rates and career-preparation anxiety (Chandrasiri, 2008; Wijayawardhana, 2019). According to the 2019 Labor Force Survey, youth unemployment stands at 23.3%, with 54% of graduates struggling to find employments (Dayaratna-Banda & Dharmadasa, 2022). These statistics underscore the emotional and psychological challenges faced by students as they prepare for the workforce, contributing to stress and uncertainty about their future.

This study aims to explore the experiences of undergraduates in Kandy, Sri Lanka, during their career preparation phase. It investigates the emotional and practical challenges students encounter and the coping mechanisms employ to manage career-related stress and anxiety. The study employs a qualitative research approach, utilizing in-depth interviews to gather personal narratives and insights into the factors influencing students' career preparation.

The significance of this research lies in its potential to inform policy and improve support systems within universities and career counseling services. By understanding the coping strategies and resilience of undergraduates, the study provides actionable recommendations for enhancing educational practices and career guidance. Ultimately, this study contributes to a deeper understanding of the factors shaping career preparation in Sri Lanka and provides insights for enhancing the employability and well-being of undergraduates in the region.

Method

Participant

This study employed convenience sampling to select a mixed sample of eight final-year undergraduate students (aged 18-25) from Kandy, Sri Lanka. The sample was balanced with four participants from government institutions and four from private institutions, ensuring equal gender representation. Participants were from diverse academic backgrounds, including management, science, finance, and arts, allowing for a comprehensive exploration of career challenges and coping strategies. The participants were recruited via social media advertisements, and interviews were conducted in English, with occasional use of Sinhala. Exclusion criteria included individuals with a history of mental health issues, those outside the age range, and those who might experience distress from participation. All participants provided informed consent, and pseudonyms were used to ensure confidentiality.

Data Collection

The study adopted qualitative design using in-depth, semi-structured interviews to gather data on the participants' career preparation, stress sources, coping mechanisms, resilience, and their transition from academia to the workforce. The interviews, lasting 30-40 minutes, were conducted via Microsoft Teams, recorded, and transcribed. Participants were asked ten major questions, with follow-up questions when necessary to gain deeper insights. Informed consent was obtained verbally, and participants were fully briefed on the study's aims, potential risks, and benefits. Ethical approval was granted by Cardiff Metropolitan University's ethical review board, ensuring the protection of participants' rights.

Method of Analysis

The data were analyzed using thematic analysis, following Smith's (2004) approach, which involved three stages of coding: open, axial, and selective coding. This process helped identify key themes and patterns in the data, which were refined and clustered to form overarching themes. Emergent themes were reviewed, and connections between them were identified, leading to the final interpretation. Member checking was employed to ensure the credibility of the findings, with participants verifying whether the results accurately reflected their experiences. This thorough analysis provided valuable insights into the coping strategies and resilience of students during their career preparation.

Results

The thematic analysis of the data (Smith, 2004) revealed three main themes and seven subthemes, reflecting the coping mechanisms and resilience strategies employed by undergraduates during their career preparation. These themes are: Transformative Coping: Turning Stress into Strength, Adaptive Resilience: Flexibility to Challenges, and Empowered Coping through Community and Connection. Each theme highlights how participants navigated the challenges and uncertainties of career preparation. Table i below summarizes the identified themes, subthemes, and initial codes.

Table i: Codes, Themes, Subthemes

Initial Codes	Themes	Subthemes
Stress as motivation, challenges seen as growth, future planning, goal setting	Transformative Coping: Turning Stress into Strength	Stress as a Growth
Structured future goals, using stress as motivation, embracing challenges		Proactive Coping through Future Planning
Emotional balance, optimistic outlook combined with realism, emotional regulation via creative outlets	Adaptive Resilience: Flexibility to the challenges	Balancing Optimism with Realism
Guitar playing, travel, hobbies, emotional refresh through creative outlets		Emotional Regulation through Creative Outlets
Support systems, mentor guidance, family encouragement, drawing inspiration from peers	Empowered Coping through Community and Connection	Collective Resilience through Peer Support
Motivated by success stories, external success stories and role models		Inspirational Role Models and Stories
Learning from comparisons, viewing peer success as motivation		Social Comparison as a Motivator, Not a Stressor

Theme 1: Transformative Coping: Turning Stress Into Strength

Participants were able to reframe stress as an opportunity for personal growth. A subtheme, Stress as Growth, emerged, where participants viewed challenges like interview failures or geographical limitations as learning opportunities. One participant noted, “Even though it has some kind of demotivated me, I take that as something I need to improve” (Participant 002). Another subtheme, Proactive Coping through Future Planning, showed that students who set multiple long-term career goals and backup plans managed uncertainty more effectively. One

participant shared, “I have a few plans at the same time, so that is one mechanism that I can cope with” (Participant 001).

Theme 2: Adaptive Resilience: Flexibility To Challenges

This theme highlights how participants balanced optimism with the tough realities of career preparation. The subtheme Balancing Optimism with Realism illustrated how students maintained hope despite career preparation challenges, with one participant explaining, “I take it as a positive thing, not a negative thing” (Participant 003). Another subtheme, Emotional Regulation through Creative Outlets, highlighted how hobbies like music, journaling, or travel helped participants manage stress.

Theme 3: Empowered Coping through Community and Connection

The importance of social support emerged in the subtheme Collective Resilience through Peer Support. Participants highlighted the role of family, friends, and mentors in helping them stay resilient. One participant said, “My parents were real inspiration, especially my dad” (Participant 004). Social Comparison as a Motivator, not a Stressor revealed that participants viewed peer success as a source of motivation: “I see my friend’s success as something to strive for” (Participant 001).

Discussion

The findings of this study reveal that undergraduates face significant challenges during career preparation, yet they employ diverse coping mechanisms to navigate these stressors. These mechanisms align with Lazarus and Folkman’s (1984) Stress and Coping Model, distinguishing between problem-focused and emotion-focused coping. Participants used both coping types to manage stress and uncertainty, transforming challenges into opportunities for growth, developing adaptability, and relying on social connections for support.

As previous research indicates (Pisarik, Rowell & Thompson, 2017; Kim, Oh & Rajaguru, 2022), participants identified common stressors such as job scarcity, academic pressures, and the fear of unemployment. Rural participants expressed concerns about fewer career opportunities compared to urban areas, reflecting findings from Chamudika (2022) and William et al. (2018). Internal challenges like self-doubt and fear of failure were also prominent, which is consistent with findings from Pisarik et al. (2017), who noted that students often experience anxiety and depression linked to these pressures.

The first theme, Transformative Coping: Turning Stress into Strength, reflects participants’ use of problem-focused coping strategies. They reframed setbacks, such as job rejections, as learning experiences, demonstrating proactive goal-setting. This contrasts with studies by Kim, Oh, and Rajaguru (2022), who found that many students often felt overwhelmed and lacked coping strategies. The second theme, Adaptive Resilience: Flexibility in the Face of Uncertainty, highlights emotion-focused coping. Participants maintained optimism, used creative outlets, and sought social support. This aligns with previous studies (Belle et al., 2022) showing that resilience is vital for managing career uncertainty. The third theme, Empowered Coping through Community and Connection, underscores the importance of social support

systems. Participants emphasized the value of mentors, family, and peers. Social comparison emerged as a motivator, reflecting findings from Creed et al. (2021), where peer success acted as a positive influence rather than a stressor.

These findings demonstrate how undergraduates combine problem-focused and emotion-focused coping to manage career preparation stress. By turning stress into growth opportunities, remaining flexible, and relying on social support, participants exhibited resilience during career preparation.

Conclusion and Recommendation

This study explored how undergraduates cope with career-related stress, highlighting the use of transformative coping, adaptive resilience, and social support. The findings emphasize the importance of problem-focused and emotion-focused coping strategies in navigating the challenges of career preparation.

Future research could expand the sample size and incorporate diverse geographic and cultural contexts to capture a broader range of coping mechanisms. Longitudinal studies can provide insights into how coping strategies evolve throughout students' academic careers. Additionally, including perspectives from career counselors, academic advisors, and employers will offer a more comprehensive understanding of the factors influencing undergraduates' coping strategies, ultimately informing more effective support systems for career preparation.

References

- Belle, M.A., Antwi, C.O., Ntim, S.Y., Affam-Osei, E. & Rem, J., (2022). 'Am I gonna get a job? Graduating students' psychological capital, coping styles, and employment anxiety'. *Journal of Career Development*, 49(5), pp.1122-1136. [online]. Available at: <https://doi.org/10.1177/08948453211020124> (Accessed by: 28 May 2021).
- Chamudika, M., (2022). 'Impact of the Internship program on the professional and personal development (Special Reference to Art Faculties in Sri Lanka state Universities'. *8th National Research Conference on Applied Social Statistics*, pp. 41-46.
- Creed, P.A., Sawitri, D.R., Hood, M. & Hu, S., (2021). 'Career goal setting and goal pursuit in young adults: The role of financial distress'. *Journal of Career Development*, 48(6), pp.801-816.
- Dayaratna-Banda, O.G. & Dharmadasa, P.D.C.S., (2022). 'An economics analysis of employability and unemployment of humanities and social sciences graduates in Sri Lanka'. *South Asian Survey*, 29(2), pp.155-180. [online] Available at: <https://doi.org/10.1177/09715231221124714> (Accessed by: 17 October 2022).
- Kim, J., Oh, J. & Rajaguru, V., (2022). 'Job seeking anxiety and job preparation behavior of undergraduate students: In Healthcare', 10(2), p.288.
- Lazarus, R.S. & Folkman, S., (1984). *Stress, appraisal, and coping*. Springer Publishing Company.

Pisarik, C.T., Rowell, P.C. & Thompson, L.K., (2017). ‘A phenomenological study of career anxiety among college students’. *The Career Development Quarterly*, 65(4), pp.339-352. [online] Available at : <https://doi.org/10.1002/cdq.12112> (Accessed by: 7 December 2017).

Smith, J.A., (2004). ‘Reflecting on the development of interpretative phenomenological analysis and its contribution to qualitative research in psychology’. *Qualitative Research in Psychology*, 1(1), pp.39-54.

William, E., Donald, M.J., Ashleigh, M.J., Yehuda, B.C., (2018). ‘Students’ perceptions of education and employability: Facilitating career transition from higher education into the labor market’. *Career Development International*, 23(5), pp.513-540.

THE DIFFERENTIAL IMPACT OF THE ECONOMIC CRISIS ON EDUCATION IN WELIGAMA, MATARA DISTRICT

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Abstract

Identifying the differential impact of the economic crisis on education of students in the Weligama area is the aim of research. The study employed mixed research methods consisting of qualitative and quantitative ways to collect primary and secondary data by reviewing the impact of economic crisis on education in macro and micro economic levels. Data were gathered through governmental reports and filled with structured questionnaires from selected samples. The National Consumer Price Index serves as a critical indicator of the cost of living and its fluctuation. It reflects the inflation pressure that affects education expenses. From January 2022 to September 2023, it exhibits 173.6 in September 2023 referring to base period 2021=100. Most respondents reported that inflation brings moderate impact, and the rest said high impact to education. This suggests a widespread perception among the sampled households that the economic crisis has significant consequences for the education of their children.

Keywords: Education, Macroeconomy, Microeconomy

Introduction

A combination of government policies and an already fragile macroeconomic environment served as the catalyst for Sri Lanka's first economic and political crisis in its' post-independence history in the year 2022 (Central Bank of Sri Lanka, 2022). The economic crisis has adversely affected the daily lives of people through rising inflation which has hindered their ability to access essential necessities. The higher cost of living has prompted people to cut back on their expenditures related to education, a fundamental necessity. This implies that the crisis has affected economic security of the country, as per the International Labor Organization (ILO) definition, which encompasses the basic needs essential for ensuring the well-being and stability of individuals.

The ongoing economic crisis in Sri Lanka has raised concerns about its potential impact on various sectors, including education. This study gives an analysis, focusing on inflation and wage data in Sri Lanka from January 2022 to September 2023, aiming to provide insights into the economic context influencing the research questions and objectives related to the impact of the income effect on education. In adopting both macroscopic approach and microeconomic standpoint, research aims to address localized barriers resulting from the economic crisis, created for the education of students in Weligama division in Matara district. The decision to focus on Weligama division of Matara District in this research is primarily driven by factors like—the ease of accessing relevant primary data and the potential collaborations with local

stakeholders. The ease of data access facilitates a comprehensive and informed analysis, enhancing the reliability and depth of our findings. Being embedded within the Weligama community opens avenues for meaningful engagement with local households. Further, Weligama represents areas where most middle-class people live in rural context in the country. Understanding the income dynamics of the local community is crucial to comprehending how families in Weligama division of Matara District are navigating the economic downturn. As the literature also suggests, whether through salary cuts or changes in income, these microeconomic factors directly impact families' capacities to invest in their children's education.

Methodology

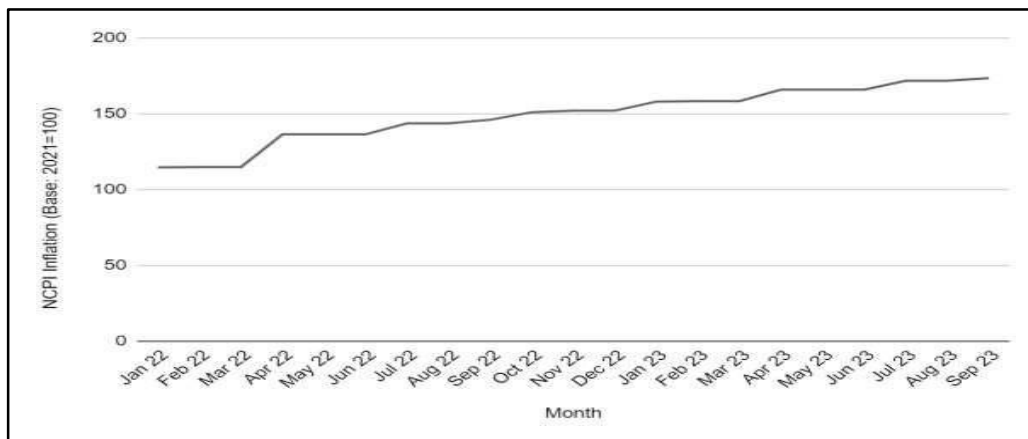
This study employed mixed research methods which consist of both qualitative and quantitative data collection methods and both primary and secondary data have been used. Annual reports from official sources; the Department of Census and Statistics and the Central Bank of Sri Lanka have been referred to in the perspective of macroeconomic context. The gathered data sets focus on the data spanning from January 2022 to September 2023. This timeframe aligns with the research objective, allowing for a comprehensive analysis of economic trends and their impact on education during the specified period. Microsoft Excel is utilized as the primary data analyzing software. Primary data are used to emphasize the collection of firsthand information directly from the field. Data were gathered through a structured survey designed to capture both quantitative and qualitative aspects of the microeconomic impact on education of students within Weligama Division. A total of 20 households were selected for in-depth interviews and nine for open-ended interviews. The sample for this research was selected using the convenience sampling method. Both quantitative data, in the form of numerical responses to survey questions, and qualitative data, derived from open-ended responses and narratives, were collected during the interviews. Thematic analysis was conducted to systematically analyze the qualitative data collected regarding the impact of economic crisis on a child's education. The data then was systematically coded to identify recurring patterns, themes, and concepts related to the impact of economic crisis on a child's education.

Results and Discussions

Education Inflation of Sri Lanka (January 2022 - September 2023)

The National Consumer Price Index (NCPI) serves as a crucial indicator of the cost of living and its fluctuations. The NCPI for education (base period 2021=100) reflects the inflationary pressures affecting educational expenses. From January 2022 to September 2023, the NCPI exhibited a steady increase, reaching 173.6 by September 2023. This escalating trend suggests a substantial rise in the overall cost of education during the specified period. The increasing cost of education, as indicated by rising inflation, likely contributes to barriers for students in Sri Lanka. The declining public sector wages may exacerbate these barriers.

Figure1: NCPI Inflation (Base 2021=100) Jan 2022-Sep 2023



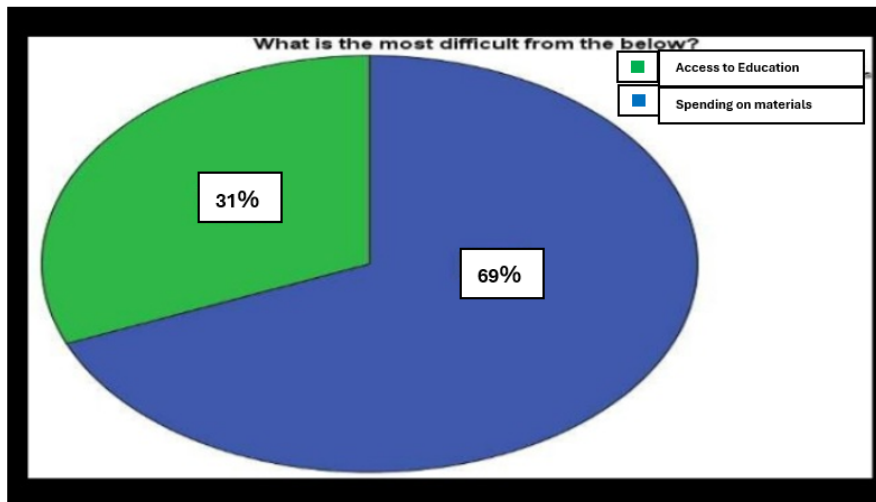
The primary data sample consists of male and female students, with 10 out of 20 students being male and 10 out of 20 being female. The age range of students in the dataset spans from 8 to 16 years. The majority fall within the 12 to 14 age group. The monthly average income of the households is concentrated in the range of 50,000 to 100,000, with a few falling into the 100,000 to 150,000 range. This indicates that the majority of the sampled households fall within a similar income bracket which is a notable limitation in the sample. The family sizes in the sample data set range from 3 to 6 members, with the most common size being 5 members. Family size can influence the economic dynamics within a household. Analyzing how family size correlates with economic impacts on education could reveal valuable insights.

The majority of respondents report a "Moderate Impact" or "High Impact", 55% and 45% respectively, of higher commodity prices on their monthly income. This suggests a widespread perception among the sampled households that the ongoing economic crisis, particularly reflected in increased commodity prices, has significant consequences for their financial well-being. Given that the research objective is to identify how the economic crisis has impacted education, these responses indicate a notable economic strain experienced by the surveyed households. Higher commodity prices, as a result of inflation, directly impact the purchasing power and financial stability of families, which, in turn, can influence their ability to support and invest in education.

The perceived impact on monthly income is indicative of potential challenges in affording educational expenses. This could include school fees, materials, and additional classes. Some respondents aptly expressed that,

When respondents were asked about the most difficult scenarios most of the families responded that the most challenging aspect was spending on education materials. This implies that respondents perceive challenges related to acquiring necessary educational materials, such as textbooks and stationery. This finding aligns with the broader research objective, which aims to identify how the ongoing economic crisis impacts education. The emphasis on material challenges reflects a nuanced aspect of the economic strain experienced by families, impacting their ability to afford essential educational resources for their children.

Figure 2 : Impact of inflation on students' education based on access to education or spending materials



The research found out through a structured questionnaire that, 65% percent of the total student sample, their family said that they paused students' extra classes as it caused economic difficulties because of rising prices of goods. 75% of them further stressed that they are encountering difficulties finding stationery as increased inflation directly caused. This clearly demonstrates that the economic stability of the country has adversely impacted areas like Weligama where even most of the middle class live. This also argues that if the middle class encounters such difficulties, to which extent it feels for the families with lower income.

Conclusion and Recommendations

The analysis of key economic indicators, including education inflation, points towards a concerning impact of the current economic crisis on education in Sri Lanka. The significant and consistent rise in headline inflation indicates an overall increase in the cost of living, directly affecting households' capacity to allocate funds for education. Specifically, the NCPI for education demonstrates a steady upward trajectory highlighting a substantial increase in the overall cost of education during the specified period. This escalating trend suggests potential barriers for students in accessing education. The decline in real wages, particularly in the public sector, further compounds the issue. This reduction in purchasing power for public sector employees may significantly impact their ability to meet educational expenses for their dependents. By shifting from the macroeconomic perspective to a microeconomic lens, the research gains depth and specificity. Results reveal significant impacts of inflation on household income and children's education. Higher commodity prices are perceived to have a "Moderate" to "High Impact" on monthly income, indicating widespread economic strain. Material challenges, particularly spending on study materials, emerge as a critical difficulty for responding.

Policy initiatives should aim to mitigate the impact of inflation on educational access and support families facing financial constraints. Policy initiatives should also consider

affordability and accessibility of supplementary education, particularly in the context of economic crises such as higher inflation. The prevalence of challenges related to spending on additional classes underscores the importance of policies and interventions that address the economic barriers to accessing supplementary education. Initiatives aimed at reducing costs or providing financial assistance for additional educational activities could be considered.

References

- Bamigboye, G., Ede, A., Adeyemi, G., (2016). Impact of Economic Crisis on Education: Case Study of Southwest Nigeria, *Proceedings of INTED 2016 Conference 7th-9th March 2016, Valencia, Spain*.
- Cader, A. A., & Perera, L. (2011). Understanding the impact of the economic crisis on child and maternal health among the poor: Opportunities for South Asia (ADB Working Paper No. 293). Tokyo: Asian Development Bank Institute. Retrieved from <http://www.adbi.org/workingpaper/2011/07/01/4624.impact.economic.crisis.child.health.poor/>
- Chia J, Francis D, Burgess M, et al. (2022) *Sri Lanka Crisis: Rapid Needs Assessment June 2022*. Colombo: Save the Children in Sri Lanka.
- Gunawaradana, A. A., & Karunarathna, J. A. M. B. (2022). A review of the effect of economic crisis on education. *International Research Symposium 2022 - Towards a Resilient Future – Opportunities and Innovations*, 277-284.
- Heyneman, S. P. (1990). Economic crisis and the quality of education. *International Journal on Educational Development*, 10(3), 115-129.
- Leanage, K., & Saito, E. (2023, February 5). Concerns about the impact of crisis on children in Sri Lanka. *Management in Education*.
- Shafiq, M. N. (2010). The effect of an economic crisis on educational outcomes: An economic framework and review of the evidence. *Current Issues in Comparative Education*, 12(2), 5-13.
- Shin, J. C., & Kim, Y. (2014). Economic crises and the post-massification of higher education. In J. Shin & U. Teichler (Eds.), *The Future of the Post-Massified University at the Crossroads*, Knowledge Studies in Higher Education, Vol. 1, pp. 4.
- Thomas, D., K. Beegle, E. Frankenberg, B. Sikoki, J. Strauss, and G. Teruel. (2004). 'Education in a crisis.' *Journal of Development Economics* 74(1):pp. 53–85.
- Wagner, L., & D'Aiglepierre, R. (2017). Macroeconomic Crisis, Primary Education and Aid Effectiveness (AFD Research Paper Series No. 2017-37, February)

**THE ROLE OF PARENTAL CARE AND CHILDHOOD MEMORIES ON LIFE
SATISFACTION AMONG YOUNG ADULTS IN SRI LANKA**

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Abstract

This research examines the role of parental care and childhood memories in shaping the life satisfaction of young adults. Life satisfaction is a multidimensional concept influenced by different factors including family and early life experiences. In this study, a quantitative approach was used utilizing 128 Sri Lankan young adults from 18-35 years of age. The Satisfaction with Life Scale, The Benevolent Childhood Experiences Scale and The Memories of Home and Family During Childhood Scale – Short Form was administered to measure life satisfaction, parental care and childhood memories among a diverse sample of young adults based on different demographic variables. The findings suggest that parental care ($p = < 0.001$) and childhood memories ($p = 0.003$) are significant predictors of life satisfaction ($p = < 0.001$). The findings of the study underscore the significance of flourishing positive childhood memories and encouraging a supportive family environment as a potential approach to promoting life satisfaction among young adults.

Keywords: Childhood memories, Life satisfaction, Parental care, Well-being, Young adults

Introduction

Life satisfaction (LS) has gained much attention in the world due to many individuals showcasing interest. Prasoon and Chaturvedi (2016), encompass LS as an overall evaluation of an individual's positive and negative emotions and attitudes toward their life and merely not the level of happiness experienced at present but during one's whole life. Veenhoven (2011) carried out a longitudinal study to examine the impact of specific life events on an individual such as relationships, education and employment, showing the critical transitions in life among young adults. However, the LS of young adults could be comprehensive to understand in terms of its determinants. To counterargue, Ruggeri et al. (2020) present the idea that such insights on LS offer the background to create interventions to enhance the well-being of young adults to achieve LS.

Heisig and Zierow (2021) investigated the impact of the bond between the children and their parents on children's LS in Israel and Germany. The study revealed that parental care (PC) and support are tied to the well-being of children in both countries and it maintains their relationships even once they grow up and leave home. Moreover, Litwin et al. (2008) interpret how PC differs with the high levels of familism in the Asian and Mediterranean cultures compared to the West. The results highlighted the degree of emotional closeness and frequency

of support by their parents are assumed to be factors that determine the fulfilment of children's lives. Considering the Sri Lankan context, Pannilage (2017) states that lack of love, care and affection and occurrence of discrimination to the children cause negative effects on their well-being.

In an analysis of the relationship between childhood memories (CM) and LS, Chang et al. (2003) hypothesized that the educational experiences during childhood among Asian children impact their LS. The research found that individuals who experienced high levels of parental expectations reported low levels of satisfaction with their lives. Frost et al. (2020) carried out a study to understand the generational differences in the interpretation of CM and their coping mechanisms. The study found that there are variations in the types of CM of the second or third generation compared to the first and they enhance satisfaction with life through their coping mechanisms such as mindfulness, participation in community work, and meditation. Despite the existing literature on PC and CM individually, there is a lack of comprehensive studies examining the combined effect on LS among young adults. The current study addresses this gap by investigating the influence of these variables simultaneously on LS. The objective of the study was to determine if PC and CM are significant predictors of LS.

The study hypothesized that,

H₁: Parental care and childhood memories are significant predictors of life satisfaction.

Methodology

Participants

The minimum required sample size for the study was 107 participants based on the calculation through G-power version 3.1.9.7. Under the parameters of F tests, multiple linear regression: fixed model, R² increase, effect size = 0.15, and total number of predictors = 3. A sample of 128 Sri Lankan young adults from the age 18-35 (M=24.91, SD=4.387) were recruited using the convenience sampling method. It was observed that, out of these participants, 28.91% were males and 71.09% were female. In terms of their marital status, 23.44% were married, 1.56% were divorced, and 75.00% were single.

Design and Procedure

A quantitative, cross-sectional research design was employed to determine if PC and CM are significant predictors of LS among young adults. Upon the ethical clearance, the online questionnaire was created using Qualtrics with the Participant Consent Form, the Demographic Form and the standardized scales. The link to the survey was distributed with an advert specifying the eligibility to participate in the study. The advert was circulated across social media platforms where the survey was opened for two weeks for the data collection.

Materials

The Satisfaction with Life Scale (SWLS)

The SWLS which is a 5-item scale was used to assess how satisfied an individual is with their life (Akyuz & Aydin, 2020). The scale has been validated to the Sri Lankan context in a study

by Dissanayake et al., (2017) that investigated happiness and LS in respect of individual perception (Overall scale $\alpha = 0.74$).

The Benevolent Childhood Experience Scale (BCES)

The BCES is a 10-item questionnaire (Overall scale $\alpha = 0.70$) that was used to measure how personal and social relationships such as parental bonds, household routines, and beliefs provide the lead to a better life in adulthood (Merrick et al., 2019).

Memories of Home and Family during Childhood Scale - Short Form (MHFS-SF)

The shortened version of the MHFS-SF contains 12 items in total and it is used for the subjective memories of experiences at home and with family during childhood (Shevlin et al., 2022).

Demographic Questionnaire

The data on age, sex, marital status, educational background, household income per month which is based on a local report on income (Household Income and Expenditure Survey, 2019), and occupational background were gathered.

Method of Analysis

The collected data was analyzed using IBM-SPSS version 29.0. Confirming the normality of the findings, a multiple linear regression was used to test if PC and CM are significant predictors of LS.

Results

Table 1: Descriptive Statistics

		Life Satisfaction	Childhood Memories	Parental Care
N	Valid	128	128	128
	Missing	0	0	0
Mean		20.5859	48.7422	8.2500
Median		21.0000	52.0000	9.0000
Mode		20.00	60.00	9.00
Std. Deviation		7.16787	11.33682	1.74789

Table 2 :Tests of Normality

Kolmogorov-Smirnov ^a			Shapiro-Wilk		
Statistic	df	Sig.	Statistic	df	Sig.

Life Satisfaction	.065	128	.200*	.983	128	.098

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Based on the Shapiro-Wilk measure, the population was considered normally distributed ($p = 0.098$).

Hypothesis Testing

Table 3 : Model Summary of Multiple Linear Regression Analysis

Model	R Square	F	df	Sig	Std. Error of the Estimate
1	31.9%	29.26	2	<.001	5.96269

Table 4 : Coefficient Table of the Multiple Linear Regression Analysis

		Unstandardized Coefficients		Standardized Coefficients	
Model		B	Std. Error	Beta	t
1	(Constant)	.132	2.727		.049
	Childhood Memories	.176	.059	.279	3.006
	Parental Care	1.438	.380	.351	3.783

The results of the regression shown in Table 3 indicated that the model explained 31.9% of the variance and CM and PC are significant predictors of LS, ($F = 29.26$, $p = < 0.001$) implying that the null hypothesis could be rejected and therefore, the results of the study supported the hypothesis. Considering Table 4, the significance of each predictor was as follows. For CM, $p = 0.003$ and for PC, $p = < 0.001$.

Discussion

In line with the hypothesis, the current study showed that CM and PC are significant predictors of LS ($F=29.26$, $p = < 0.001$) which might have controlled the potential confounding variables, assessing the unique contributions of each of these factors. The past research on the combined effects of independent variables is limited and they have been shedding light with mixed results when addressing CM and PC in respect of LS separately. Dimitrova et al., (2018), based on a sample of adults, indicated that individuals who reported better supportive PC

during their childhood tended to have higher levels of LS. Despite being a longitudinal study with a relatively homogenous sample showing clear associations between the factors reducing the effect of confounding variables, that study has been supported by the current findings. Waters et al. (2000) investigated the positive CM to predict adult LS. The results showed that there are higher scores of LS associated with the individuals who reported a high frequency of positive CM; ($F = 23.45$, $p < 0.001$) suggesting the presence of positive CM is bound with greater LS.

A contrary study by Anderson et al. (2014) depicted a very weak correlation between LS in adulthood and perceived PC during childhood, in a diverse population of adults ($r = 0.04$, $p > 0.05$), suggesting that PC did not appear as a significant predictor of LS. In addition, the study conducted by Klein et al. (2018) on the influence of CM on LS in a sample of young adults, found no significant relationship between them; $F(1230) = 0.12$, $p > 0.05$). This is a deviant result from the current study which has focused on a similar study sample. The differences could be due to different developmental stages, peer pressure, changes in career, and genetics which have not been addressed in both the studies. However, the absence of a significant relationship might not nullify the importance of them in other populations or contexts.

Limitations

With respect to the generalizability of the findings, the study has been limited by the sample bias and social desirability bias. The participants of the study might not be the representation of the broader population as the study employed convenience sampling and self-reported data with a relatively smaller sample size (Parry et al., 2021). The use of self-report data would have produced an age cohort effect where the experiences of the young adults may differ from those of previous generations due to social and cultural changes (Twenge & Blake, 2021) and would have been influenced by their current satisfaction showing the retrospective bias. The study has relied on a single data collection method to recall CM that could have altered over time, affecting the accuracy.

Conclusion and Recommendations

In conclusion, the research has underscored the significance of CM and PC in influencing LS among young adults. Although there are a few limitations, it is enriched with several strengths supporting valuable insights into the study topic. The knowledge gained through the study can be used to navigate the complexities of adulthood and avenues for future research include conducting a longitudinal study considering both the independent variables; PC and CM collectively on LS to track the impact over a while. This would provide a comprehensive understanding of how three variables evolve throughout human life and will provide insight to compare and contrast the results of the current study. Another future research idea is to explore how individuals with lesser PC and negative CM could develop coping strategies and resilience that impact positive LS. Implementation of qualitative research on this topic also would provide a rich insight into the subjective aspects of this topic as it deals with personal narratives and experiences deeply. Investigating the relationship between PC, LS and CM with other

mediating variables such as personality traits and social support can also be considered as an idea for future research.

References

- Akyüz, H., & Aydin, I. (2020). Investigation of the Relationship between Leisure Satisfaction and Life Satisfaction Levels of Individuals Participating in Physical Activity Education Programs in Civil Society Organizations. *African Educational Research Journal*, 8, 11-19. <http://dx.doi.org/10.30918/AERJ.8S2.20.049>
- Anderson, J. (2014). The impact of family structure on the health of children: Effects of divorce. *The Linacre Quarterly*, 81(4), 378-387.
<https://doi.org/10.1179/0024363914Z.00000000087>
- Chang, L., McBride-Chang, C., Stewart, S., & Au, E. (2003). Life satisfaction, self-concept, and family relations in Chinese adolescents and children. *International Journal of Behavioral Development*, 27(2), 182-189. <https://doi.org/10.1080/01650250244000182>
- Dimitrova, R., Johnson, D. J., & van de Vijver, F. J. (2018). Ethnic socialization, ethnic Identity, life satisfaction and school achievement of Roma ethnic minority youth. *Journal of adolescence*, 62, 175-183. <https://doi.org/10.1016/j.adolescence.2017.06.003>
- Dissanayake, M., Kamble, S., & Patil, A. (2017). Predicting happiness and life satisfaction from individual's perceptions of life. In *Proceeding of the 4th International Conference Journal of Management, Humanities, and Social Sciences*, 1(02), 24-31.
- Frost, D. M., Hammack, P. L., Wilson, B. D., Russell, S. T., Lightfoot, M., & Meyer, I. H. (2020). The qualitative interview in psychology and the study of social change: Sexual identity development, minority stress, and health in the generations study. *Qualitative Psychology*, 7(3), 245. <https://psycnet.apa.org/doi/10.1037/qup0000148>
- Heisig, K., & Zierow, L. (2021). Parental Leave and Long-Term Life Satisfaction of Children-Quasi-Experimental Evidence from Former East Germany.
<http://www.statistics.gov.lk/Resource/en/IncomeAndExpenditure/HouseholdIncomeandExpenditureSurvey2019FinalResults.pdf>
- Klein, R. A., Vianello, M., Hasselman, F., Adams, B. G., Adams Jr, R. B., Alper, S., ... & Sowden, W. (2018). Many Labs 2: Investigating variation in replicability across samples and settings. *Advances in Methods and Practices in Psychological Science*, 1(4), 443-490.
<https://doi.org/10.1177/2515245918810225>
- Litwin, H., Vogel, C., Künemund, H., & Kohli, M. (2008). The balance of intergenerational exchange: correlates of net transfers in Germany and Israel. *European journal of ageing*, 5(2), 91-102. <https://doi.org/10.1007/s10433-008-0079-3>

- Merrick, J. S., Narayan, A. J., DePasquale, C. E., & Masten, A. S. (2019). Benevolent Childhood Experiences (BCEs) in homeless parents: A validation and replication study. *Journal of Family Psychology*, 33(4), 493-498.
<https://psycnet.apa.org/doi/10.1037/fam0000521>
- Pannilage, U. (2017). Impact of family on children's wellbeing. *Journal of Sociology and Social Work*, 5(1), 149-158. <https://doi.org/10.15640/jssw.v5n1a15>
- Parry, D. A., Davidson, B. I., Sewall, C. J., Fisher, J. T., Mieczkowski, H., & Quintana, D. S. (2021). A systematic review and meta-analysis of discrepancies between logged and self-reported digital media use. *Nature Human Behaviour*, 5(11), 1535-1547. <https://doi.org/10.1038/s41562-021-01117-5>
- Prasoon, R., & Chaturvedi, K. R. (2016). Life satisfaction: a literature review. *The Researcher: International* <https://doi.org/10.1177/08948453221124891>
- Ruggeri, K., Garcia-Garzon, E., Maguire, Á., Matz, S., & Huppert, F. A. (2020). Well-being is more than happiness and life satisfaction: a multidimensional analysis of 21 countries. *Health and quality of life outcomes*, 18(1), 1-16. <https://doi.org/10.1186/s12955-020-01423-y>
- Shevlin, M., Redican, E., McElroy, E., Ben-Ezra, M., Karatzias, T., & Hyland, P. (2022). Measuring positive memories of home and family during childhood: The development and initial validation of the 'Memories of Home and Family Scale'. *Current Psychology*, 1-10. <https://doi.org/10.1007%2Fs12144-022-03220-w>
- Twenge, J. M., & Blake, A. B. (2021). Increased support for same-sex marriage in the US: Disentangling age, period, and cohort effects. *Journal of homosexuality*, 68(11), 1774-1784. <https://doi.org/10.1080/00918369.2019.1705672>
- Veenhoven, R. (2011). Happiness: Also known as "life satisfaction" and "subjective well-being". In *Handbook of social indicators and quality of life research* (pp. 63-77). Dordrecht: Springer Netherlands.
- Waters, E., Merrick, S., Treboux, D., Crowell, J., & Albersheim, L. (2000). Attachment security in infancy and early adulthood: A twenty-year longitudinal study. *Child development*, 71(3), 684-689. <https://doi.org/10.1111/1467-8624.00176>

**UNDERGRADUATE’S ATTITUDES TOWARD THE HOMOSEXUAL
COMMUNITY IN WESTERN PROVINCE, SRI LANKA**

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Abstract

This research investigates undergraduate attitudes toward the homosexual community in Western Province, Sri Lanka. According to the penal code, all kinds of homosexual acts are indicated as punishable offenses, but some research has shown people have positive attitudes toward homosexuality. There were two research objectives in this study (1) to identify the undergraduate's attitudes toward the homosexual community and (2) to identify gender differences in undergraduate's attitudes toward the homosexual community. Using quantitative research with cross-sectional, data was collected from 78 university students aged between 20 to 25 through the demographic questionnaire and Homosexual Attitude Scale (HAS). A t-test was conducted to identify gender differences in undergraduate attitudes toward the homosexual community. The final results were undergraduates in the western province, of Sri Lanka have positive attitudes toward the homosexual community with no gender difference between undergraduate attitudes and the homosexual community in the western province, of Sri Lanka.

Keywords: Attitudes, Homosexuality, Sri Lanka, Undergraduate

Introduction

This study explores the attitudes of undergraduate students in Sri Lanka’s Western Province toward the homosexual community, focusing on how these views are shaped within a context where traditional values meet increasing calls for inclusivity and equality (WFD, 2021). Using frameworks like queer theory (Butler, 1990) and intersectionality (Crenshaw, 1989), the research aims to provide insights into the specific cultural and educational influences that affect perceptions of sexual orientation in Sri Lanka. By examining undergraduate students’ attitudes, this study contributes to the growing understanding of sexual orientation issues in the country. The objectives are to identify overall attitudes among undergraduate students toward the homosexual community and to assess whether gender differences exist in these attitudes. Based on these objectives, it is hypothesized that there is a positive relationship between undergraduate attitudes and the homosexual community (H1) and that there is a gender difference between undergraduate attitudes and the homosexual community (H2). Alternatively, the null hypotheses (H0) suggest no such positive relationship or gender difference exists.

Methodology

Materials

Two questionnaires were used in this study. The first collected demographic data (age, gender, province of the university, and educational level). The second used the Homosexual Attitude Scale (HAS) to measure participants' attitudes toward homosexuality. The HAS is in a Likert scale format. Developed by Kite and Deaux in 1986, the HAS comprises 21 questions with five response options: "strongly agree," "agree," "neutral," "disagree," and "strongly disagree. This is a scale with excellent internal consistency (alphas > 0.92). Also, it has good test-retest reliability ($r=0.71$).

Participants

A sample of 78 was selected: 39 males and 39 females. Participation criteria stated the selection of participants based on age, with a range of 20 to 25 years of age, and currently university students at government or private universities in the Western Province of Sri Lanka (Ex – the University of Colombo, University of Sri Jayawardanapura, University of Kelaniya, ICBT campus, NSBM green university, NIBM campus, etc.). This age range was chosen as it represents a developmental stage where individuals form and solidify their attitudes and opinions, making it a critical period for studying perceptions and attitudes.

Design

This research used a quantitative research method with a cross-sectional design. Quantitative research enables the measurement of variables such as behaviors, opinions, attitudes, and other factors in a quantifiable manner, facilitating the generalizability of data to a broader population. This study's independent variable was education level, and the dependent variable was attitudes toward homosexuality. This research also quantified undergraduate perceptions and attitudes. Quantitative research uses quantifiable data to articulate facts and reveal patterns in research.

Procedure

Data was collected using a random sampling technique. The questionnaire was distributed using WhatsApp. Each respondent participated in this research by clicking on an online questionnaire survey. Participation was voluntary, and consent was provided electronically through the online survey before answering the questions. There was an option to discontinue at any point if they felt uncomfortable. Data analysis was done for 78 samples after collecting the data. Results obtained after analyzed data.

Method of Analysis

According to the author, the raw data was analyzed by scoring the responses to the HAS questionnaires. These items 1, 2, 6, 8, 13, 14, 15, 18, 19, 20, and 21 are reverse scored. Data analysis was done using SPSS. There has been a run a t-test. A t-test is a type of inferential statistic used to determine if there is a significant difference between the means of two groups. Therefore, this study conducted a t-test to identify if there are any gender differences in undergraduate perceptions and attitudes toward the homosexual community.

Results

Participants in the sample were aged between 20 and 25 years. Most of them (39.7%) were 22 years old, while the rest were 14.1% each for 21 and 25 age brackets. The mean age was 22.44 (SD=1.465) with a median of 22 and a mode of 22.

The questionnaire on attitudes towards homosexuality had a scoring system from least favorable at 21 points to most favorable at 105 points. The present study found the minimum score to be 44 and the maximum score was 105. The mean score was 75.58 (SD=16.024) which implied a generally favorable attitude. However, a comparison with previous studies is required to interpret whether this is higher or lower relative to other groups.

Independent sample t-test is used to assess differences in attitudes toward gender. No significant difference was found between men (M=74.72, SD=16.201) and women (M=76.44, SD=15.836); $t(76)=-0.474$, $p=0.637$. This means that gender did not have a significant influence in this sample on undergraduate attitudes toward homosexuality.

Discussion

The current study has found largely positive attitudes towards homosexuality among undergraduates in the Western Province of Sri Lanka. This is consistent with the results of Passani and Debicki (2016), who noted that the majority of university students reported positive attitudes towards homosexuality. More precisely, our sample had a mean attitude score of 75.58 (SD = 15.939), reflecting an overall favorable attitude. These findings do not hold universally. For example, Swank and Raiz (2010) reported that university students in religious social work programs had hostile attitudes toward homosexuality, which is opposite to the findings of the present study. Such a discrepancy may be due to cultural context, academic orientation, or exposure to diverse social perspectives in higher education.

This study also did not find any significant gender differences in undergraduate students' attitudes toward the homosexual community. This is inconsistent with Chi and Hawk's 2016 study on 2,644 Chinese university students, where women showed a significantly more positive attitude than men. The lack of significant gender differences in the present findings could reflect unique cultural or societal dynamics in Sri Lanka, where collective societal norms might influence attitudes more uniformly across genders. Alternatively, given the relatively small sample size (N = 78), this may be due to reduced statistical power to detect subtler effects.

Conclusion and Recommendation

The present study focusing on a knowledgeable and influential segment of the population, namely undergraduate students, and their attitudes towards the homosexual community in Western Province, Sri Lanka, has obtained generally positive attitudes. It is thus implied that higher education instills higher levels of acceptance; however, specific limitations to the sample size and demographic characteristics need further investigation. The following studies should, therefore, be based on larger and more diverse samples, establishing the effects of

cultural background, religion, level of education, age, and ethnicity on attitudes toward homosexuality. Longitudinal designs would also be interesting to note and might begin to unpack whether and how such attitudes change as a function of time or perhaps with increased exposure to education and multiple perspectives. Deepening the scope of analysis, such future research would yield more fine-grained insight into what shapes attitudes toward the lesbian and gay community and inform targeted interventions to foster inclusivity.

Reference

- Chi, X. and Hawk, S.T. (2016) 'Attitudes toward Same-Sex Attraction and Behavior among Chinese University Students: Tendencies, Correlates, and Gender Differences,' *Frontiers in Psychology*, 7. <https://doi.org/10.3389/fpsyg.2016.01592>.
- Kite, M.E. and Deaux, D. (1986) 'Attitudes toward Homosexuality: assessment and Behavioral Consequences,' *Basic and Applied Social Psychology*, 7(2), pp. 137–162. https://doi.org/10.1207/s15324834basp0702_4.
- Passani, A. and Debicki, M. (2016) 'Students opinions and attitudes toward LGBT persons and rights: Results of a transnational European project,' *Journal of LGBT Youth*, 13(1–2), pp. 67–88. <https://doi.org/10.1080/19361653.2015.1087927>.
- Swank, E. and Raiz, L. (2010) 'Attitudes toward gays and lesbians among undergraduate social work students,' *Affilia*, 25(1), pp. 19–29. <https://doi.org/10.1177/0886109909356058>.

**A QUANTITATIVE ANALYSIS OF ENGLISH LANGUAGE PROFICIENCY OF
VOCATIONAL TRAINING STUDENTS BASED ON ITEM ANALYSIS**

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Abstract

This study examines the receptive skill proficiency of vocational training students enrolled in the National Diploma in Information Communication Technology in Sri Lanka, focusing on reading and listening sub-skills. Guided by Shephard and Ainsworth's (2018) findings, a quantitative approach was employed using a clustered sample of 30 students (ages 17–22) with UTEL benchmark 4 proficiency. Data collection involved administering two tests, comprising 15 questions targeting specific sub-skills. SPSS analysis revealed moderate difficulty levels across most sub-skills, with mean scores indicating slightly higher listening proficiency (9.96/15) over reading (9.86/15). Students excelled in listening for the main ideas but struggled with inferential listening and specific details. Similarly, reading for gist and specific information posed challenges. Findings align with prior studies, emphasizing listening as the strongest receptive skill. The study recommends incorporating targeted practice for weaker sub-skills and integrating productive skills for a more comprehensive language development approach.

Keywords: Item Analysis, Receptive Skills, Sub-skills of Reading, Sub-skills of Listening, Vocational Training Students

Introduction

Vocational training has become increasingly popular among young Sri Lankans, offering pathways to developing industry-relevant practical skills in order to meet the demands of the contemporary job market. However, despite their technical proficiency, vocational students often face challenges in English communication, which thereby remains a critical skill for employability (Ranasuriya & Herath, 2020). Therefore, due to this gap, most diploma programs offered by the Vocational Training Authority in Sri Lanka deliberately integrate English language components into their curricula. However, previous studies (Shephard & Ainsworth, 2018) have also highlighted significant disparities in students' receptive skill proficiency, with upper-secondary learners demonstrating stronger listening and reading competence than speaking and writing.

Therefore, the increasing importance of English in vocational education stems from the globalization of labor markets and the growing need for effective communication in the English language to access both local and international opportunities (Graddol, 2006). Hence, according to Canagarajah (2013), English is seen serving as a lingua franca in many professional fields, requiring vocational students to master both their general and domain-specific language skills. Furthermore, theories of second language acquisition, such as Krashen's Input Hypothesis, further emphasize the critical role of comprehensible input in

developing language proficiency. Moreover, the receptive skills of listening and reading further provide this input and form the foundation in developing productive skills (Krashen, 1985). Therefore, these theoretical perspectives further underscore the necessity of strengthening receptive skills within the learners to build a robust linguistic foundation for vocational students.

Despite prior research indicating that vocational students generally perform better in receptive skills than in productive skills (Shephard & Ainsworth, 2018; Indrarathne & McCulloch, 2021), there remains a notable gap in empirical studies examining their proficiency at the sub-skill level. Specifically, limited research has identified the particular sub-skills within listening and reading that present the greatest challenges for vocational learners in Sri Lanka. Addressing this gap, the present study conducts an item analysis to determine the strengths and weaknesses of vocational students in these receptive sub-skills. Previous studies have established that while vocational students demonstrate strong practical competencies, their linguistic abilities, particularly in productive domains, remain underdeveloped (Indrarathne & McCulloch, 2021). However, findings also suggest that receptive skills, such as listening and reading, tend to be acquired more readily than productive skills (Harmer, 2007). In light of these insights, this study aims to reassess vocational students' receptive skill proficiency, focusing on specific sub-skills within listening and reading. By identifying areas of strength and weakness, the research seeks to inform the development of more effective English language teaching strategies tailored to the needs of vocational learners in Sri Lanka.

Methodology

This study adopts a quantitative research approach, utilizing a clustered sample of 30 vocational training students aged 17 to 22 enrolled in the NDICT program. The participants were selected based on their English language proficiency, which corresponded to UTEL benchmark 4, ensuring a uniform baseline for assessment. The sample size was deemed adequate for statistical analysis, providing a representative snapshot of the broader student population within the vocational training context, which is in line with Creswell's (2014) recommendations for achieving meaningful statistical representation in educational research. The assessment was developed on the foundation that vocational training students enrolled in the National Diploma in Information Communication Technology (NDICT) program demonstrate higher proficiency in listening than in reading, with notable difficulties in inferential listening and reading for gist.

Data collection involved administering two separate test papers containing 15 questions targeting specific sub-skills. The reading test assessed sub-skills such as reading for specific information (SI), reading for gist (G), and identifying main ideas and supporting details (MISD). Similarly, the listening test evaluated sub-skills including listening for specific information and important details (SIID), listening for main ideas and supporting ideas (MISD), and inferential listening (IMP). This method follows established frameworks for assessing receptive language skills, such as those outlined by Alderson (2000), ensuring validity and reliability in testing receptive skills.

The tests were developed based on established frameworks for assessing receptive language skills, ensuring validity and reliability, as suggested by Messick (1989), who emphasized the importance of clear test construction in educational assessments. Answer sheets were analyzed using SPSS software to calculate difficulty indices and significant value percentages for each question. This method allowed for granular analysis of student performance, facilitating the identification of specific sub-skills that require further development, aligning with the approaches proposed by Field (2013) for using statistical analysis to inform pedagogical strategies. Unlike qualitative approaches, which often rely on subjective self-reports or observational data, this quantitative method provided objective performance metrics, as advocated by Shephard and Ainsworth (2018), offering a scientifically rigorous means of evaluating language proficiency.

Results

The data analysis of this study revealed a range of difficulty levels across the assessed sub-skills, with most of the questions falling within the moderate difficulty category. As shown in Table 1, the mean scores and difficulty indices for each sub-skill reflect the varying levels of proficiency among the participants in different receptive skills.

Table 1: Mean Scores and Difficulty Indices for Each Sub-Skill

Sub-skill	Mean Score (out of 15)	Difficulty Index
Reading for SI	10.2	Moderate
Reading for G	8.9	Moderate-High
Reading for MISD	9.4	Moderate
Listening for SIID	9.2	Moderate
Listening for MISD	10.5	Easy-Moderate
Listening for IMP	8.8	Moderate-High

Reading Skills

Furthermore, the reading sub-skills showed a general trend of moderate performance, with a slight variation within the difficulty levels. **Reading for Specific Information (SI)** received the highest mean score (10.2), which thereby indicates that students were relatively proficient at locating and extracting specific details from the text. This is further consistent with previous research, such as that by Alderson (2000), in which it was found that the readers typically perform better on tasks requiring the identification of specific information rather than more complex tasks like understanding the main ideas or gist.

However, **Reading for Gist (G)**, which showcased the lowest mean score of 8.9, fell into the moderate- high difficulty category, pointing out the students' challenges in grasping the overall meaning or thematic essence of texts. Moreover, this result also aligns with Shephard and Ainsworth's (2018) findings, which thereby emphasized that tasks requiring holistic comprehension, such as reading for gist, usually place higher cognitive demands on learners. Furthermore, the relatively lower scores in this category reflect the cognitive load required for synthesizing information beyond literal meanings and recognizing overarching themes.

Reading for Main Ideas and Supporting Details (MISD) scored 9.4, indicating moderate proficiency. Therefore, it could be said that the students were reasonably skilled at identifying the main ideas and supporting details in the texts, but their performance still showed room for improvement. Furthermore, this finding is also in line with Koda (2005), who emphasized that understanding the main ideas requires both linguistic competence and the ability to identify key information in relation to supporting details.

Listening Skills

Listening, on the other hand, emerged as a slightly stronger skill overall. Thereby, the mean score for **Listening for Main Ideas and Supporting Details (MISD)** was 10.5, categorized as easy-moderate, which thereby indicates that the students could comprehend and extract the main ideas prevailing and supporting details from spoken language with relative ease. Hence, this result aligns with the findings of Vandergrift (2007), who suggested that listening tasks that are usually centered around the main ideas and supporting details tend to be less complex and more accessible to learners who possess basic proficiency.

However, **Listening for Specific Information and Important Details (SIID)** and **Listening for Inferential Meaning (IMP)** posed more challenges. Both sub-skills received moderate-high difficulty ratings, with mean scores of 9.2 and 8.8, respectively. Moreover, these findings are also supported by Field's (2009) observation which states, that listening tasks that involve detailed or inferential listening are more demanding for learners. Nonetheless, Inferential listening, in particular, requires a basic understanding of the spoken content and the ability to make inferences and interpret implied meanings, emphasizing a skill that is often more difficult to master (Rost, 2011).

Overall Proficiency

Hence, the overall mean scores for the reading and listening tests were 9.86 and 9.96, respectively, which thereby suggests a moderate level of proficiency across both receptive skills. However, this slight advantage in listening proficiency is consistent with the findings of Shephard and Ainsworth (2018), who noted that listening skills tend to develop more quickly than reading skills in language learners, particularly when the tasks are centered around understanding main ideas and specific details.

While both reading and listening skills thereby show an adequate level of proficiency, the results further indicate significant areas for a lot of improvement, particularly in tasks that require higher-level comprehension, such as reading for gist and listening for inferential meaning. This further aligns with Alderson (2000), who suggested that while learners may have foundational proficiency in receptive skills, more complex sub-skills often require targeted instruction and practice. Thereby, overall, these findings underscore the need for a curriculum that emphasizes these areas of difficulty to ensure a more balanced development of receptive skills among vocational students.

Discussion

Therefore, the findings of this study align with previous research indicating that listening is the most proficient receptive skill among vocational students. The higher mean score for listening reflects students' ability to comprehend spoken English, particularly in identifying main ideas and supporting details. This result supports and tallies with the findings of Vandergrift (2007), who highlighted that listening comprehension is often stronger in learners when tasks are designed to focus on main ideas rather than inferential or specific details. However, a number of challenges were also noted in inferential listening (IMP) and listening for specific information and important details (SIID), which are also directly consistent with the findings of Field (2009), who found that vocational learners often struggle with the listening tasks that require higher levels of inference and detail extraction. These issues, therefore, indicate areas for targeted intervention, as suggested by Rost (2011), who emphasized the need for explicit practice in these sub-skills to improve overall listening proficiency.

However, in reading, students demonstrated competency in extracting specific information and understanding the main ideas with supporting details yet struggled with reading for gist. These results corroborate earlier studies that emphasize the cognitive demands of synthesizing overarching themes (Shephard & Ainsworth, 2018). Nonetheless, according to Grabe and Stoller (2011), reading for gist involves higher-order cognitive skills, which can be particularly challenging for students with limited language proficiency or insufficient exposure to more complex texts. Therefore, such difficulties are further supported by Koda (2005), who argued that reading for gist requires not only linguistic competence but also the ability to infer meaning from context and identify broad thematic elements.

Comparing these findings to the international benchmarks, the results suggest that Sri Lankan vocational students possess a foundational level of receptive skills but lack the advanced

comprehension abilities required for complex academic or workplace tasks. This aligns with the work of Ranasuriya & Herath (2020), who observed similar trends in vocational education, where students often demonstrate a solid grasp of basic language skills but struggle with higher-order comprehension required in professional or academic contexts. Thereby, this gap underscores the need for curriculum enhancements that prioritize sub-skill development, which once again as highlighted by Alderson (2000), is important in addressing specific receptive skills in language education to bridge the gap between foundational skills and the demands of academic and workplace environments.

Conclusions and Recommendations

This study, therefore, reaffirms that listening is the strongest receptive skill among vocational training students, followed closely by reading, though specific sub-skills within these domains, such as inferential listening and reading for gist, which requires targeted attention. Moreover, addressing these gaps are critical, as English language proficiency significantly influences students' employability and professional growth within the contemporary world. Therefore, to bridge these evident gaps, the curriculum should be revised to include targeted activities and exercises aimed at enhancing weaker sub-skills. Instructional strategies should also incorporate multimedia resources and interactive techniques that simulate real-world listening and reading scenarios, thereby fostering deeper comprehension within the students. Additionally, diagnostic tools should be developed to continuously monitor sub-skill proficiency, enabling the adaptation of instructional approaches to meet students' needs effectively. While this study focuses on receptive skills, integrating productive skills into future research could offer a more holistic approach to language development. These measures would thereby better equip vocational training students with the language skills necessary for success in the modern workforce and encourage further research to validate these findings across diverse disciplines and proficiency levels.

References

- Alderson, JC 2000, *Assessing reading*, Cambridge University Press.
- Canagarajah, AS 2013, *Translingual practice: Global Englishes and Cosmopolitan Relations*, Routledge.
- Creswell, JW 2014, *Research design: Qualitative, Quantitative, and Mixed Methods Approaches*, SAGE.
- Field, A 2013, *Discovering statistics using IBM SPSS Statistics*, SAGE.
- Grabe, WP & Stoller, FL 2013, *Teaching and Researching: reading*, <https://doi.org/10.4324/9781315833743>.
- Graddol, D 2006, *English next: Why Global English May Mean the End of “English as a Foreign Language.”*
- Graham, S 2012, “Michael Rost, 2011, *Teaching and Researching Listening*. Longman,

407 pages, ISBN: 9781408205075,” *International Journal of Applied Linguistics*, 22(3):420–423, <https://doi.org/10.1111/ijal.12003>.

Harmer, J 1983, *The practice of English language teaching*, Longman Publishing Group.
Indrarathne, B & McCulloch, S 2021, *English language teaching, learning and assessment in Sri Lanka: Policies and practices in the school education system*, British Council, December 12, 2024, [https://www.teachingenglish.org.uk/sites/teacheng/files/2022-04/ELT%20learning%20and%20assessment%20in%20Sri%20Lanka April%202022_new2.pdf](https://www.teachingenglish.org.uk/sites/teacheng/files/2022-04/ELT%20learning%20and%20assessment%20in%20Sri%20Lanka%20April%202022_new2.pdf).

Koda, K 2005, *Insights into second language reading: A Cross-Linguistic Approach*, Cambridge University Press.

Krashen, SD 1985, *The input hypothesis: Issues and Implications*, Longman Publishing Group.

Messick, S 1989, “Meaning and Values in Test Validation: The Science and Ethics of Assessment,” *Educational Researcher*, 18(2):5–11, <https://doi.org/10.3102/0013189x018002005>.

Ranasuriya, DL & Herath, SM 2020, “A Needs Analysis on the language skills required by the industry from vocational graduates,” *Sri Lanka Journal of Social Sciences*, 43(2):85, <https://doi.org/10.4038/sljss.v43i2.7932>.

Sheperd, E & Ainsworth, V 2019, *ENGLISH IMPACT SRI LANKA: AN EVALUATION OF ENGLISH LANGUAGE CAPABILITIES*, British Council, December 12, 2024, https://www.britishcouncil.org/sites/default/files/h203_01_english_impact_report_sri_lanka_aw5.pdf.

Vandergrift, L 2007, “Recent developments in second and foreign language listening comprehension research,” *Language Teaching*, 40(3):191–210, <https://doi.org/10.1017/s0261444807004338>.



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