# ANNUAL INTERNATIONAL RESEARCH SYMPOSIUM

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*"Bridging the Innovation Gap: Multidisciplinary Perspective"*

**AIRS'23**
Symposium Proceedings

AIRS
ICBT CAMPUS
ANNUAL INTERNATIONAL
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ICBT CAMPUS

# AIRS' 23

Proceedings of the
6th Annual International Research Symposium

15th February 2024

International College of Business and Technology
Sri Lanka

# Proceedings of
# 6ᵗʰ Annual International Research Symposium -2023

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**Message from the Conference Chair**

*Dr. Sampath Kannangara*

**Executive Director CEO & Executive Dean – International College of Business and Technology**

It is a great privilege to Chair the Annual International Research Symposium of ICBT, 'AIRS' 2023' to be held on 15th February 2024 at 9.00AM Sri Lanka Time. This is the sixth international research symposium organized by the International College of Business and Technology. This will continue to move forward in the research arena under the digital ISSN:2961-502X.

The theme for this year is "Bridging the innovation Gap: Multidisciplinary perspective". Peer reviewed research papers under this theme will be presented according to thematic tracks, ensuring a cohesive exploration of diverse topics within each track, namely, Business Management, Information Technology, Health Science, Social Science, Engineering, Construction. This year the review panel consists of 43 international and local reviewers.

This year's research theme addresses the challenges of connecting innovation efforts across various disciplines to enhance collaboration, knowledge exchange, and problem-solving in this post pandemic era. We must understand that the multidisciplinary approach where inter-disciplinary collaboration, is essential to translate research findings into real-world solutions. Closing the innovation gap requires concerted efforts from various stakeholders, including researchers, entrepreneurs, policymakers, investors, and communities. Strategies for addressing the innovation gap involve fostering collaboration across disciplines and sectors, investing in technology transfer and commercialization initiatives, promoting innovation-friendly policies and regulatory frameworks, and enhancing education and training in entrepreneurship and innovation management. By bridging the innovation gap, societies can unlock the full potential of new ideas and technologies to address pressing challenges and improve quality of life.

I congratulate the organizing team for setting up the momentum to discuss this intellectual scholarship.

## Message from the Editor-in-Chief

### *Dr. Sanath Divakara*

Welcome all to the Proceedings of the 6th ICBT Annual International Research Symposium- AIRS'23 under the theme of "Bridging the Innovation gap: Multidisciplinary Perspective".

It is a great honor to assume the role of Editor-in-Chief in Annual International Research Symposium. My sincere appreciation to all the authors and co-authors for your precious technical commitment made upon the success of the proceedings of 6th AIRS' 23. Your enthusiasm to share the knowledge in AIRS'23 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 the conference.

AIRS opens an opportunity for the authors to publish the invaluable piece of research on sharing knowledge. Research publication is an essential requirement of your research journey as part of the knowledge contribution to the society that enables the continuation of the meaning of research. Completing research is not merely adding a qualification, it embeds the research mindset to the researchers and changes the researchers mind set in solving problems in a scientific and systematic manner. Research publication would add more value to your career and consolidate the philosophical and system thinking toward the bridging the innovation gap.

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 and the volunteer contribution as reviewers, the conference technical program committee members, and the designated reviewers. I wish to request all of you, valuable suggestions to improve the symposium in future.

I sincerely extend my gratitude to contributors, 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 technical ideas with colleagues from around the world. My great appreciation for all participants to the conference and I hope that everyone will enjoy the conference AIRS' 23.

Dr Sanath Divakara

Editor in Chief

AIRS'23

## KEYNOTE SPEAKERS

| Profile | Title of Speech |
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| *Chief guest and Keynote Speaker* <br><br> **Dr Jagath Alwis** <br> Chairman, ICBT Campus <br> Executive Chairman <br> Ceylinco General Insurance Limited | *Innovation: the way forward* |
| *Keynote Speaker* <br><br> **Prof. Ranjith Dissanayake** <br> The President, <br> The Institution of Engineers Sri Lanka (IESL) <br> Senior Professor, <br> University of Peradeniya | *Bridging the Gap Between Academia and the Industry* |
| *Keynote Speaker* <br><br> **Dr. (Eng.) Sujithra Weragoda** <br> PhD, M Eng, BSc (Hons), C Eng, MIESL, MIWA (Water Treatment Process Engineer, Water Safety Plan Master Trainer and Auditor) <br> Director, <br> Joint Research and Demonstration Center for Water Technology, <br> Ministry of Water Supply | *Embracing Resilience: Navigating Sri Lanka's Future in the Face of Climate Challenges* |

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*Bridging the innovation gap in construction with application of machine learning for selection of telescope clamshell enclosure*

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# AIRS' 23

## *Chapter 01:*
## BUSINESS MANAGEMENT

# EXPLORING THE FACTORS AFFECTING THE ADOPTION OF BIM IN MEP SECTOR OF SRI LANKAN BUILDING CONSTRUCTION PROJECTS

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**Abstract**

The construction industry in Sri Lanka faces challenges in efficiency and productivity, particularly in the MEP sector. This study investigates the adoption of Building Information Modelling (BIM) in MEP projects with research objectives of evaluating awareness levels, identifying barriers, determining influencing factors, and proposing strategies for BIM literacy improvement and increased adoption in the MEP sector. The research reveals a significant lag in BIM implementation, impacting MEP coordination, costing, and overall project success. Surveying 195 MEP professionals, the study identifies barriers, including low awareness, insufficient skills, and cost-related concerns. Consultants exhibit higher BIM adoption rates than contractors. Statistical analyses confirm the negative correlation between BIM adoption and identified barriers. Recommendations include enhancing BIM education, fostering collaboration between industry and academia, and promoting government mandates. The study emphasizes the urgent need for BIM knowledge improvement in the MEP sector to unlock its potential benefits.

**Key Words:** BIM Adoption, BIM Awareness, Building Information Modelling, Construction Industry, MEP

## Introduction

The construction industry suffers from poor performance, and it lags behind other industries with regard to efficiency improvements. According to Fulford & Standing (2013) investments in information technology has been a driving factor for productivity improvements in many sectors. Developed countries such as USA, UK, Europe Union, Canada, Singapore, and Australia etc. have adopted BIM into their construction sector (Naborczyk, 2020). Sri Lanka's uptake in BIM significantly lags behind other Asian nations. Although the concept of BIM is slightly practiced in Sri Lankan construction industry, the majority of organizations still haven't adopted BIM (Rathnayake, et al., 2018). MEP coordination is a critical, complex, and time-consuming task which is utmost important to the smooth flow of work in the project without hindrances. In most of the building construction projects the site team faces issue of MEP clashes due to design coordination problems. MEP costing is also a critical task for the consultants as well as contractors to secure the project and to earn profit. Project cost over runs is seen due to variations and also due to improper cost estimations. Manual quantity take off is the method to quantify the MEP scope for pricing. Which depends on the person who do the take off and his knowledge and experience of the relevant field. The percentage of MEP works for the total construction work of high-rise building projects is equal to 26 % which is a significant portion of the project cost (Ashuri, et al., 2014). Therefore, any cost overrun in MEP

trades of the project adversely affect the total successful delivery of the building. In the world BIM adaptation has increased over the years, specially by commercial contractors. In North America BIM adoption was 28% in 2007 but this was increased to 71% by 2012. In the United Kingdom, using BIM is mandatory for the public construction projects (Mohammad, et al., 2017). The use of modern technologies, such as BIM, has been found to enhance the accuracy of pre-tender cost estimates in many countries by reducing the influence of conventional practices (Rathnayake & Samir, 2019). BIM offers the potential to achieve the objectives of increasing productivity and quality, decrease project cost and reduce project delivery time (Azhar, 2011). As Ismail et al. (2017) mentioned Sri Lanka has not adopted BIM into their construction industry even though the interest on the topic is rising. By considering the above facts, it can be justified that Sri Lankan MEP sector lags behind in using BIM and it can benefit to resolve the issues that the industry is facing. Therefore, the objectives of the study have been defined as below:

To understand the level of awareness about BIM among the Engineers in the MEP sector.

To identify the present status of BIM adoption rate among the MEP contractors and consultants in Sri Lanka.

To determine the factors affecting the decision of adopting BIM over the conventional practices by the MEP professionals in Sri Lanka

To recommend strategies to improve BIM literacy and adoptability of BIM in the MEP sector.

**Research Methodology**

Following four factors were selected as the independent variables. BIM adoption rate was selected as the dependant variable.
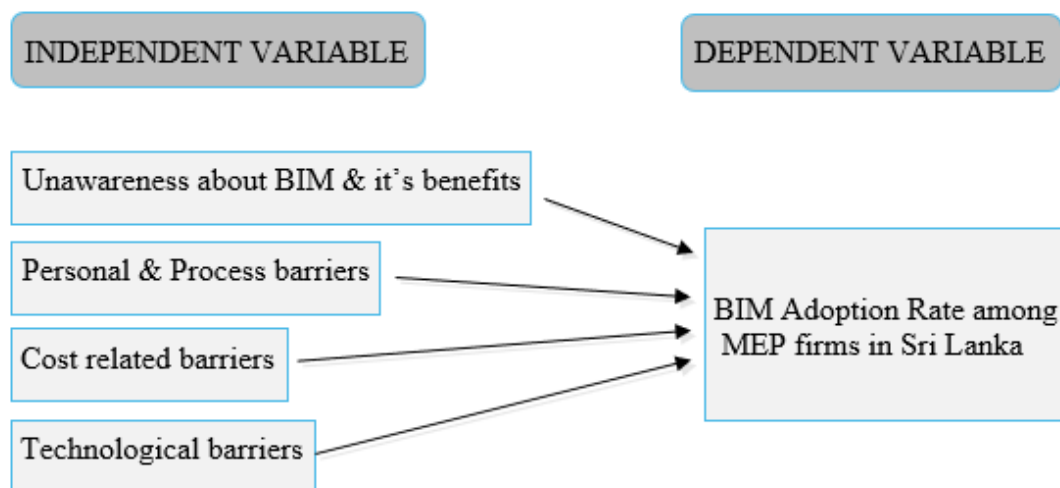


*Figure 1:Conceptual Framework*

To achieve the objectives that were mentioned above, below mentioned Hypotheses were developed based on the potential factors affecting the decision of adopting BIM.

$H_0$ – Null Hypothesis

$H_a$ – Alternative Hypothesis

| Hypothesis 1 | $H_{10}$ | There is no relationship between the **Unawareness about BIM & it's Benefits** and BIM Adoption Rate among MEP firms in Sri Lanka |
| | $H_{1a}$ | There is a relationship between the **Unawareness about BIM & it's Benefits** and BIM Adoption Rate among MEP firms in Sri Lanka |
| Hypothesis 2 | $H_{20}$ | There is no relationship between **Personal & Process barriers** and BIM Adoption Rate among MEP firms in Sri Lanka |
| | $H_{2a}$ | There is a relationship between **Personal & Process barriers** and BIM Adoption Rate among MEP firms in Sri Lanka |
| Hypothesis 3 | $H_{30}$ | There is no relationship between **Cost Related Barriers** and BIM Adoption Rate among MEP firms in Sri Lanka |
| | $H_{3a}$ | There is a relationship between **Cost Related Barriers** and BIM Adoption Rate among MEP firms in Sri Lanka |
| Hypothesis 4 | $H_{40}$ | There is no relationship between **Technological Barriers** and BIM Adoption Rate among MEP firms in Sri Lanka |
| | $H_{4a}$ | There is a relationship between **Technological Barriers** and BIM Adoption Rate among MEP firms in Sri Lanka |

*Figure 2: Development of Hypotheses*

The population for this research was the MEP contractors and Consultants in Sri Lanka. The population size was 390. Proportionate stratified random sampling technique was used to select the sample for this survey because there are two categories of population such as MEP contractors and consultants. With a 95% confidence level and 5 confidence interval the sample size for the population of 390 is 194

Table 1: Stratified Sample Size

| Category | Number of Elements | No. of subjects in the sample |
| --- | --- | --- |
| MEP Contractors | 252 | 125 |
| MEP Consultants | 138 | 69 |
| Total | 390 | 194 |

Chan, et al. (2019), Ramilo, et al. (2017), Bouhmoud & Loudyi (2021) researchers have used a quantitative approach using questionnaires to determine the effect of critical factors and barriers to adopt BIM. Author has followed the same approach in this research based on the literatures mentioned above. Primary data were gathered using Google Forms from the MEP professionals in Sri Lanka. Chan, et al. (2019) has used the Cronbach's α reliability test, Pearson correlation test and Regression Analysis to analyse the questionnaire and the collected data to find critical success factors for building information modelling (BIM) implementation in Hong Kong. Author has followed the same method for this research based on the literature review. The primary data collected from the structured questionnaire were analysed using the SPSS V20 Software and MS Excel 2016.

**Results**

A reliability coefficient of .70 or higher is considered "acceptable" in most social science research situations (UCLA, 2021). In this research the Cronbach's Alpha value was 0.805 which is >0.7 when all the variables were considered together. Furthermore, each variable also has a Cronbach's Alpha value greater than 0.7. Therefore, the set of data can be acceptable and reliable.

Out of the 195 responses 125 was from MEP contractors and 70 was from MEP consultants which account for 64.1% and 35.9% respectively. 101 No. of Electrical or Mechanical Engineers, 50 No. of Project Managers, 26 No. of Quantity Surveyors, 16 No. of MEP Draftsman and 2 No. of BIM Operators had responded. It was evident that a good mix of job profiles has responded with the M&E Engineers being the highest. There were only two BIM operators in the mix, that was also only from the consultant side which gave an indication of low BIM adoption in the field.

Table 1: BIM adoption as per field category

| Level of Adoption | Overall Response | Contractor | Consultant |
|---|---|---|---|
| No adoption | 79 (40.5%) | 65 (52%) | 14 (20%) |
| Limited Adoption | 99 (50.8%) | 56 (44.8%) | 43 (61.4%) |
| Moderate Adoption | 17 (8.7%) | 4 (3.2%) | 13 (18.6%) |
| Extensive Adoption | 0 | 0 | 0 |
| Full Adoption | 0 | 0 | 0 |
| Total | 195 (100%) | 125 (100%) | 70 (100%) |

When the contractors and consultants were compared together, it was obvious that consultants have adopted BIM more than the contractors as only 20% of the responses from the consultants selected 'No Adoption' while 52% of the responses from the contractors said that they have not adopted BIM. It could happen because the consultants work with the Architects when designing the buildings.

| Correlation | Relation-ship | P Significance | $R^2$ | Result: Null Hypothesis | Result: Alter-nate Hypothesis |
|---|---|---|---|---|---|
| H1: Unawareness about BIM & it's Benefits | | | | | |
| -0.807 | Strong Negative | 0.000 | 0.652 | $H_{10}$: Rejected | $H_{1a}$: Accepted |
| H2: Personal & Process barriers | | | | | |
| -0.682 | Strong Negative | 0.000 | 0.465 | $H_{20}$: Rejected | $H_{2a}$: Accepted |
| H3: Cost Related Barriers | | | | | |
| -0.653 | Strong Negative | 0.000 | 0.426 | $H_{30}$: Rejected | $H_{3a}$: Accepted |
| H4: Technological Barriers | | | | | |
| -0.689 | Strong Negative | 0.000 | 0.474 | $H_{40}$: Rejected | $H_{4a}$: Accepted |

*Figure 3: Status of Hypotheses - Summary*

**Discussion**

As per the correlation analysis, Pearson Correlation R = -0.807, -0.682, -0.653, -0.689 respectively. This value indicates that there is a strongly negative relationship between BIM adoption rate and the independent variables. All the factors that act as independent variables are barriers. P Value = 0.000, As $P < 0.05$ the null hypotheses can be rejected, and alternates can be accepted. It concludes that there is a significant relationship between the selected independent variables and BIM adoption rate. According to the model summary of Regression Analysis, Adjusted R Square value is 0.655. This value indicates that when all the independent variables are considered together, they have only 65.5% of representation towards BIM adoption rate. Which means 34.5% are still other factors. As per the ANOVA table, P Value is 0.000 which is less than 0.05. Therefore, the conceptual framework can be accepted. According to the Coefficients table all the independent variables have received negative coefficients. This reassures the negative relationship between the dependent and independent variables. P values are .000, .000, .042 & .028 respectively which all are less than 0.05. Therefore, the null hypotheses can be rejected, and the alternate hypotheses can be accepted.

**Variables Entered/Removed<sup>a</sup>**

| Model | Variables Entered | Variables Removed | Method |
|---|---|---|---|
| 1 | Technical, Cost, Unawarenss, Personal_Process[b] | . | Enter |

a. Dependent Variable: Adoption_Rate

b. All requested variables entered.

**Model Summary**

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate |
|---|---|---|---|---|
| 1 | .814[a] | .662 | .655 | .70247 |

a. Predictors: (Constant), Technical, Cost, Unawarenss, Personal_Process

**ANOVA<sup>a</sup>**

| Model | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| 1 | Regression | 183.764 | 4 | 45.941 | 93.099 | .000[b] |
| | Residual | 93.759 | 190 | .493 | | |
| | Total | 277.523 | 194 | | | |

a. Dependent Variable: Adoption_Rate

b. Predictors: (Constant), Technical, Cost, Unawarenss, Personal_Process

**Coefficients<sup>a</sup>**

| Model | | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. |
|---|---|---|---|---|---|---|
| | | B | Std. Error | Beta | | |
| 1 | (Constant) | 5.528 | .164 | | 33.768 | .000 |
| | Unawarenss | -1.071 | .110 | -.980 | -9.737 | .000 |
| | Personal_Process | -.068 | .128 | -.062 | -.534 | .000 |
| | Cost | -.211 | .103 | -.211 | -2.043 | .042 |
| | Technical | -.051 | .121 | -.050 | -.421 | .028 |

a. Dependent Variable: Adoption_Rate

*Figure 4: SPSS - Regression Analysis*

**Conclusions and Recommendations**

The most influential factor among the selected independent variables is the Unawareness about BIM and its benefits. This provides a clear indication that the awareness of BIM among the MEP professionals should be increased. Not having the professional skills to operate BIM software and tools is a major concern in the field. Professionals who work as consultants have adopted BIM more than the contractors. Cost model for budget analysis or sustainability model for evaluation of energy consumption etc are not utilized at all. Lack of BIM education by the academia is identified as one of the major reasons for unawareness. Lack of client demand is

another barrier that discourage the adoption of BIM. It is important to increase the awareness of property owners in the field of BIM specially in the operations phase to increase the client demand. Cost related barriers are identified as the initial investment for BIM, the operation cost, and expenses on continuous improvement of the staff by providing necessary trainings. Also, most of the MEP firms are not yet confident that the potential long-term benefits of adopting BIM will outweigh the initial financial investment required. There is an urgent need to improve BIM knowledge among MEP professionals. This can be achieved through the implementation of comprehensive BIM training programs. Collaboration between MEP companies and educational institutions should be actively encouraged. Industry advocacy and awareness campaigns, led by trade associations, play a crucial role in increasing the acceptance of BIM within the MEP sector. Financial incentives, such as tax benefits, should be offered to companies that choose to adopt BIM. Government mandates requiring the use of BIM in public projects can significantly boost its adoption among MEP companies. The integration of BIM courses into the academic programs of MEP-related disciplines is crucial. It ensures that future professionals are well prepared and equipped with the necessary BIM knowledge and skills.

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# THE EFFECT OF SELF-LEADERSHIP ON EMPLOYEE COMMITMENTS

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## Abstract

Self-leadership is an exercise of intentionally influencing oneself by way of thinking, feeling, and behavior to accomplish a goal by achieving his or her full potential. Self-leaders are tremendously empowered to make decisions based on their highest values, positively increasing employee commitment that ultimately leads to boosting the overall performance of an organization.

While leadership interventions dominate the business landscape, the attention given to self-leadership qualities is lacking. This deficiency contributes to the challenges faced by many organizations in realizing their objectives. Hence, this study seeks to empirically investigate the link between self-leadership and employee commitment. It aims to underscore practical implications for organizations, enrich academic understanding, address gaps in current literature, and propose directions for future research.

Conducted an online survey utilizing a purposive approach, designing a questionnaire (Google form) for data collection. Targeted 300 executive and management employees within Sri Lankan Airlines, ultimately gathering responses from 129 participants. Employed multiple linear regression analysis to analyze the data, revealing a robust and positive correlation between self-leadership and employee commitment.

**Keywords:** Employee commitment, Internal motivation, Leadership impact, Organizational commitment, Self-leadership

## Introduction/Background

The text discusses the historical roots of leadership across various sectors and introduces the concept of self-leadership as a recent addition to human resources development. Self-leadership focuses on enhancing individual attributes such as self-motivation, self-awareness, self-discipline, and self-regulation to improve overall leadership effectiveness (Carver & Scheier, 2001). In the current global landscape, organizations are urged to adopt innovative strategies to compete effectively, making the implementation of self-leadership crucial for empowering teams and achieving peak organizational performance. Despite its growing recognition, research in the area of self-leadership has been relatively scarce since its introduction in 1980 (Neck & Houghton, 2006). Commitment-driven performance, influenced by self-leadership characteristics, is emphasized as essential for organizational success. The paper aims to empirically examine the relationship between self-leadership and employee commitment, addressing the potential gap in understanding effective self-leadership strategies in the modern context.

*Main Objective*

To investigate the relationship between self-leadership and employee commitment.

*Specific Objectives*

To measure self-leadership behaviors, within the organizational context. Assess self-leadership behaviors such as self-awareness, self-motivation, and self-regulation.

To measure employee commitment.

To identify key self-leadership factors influencing employee commitment.

To provide practical recommendations for organizations.

To contribute to academic understanding.

To suggest future research directions.

**Research Methodology**

The research employed a quantitative approach to empirically investigate the relationship between self-leadership and employee commitment. The study focused on executives and management employees within an airline organization, which boasts a total workforce of over 6,000 individuals. Among these, 300 individuals fall under the executive and management category, representing diverse departments such as Marketing, Finance, Technology, Engineering, pilots, Research and development, Sales, Customer Affairs, Human Resources, and Administration.

The sample size was calculated using an online sample calculator, setting the desired confidence level at 95% and a margin of error of 5%. The questionnaire, structured on a 5-point Likert scale where 1 denotes strong agreement and 5 indicates strong disagreement, encompassed questions for both independent and dependent components. Employing a purposive approach, an online survey was conducted, utilizing a questionnaire designed on Google Forms. The survey was distributed among 300 employees in the executive and management categories within the airline company, ultimately collecting data from 129 respondents.

*Conceptual Framework*
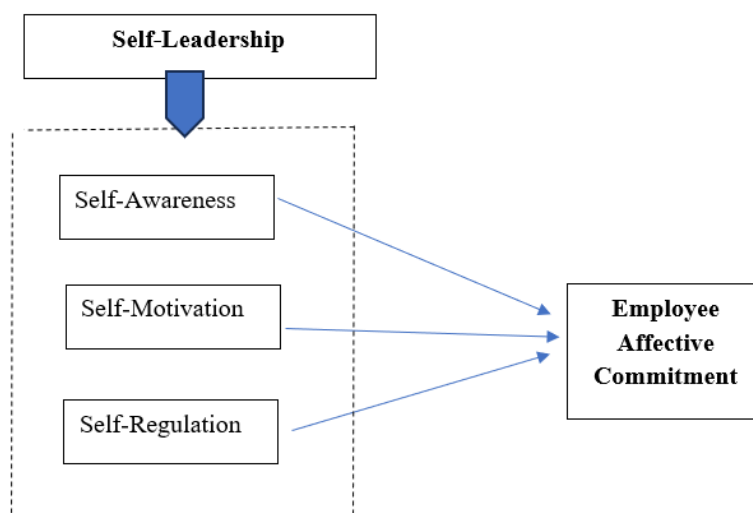


*Figure 1 : Conceptual Framework*

**Research Hypotheses**

**H1:** Self-awareness effect employee affective commitment.

**H2:** Self-motivation effect employee affective commitment.

**H3**: Self-regulation effect employee affective commitment.

**Results**

The results presented below were generated using the Statistical Package for the Social Sciences (SPSS) software.

*Analyze*

The Correlation between Self-awareness and Affective commitment was statistically significant at the 0.001 level with a Pearson correlation coefficient of + .671. It indicates that there is a positive relationship between Self-awareness and Affective commitment. (Table 1)

The Correlation between Self-motivation and Affective commitment was statistically significant at the 0.001 level with a Pearson correlation coefficient of + .663. It shows that there is a positive relationship between Self-awareness and Affective commitment.

The Correlation between Self-regulation and Affective commitment was statistically significant at the 0.001 level with a Pearson correlation coefficient of + .596. It shows that there is a positive relationship between Self-awareness and Affective commitment.

The results indicate a positive correlation among the three mentioned occasions. Specifically, the connection between self-awareness and affective commitment is moderately positive, and similarly, self-motivation and affective commitment, as well as self-regulation and affective commitment, are positively related.

Table 2 Correlation

| Correlations | | | | | |
|---|---|---|---|---|---|
| | | affective commitment | Self-awareness | Self-motivation | Self-regulation |
| affective commitment | Pearson Correlation | 1 | .671** | .663** | .596** |
| | Sig. (2-tailed) | | <.001 | <.001 | <.001 |
| | N | 129 | 129 | 129 | 129 |
| Self-awareness | Pearson Correlation | .671** | 1 | .992** | .682** |
| | Sig. (2-tailed) | <.001 | | <.001 | <.001 |
| | N | 129 | 129 | 129 | 129 |
| Self-motivation | Pearson Correlation | .663** | .992** | 1 | .672** |
| | Sig. (2-tailed) | <.001 | <.001 | | <.001 |
| | N | 129 | 129 | 129 | 129 |
| Self-regulation | Pearson Correlation | .596** | .682** | .672** | 1 |
| | Sig. (2-tailed) | <.001 | <.001 | <.001 | |
| | N | 129 | 129 | 129 | 129 |

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

Table 2 shows the summary of the model in which R squared (Coefficient of Determination) statistics is .486 with the statistical significance of P < .005. This indicates that 48.6% of the variant in the Affective commitment was predicted (Outcomes) from the level of self-leadership styles (Predictors). The Durbin-Watson value was 2.215 which is in between +I and +3 confirming that the independence of the observations has been met.

Table 2 Model Summary

| Model Summary | | | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | | | | | Change Statistics | | | | |
| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate | R Square Change | F Change | df1 | df2 | Sig. F Change | Durbin-Watson |
| 1 | .697ᵃ | .486 | .474 | .530 | .486 | 39.419 | 3 | 125 | <.001 | 2.215 |

a. Predictors: (Constant), Self-regulation, Self-motivation, Self-awareness
b. Dependent Variable: affective commitment

Table 3 indicates that independent variables (Self-leadership styles) significantly predict the dependent variable (Affective commitment) statistically, $F(3,125) = 39.419$, P < 005. Shows that the Regression model is a good fit for the data.

Table 3 Regression

| ANOVAᵃ | | | | | |
| --- | --- | --- | --- | --- | --- |
| Model | | Sum of Squares | df | Mean Square | F | Sig. |
| 1 | Regression | 33.275 | 3 | 11.092 | 39.419 | <.001ᵇ |
| | Residual | 35.172 | 125 | .281 | | |
| | Total | 68.447 | 128 | | | |

a. Dependent Variable: affective commitment

b. Predictors: (Constant), Self-regulation, Self-motivation, Self-awareness

Table 4 shows the Unstandardized coefficient, B1 for TSA is equal to .755. That means per one-unit increase in TSA there is an increase in affective commitment of .755 times units. the Unstandardized coefficient, B2 for TSM is equal to -.103. which means in TSM one-unit increases, and there is a decrease in Affective commitment of -.103 times units. the Unstandardized coefficient, B3 for TSR is equal to .302. That means per one-unit increase in TSR there is an increase in affective commitment of .302 times units. The above results are evident that Self-awareness, Self-motivation, and Self-regulation of leadership styles have unstandardized coefficients of .755, (positive relationship) -.103, (Negative relationship) and .302 (positive relationship) respectively. This Unstandardized coefficient analysis (Table 4) shows a negative (-) relationship in the relationship between self-motivation and affective commitment whereas Correlation analysis (Table 1) shows a Positive (+) relationship between self-motivation and affective commitment. This contradiction may have been caused by to following,

Multicollinearity: when one or more independent variables are highly correlated with each other in the regression model.

Interaction effect: When the relationship between one independent variable and the dependent variable depends on the value of another independent variable.

Suppression effect: When one independent variable considered in isolation may have either a positive or negative effect and when other variables are included in the model it may enhance the relationship (opposite direction of its initial movement) of other variables with the dependent variables.

To investigate further this contradiction issue in the result of two analysis models (Correlation and Unstandardized coefficients), performed a re-analysis to re-assess the coefficient effect of three independent variables separately from the dependent variable. (Table 5,6,7) and that shows once again a positive relationship in all three scenarios of these relationships.

Table 4 Unstandardized Coefficient

| Coefficients | | | | | | |
|---|---|---|---|---|---|---|
| | | Unstandardized Coefficients | | Standardized Coefficients | | |
| Model | | B | Std. Error | Beta | t | Sig. |
| 1 | (Constant) | -.045 | .159 | | -.282 | .779 |
| | Self-awareness | .755 | .673 | .571 | 1.122 | .264 |
| | Self-motivation | -.103 | .670 | -.077 | -.154 | .878 |
| | Self-regulation | .302 | .102 | .259 | 2.951 | .004 |

Dependant Variable: affective commitment

Table 5 Self Awareness- TSA

| Coefficients<sup>a</sup> | | | |
|---|---|---|---|
| | | Collinearity Statistics | |
| Model | | Tolerance | VIF |
| 1 | TSA | 1.000 | 1.000 |
| a. Dependent Variable: TAC | | | |

| Collinearity Diagnostics<sup>a</sup> | | | | | |
|---|---|---|---|---|---|
| | | | | Variance Proportions | |
| Model | Dimension | Eigenvalue | Condition Index | (Constant) | TSA |
| 1 | 1 | 1.946 | 1.000 | .03 | .03 |
| | 2 | .054 | 5.982 | .97 | .97 |
| a. Dependent Variable: TAC | | | | | |

Table 6 Coefficients

| Coefficientsª | | Collinearity Statistics | |
| --- | --- | --- | --- |
| Model | | Tolerance | VIF |
| 1 | TSM | 1.000 | 1.000 |
| a. Dependent Variable: TAC | | | |

| Collinearity Diagnosticsª | | | | Variance Proportions | |
| --- | --- | --- | --- | --- | --- |
| Model | Dimension | Eigenvalue | Condition Index | (Constant) | TSM |
| 1 | 1 | 1.945 | 1.000 | .03 | .03 |
| | 2 | .055 | 5.931 | .97 | .97 |
| a. Dependent Variable: TAC | | | | | |

Table 7 Self-Regulation-TSR

| Coefficientsª | | Collinearity Statistics | |
| --- | --- | --- | --- |
| Model | | Tolerance | VIF |
| 1 | TSR | 1.000 | 1.000 |
| a. Dependent Variable: TAC | | | |

| Collinearity Diagnosticsª | | | | Variance Proportions | |
| --- | --- | --- | --- | --- | --- |
| Model | Dimension | Eigenvalue | Condition Index | (Constant) | TSR |
| 1 | 1 | 1.950 | 1.000 | .02 | .02 |
| | 2 | .050 | 6.262 | .98 | .98 |
| a. Dependent Variable: TAC | | | | | |

**Discussion**

**H1:** Self-awareness effects employee affective commitment.

The study's first hypothesis (H1) posited that self-awareness influences employee affective commitment, and the analysis, conducted using SPSS, revealed a positive relationship between self-awareness and affective commitment.

Compared to previous research findings, there is consistency with a body of literature that emphasizes the importance of self-awareness in predicting employee affective commitment. Prior studies have often identified self-awareness as a key component of emotional intelligence, associating it with higher levels of engagement and commitment to the organization. The positive correlation found in the current study aligns with these earlier observations, reinforcing the idea that individuals who possess a heightened sense of self-awareness may develop stronger emotional bonds with their workplace.

**H2:** Self-motivation effects employee affective commitment.

The second hypothesis (H2) of the study posited that self-motivation influences employee affective commitment, and the analysis, conducted using SPSS (software), provided evidence supporting a positive relationship between self-motivation and affective commitment.

Compared to previous research findings, there is alignment with existing literature that highlights the significance of self-motivation in predicting employee affective commitment. Prior studies have consistently identified self-motivation as a crucial aspect of an individual's commitment to an organization. Employees who are intrinsically motivated and driven by personal satisfaction and fulfillment in their work, are often found to exhibit higher levels of affective commitment. The positive correlation found in the current study reinforces these earlier observations, suggesting that employees with strong self-motivation are likely to form stronger emotional bonds with their workplace.

**H3**: Self-regulation effects employee affective commitment.

The third hypothesis (H3) of the study posited that self-regulation influences employee affective commitment, and the analysis, conducted using SPSS (software), revealed a significant and positive relationship between self-regulation and affective commitment.

Compared to previous research, there is alignment with existing literature emphasizing the importance of self-regulation in predicting employee affective commitment. Prior studies have often associated self-regulation, particularly in terms of emotional regulation and self-discipline, with higher levels of commitment to the organization. Employees who can effectively manage their emotions and regulate their behavior are likely to experience greater satisfaction and connection with their workplace. The positive correlation found in the current study aligns with these earlier observations, suggesting that self-regulation plays a key role in shaping employees' emotional commitment to their organization.

Overall, in summary, the study's findings regarding the positive relationship between all three occasions contribute to the existing body of knowledge in organizational psychology. The consistency with prior research supports the notion that self-awareness, self-motivation, and self-regulation remain a relevant and influential factor in shaping employees' emotional commitment to their workplace. Future research should continue to explore these connections, considering contextual nuances and potential moderating variables, to further refine our understanding of the intricate relationship in these occasions in different organizational settings.

The test on unstandardized coefficients yielded negative results when evaluating the connection between self-motivation and affective commitment. Therefore, it is recommended to pursue further research to gain a more thorough understanding of this relationship and address any discrepancies in the results.

**Conclusion and Recommendations**

The study decisively establishes a compelling and affirmative correlation between self-leadership and employee commitment. Through meticulous research, the study furnishes robust evidence that underscores the paramount significance of this relationship, underscoring a robust and positive interconnection between self-leadership and the commitment levels of employees. The findings elucidate a statistically significant and positive correlation, signifying

that an escalation in the impact of self-leadership variables aligns with a corresponding increase in employee commitment to the organization. These affirmative discoveries bear profound implications for organizations, suggesting a promising avenue to augment employee commitment by harnessing the potential of self-leadership.

The statistical results, encompassing correlations, coefficients, and ANOVA tests, consistently fortify and validate this analytical framework. Collectively, the research findings consistently underscore a commendable and noteworthy nexus between self-leadership and employee commitment, providing organizations with a compelling insight into a potent lever for fostering heightened dedication and allegiance among their workforces.

### *Recommendations*

In light of the insightful analytical results and comprehensive reviews stemming from this study, it is strongly advocated that organizations investing in leadership development programs hone in on specific facets of self-leadership, notably, self-awareness, self-motivation, and self-regulation. The incorporation of strategies identified in this study holds the promise of significantly fortifying employee commitment. By actively promoting and rewarding self-leadership behaviors, organizations can cultivate a workplace culture that champions and supports self-leadership, motivating leaders to embody these qualities while inspiring their subordinates to follow suit.

A key recommendation is for organizations to seamlessly integrate self-leadership assessments into their employee performance evaluation processes, assigning due weightage to these assessments. Providing constructive feedback based on self-leadership evaluations can serve as a powerful motivator, propelling employees to further develop and refine their self-leadership competencies. Furthermore, it is advised that organizations establish robust mechanisms for open communication between employees and leaders, fostering an environment of trust and collaborative efforts. This collaborative approach ultimately contributes to an enriched sense of employee commitment, aligning individual and organizational objectives seamlessly.

### *Suggestions for further Research*

In this research endeavor, our focus centered on three pivotal variables—self-awareness, self-motivation, and self-regulation—within the realm of self-leadership styles, driven by time and practical constraints. While these variables offer valuable insights, future investigations are encouraged to explore a broader spectrum of facets, including self-rewards, self-punishment, self-discipline, self-empathy, and other dimensions that can contribute to a more comprehensive understanding of the multifaceted nature of self-leadership.

Moreover, we propose that upcoming research endeavors delve into continuance and normative employee commitment, alongside affective commitment, to enrich our knowledge about the intricate dynamics between self-leadership and employee commitment. Understanding how these different dimensions of commitment interplay can offer a nuanced perspective on the impact of self-leadership on organizational engagement.

The exploration of moderating and mediating variables, such as organizational culture, job satisfaction, and autonomy levels, is deemed critical for unraveling the intricate web of relationships between self-leadership and employee commitment. Future research endeavors

should prioritize examining these factors to gain deeper insights into the contextual influences that shape the effectiveness of self-leadership initiatives. By understanding how these variables moderate or mediate the impact of self-leadership, we can refine strategies to foster greater employee commitment.

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# FACTORS INFLUENCE ON EMPLOYEE TURNOVER IN PILING INDUSTRY IN SRI LANKA

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**Abstract**

One of the major issues facing Sri Lanka's piling industry is high employees' turnover, which has a direct influence on the success and profitability of the businesses. Employee turnover increases a company's direct and indirect costs and presents challenges for managers in the process of managing an employee's life cycle. Due to a lack of qualified workers in the piling industry, business managers are responsible for addressing employees' turnover.

The study has been used primary and the secondary data. Primary data has been collected through the survey questionnaire and the secondary data has been collected from the books, articles, journals and the industry reports. The collected primary data (150 samples were collected) that has been analysed through the SPSS analyses and the analyses were statistically presented on this study. Due to the primary and the secondary data that supported to the study to reach the objectives of the study. Through the findings from the primary data, there were recommendations proposed by the researcher at the end of the study.

**Keywords:** Employee turnover, Job satisfaction, Management support, Co-worker support, Training and Development, Work environment.

**Introduction**

Many studies have been done on the subject with diverse demographic and geographic samples because employee turnover is one of the most important indicators for a business. The extant literature explores this subject theoretically or methodologically. As a result, this study summarized the independent factors that influence employee retention and included the majority of the variables that considerably impact on employee turnover (Kanchana and Jayathilaka, 2023). Employee turnover, which refers to the rate at which employees leave an organization, has been examined by many scholars and is frequently used interchangeably (Akinyomi, 2016).

According to Babu et al. (2020), a pile is a columnar part of a foundation that distributes loads from the superstructure to weak soil at shallow depths, compressible strata or water, less compressible soils, or rock. Rooted retaining walls are reinforced by piles to carry out vertical and horizontal loads, just like building foundations, machinery foundations, bridge piers and abutments, and other structures (Xu et al., 2015)

There are many factors that influence on employee turnover. Those are salary, working environment, job satisfaction, management support, co-worker support, reward, etc. (Kumara and others, 2021). Piling industry face the issue that relevant to employee turnover. In the piling sector, increased personnel turnover is a major problem that has a direct influence on

profitability and corporate performance. On the other side, this industry's poor performance and productivity can have an impact on Sri Lanka's GDP and overall economic process.

The objectives of the study are [1]to determine the factors influence on Employee Turnover in the Piling Industry in Sri Lanka, [2]to identify the relationship between factors influence on Employee Turnover in the Piling Industry in Sri Lanka and [3]to determine the strategies that can be implement in overcoming employee turnover in the piling industry in Sri Lanka

The top management of the piling industry will find this study to be very important as it will help them make decisions about appropriate and successful business practices that will enhance the performance of the piling industry. Additionally, the study's recommendations may be used by piling industry engineers and constructors to enhance industry performance. This study will give the benefit for policy makers with Government of Sri Lanka and The National Construction Association of Sri Lanka (NCASL).

**Methodology**

The quantitative research paradigm of post-positivism focuses on reality and draws conclusions using quantitative data. The study concludes, randomly collected set of data from people, who are working in piling industry in Sri Lanka. The major factors (Job satisfaction, Management support, Co-worker support, Training and Development, Work environment) were identified by critically analyzed literature review, and re-evaluated by expressly designed questionnaire and that was distributed between staff of the piling industry in western province in Sri Lanka. 150 samples have been selected by the researcher of this study from the 2400 target population in piling industry. MS Excel and the SPSS Version 23 programme are used for the analyses of the quantitative data

The conceptual framework for the study was developed followed the literature review by highlighting the factors that influencing employee turnover intention in Piling industry in Sri Lanka. The schematic diagram of the conceptual model is developed in figure 1.
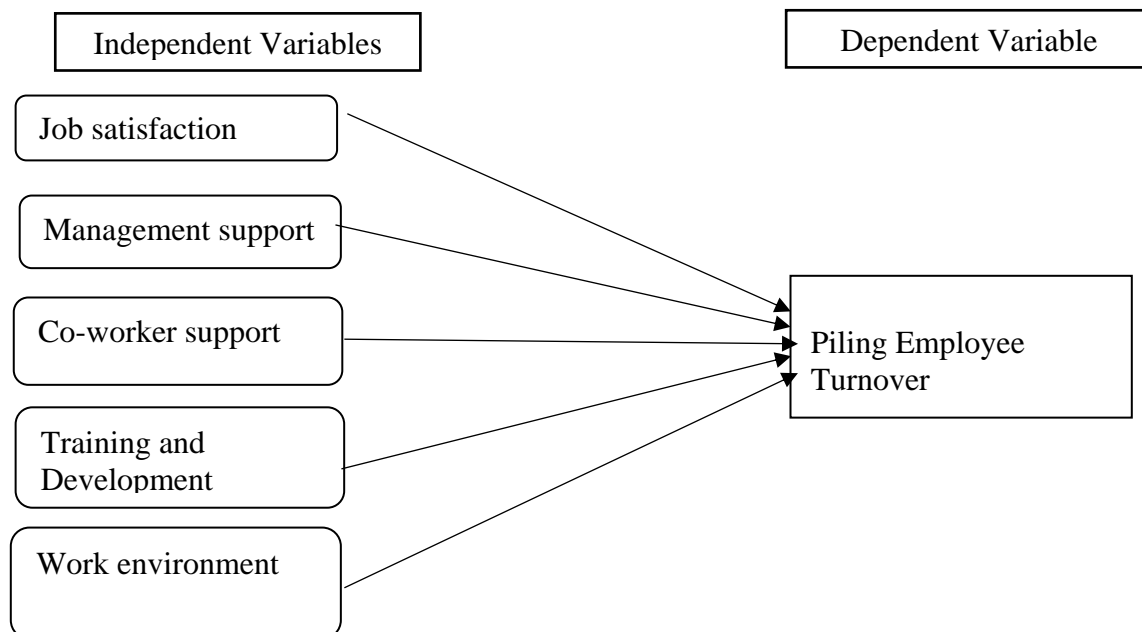


*Figure 1: Conceptual Framework*

The operationalization table was designed by using major indicators, which were found by literature review. Regular work task, Responsibilities, Good attitude, and Positive emotional state (Rana and Singh 2016, Simatwa 2011) were the major indicators of the job satisfaction. Competitive advantage (Dawley et al, 2010), Employers and employees commitment (Islam et al, 2014), Employee independence (Van den Heuvel and Freese, 2017), and Job stability (Wong and Wong, 2017) were the major indicators of the Management support. Intention, Care, Empathy and Working conditions (Dawley et al, 2010, Bateman, 2009) were the major indications for the Co-worker support. Performance enhancement, Greater productivity, Increased profit, and Improved employee satisfaction (David, 2008) were the indicators of the Training and Development. Unsafe work environment, Employment insecurity, Lack of Consistency, Irrational procedural justice, (Ali and Baloch, 2008) were the major indicators of work environment. Competitive salary, Welcoming workplace, Interpersonal relationships, and Job security (Kinnear and Sutherland, 2000), Maertz and Griffeth, 2004), Samuel and Chipunza, 2009) were the indications of the employee turnover in piling Industry.

The sample was selected from the population using simple random sampling, a probability sampling technique. The Morgan Table for the sample selection is indicates that 331 represents a sample of the 2400 target population, was the middle and top level management staff of the piling industry in Sri Lanka. Due to the availablity of the sample, the researcher of this study selected 150 samples. Designed questionnaire was distributed through mails for the real-time data for the analysis.

**Results**

Multiple Regression Analysis of Dependent Variables vs. Independent Variables

Table 1: Model Summary Dependent Variables vs. Independent Variables
**Model Summary**

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate |
|---|---|---|---|---|
| 1 | .984[a] | .969 | .968 | .48302 |

Predictors: (Constant), Work Environment, Job Satisfaction, Training and Development, Co Worker Support, Management Support
Source: Survey data, (2023)

Table 2: ANOVA- Dependent Variables vs. Independent Variables

**ANOVAᵃ**

| Model | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| 1 | Regression | 1040.776 | 5 | 208.155 | 892.177 | .000ᵇ |
| | Residual | 33.597 | 144 | .233 | | |
| | Total | 1074.373 | 149 | | | |

a. Dependent Variable: Employee Turnover

b. Predictors: (Constant), Work Environment, Job Satisfaction, Training and Development, Co Worker Support, Management Support

*Source: Survey data, (2023)*

Table 3: Summary of data analyses

| Hypothesis | Sig Value | R square | Pearson Correlation | Status |
|---|---|---|---|---|
| H₁- Job satisfaction has influence on employee turnover in piling industry in Sri Lanka. | 0.000 | 0.724 | 0.851 | Accepted |
| H₂- Management support has influence on employee turnover in piling industry in Sri Lanka | 0.000 | 0.952 | 0.976 | Accepted |
| H₃- Co-worker support has influence on employee turnover in piling industry in Sri Lanka. | 0.000 | 0.796 | 0.892 | Accepted |
| H₄- Training and development has influence on employee turnover in piling industry in Sri Lanka. | 0.000 | 0.695 | 0.834 | Accepted |
| H₅- Work environment has influence on employee turnover in piling industry in Sri Lanka | 0.000 | 0.547 | 0.740 | Accepted |

*Source: Survey data, (2023)*

**Discussion and conclusions**

The overall of this study concluded for the achievement of the objectives of the study. When analyze the independent and the dependent correlation analyses.

According to the survey results of Model summery, R Square is 0.969; it is denoted that all five independent variables are emphatically influence on dependent variable. The results of R Square is 0.7; it is more than the expected significant value. It can draw important conclusions

about the conceptual model that is used to satisfactorily analyze the problem under this research study.

Since the significance level for each variable is p=0.000, it is less than p=0.05. There is a significance of the static can be determined for each variable as stated the above mentioned ANOVA performance.

The outcome from Pearson correlation showed that, there were significant relationship between Independent variables, job satisfaction (R=0.851), Management support (R=0.976), Co-worker support (R=0.892), Training and development (R=0.84), Work environment (R=0.740), and Dependent variable (employee turnover) due to the positive outcome.

As mentioned the above findings from primary data and also findings from the secondary data, the first two objectives have been reached for this study and the third objective is reached end of this study.

*Recommendations*

Eventually all the hypothesis was accepted in this study, the study should need to focus other factors that impact on the employee turnover in Piling Industry, In Sri Lanka.

There are various strategies that support to increase the job satisfaction, Management support, Co-worker support, Training and development and work environment and minimize the employee turnover. The industry should need to review about the payment and the benefit packages and also consider about the job security. These aspects will increase the job satisfaction and minimize the employee turnover in the piling industry in Sri Lanka.

The management of piling industry in Sri Lanka has to make such opportunities for employees to use and develop relevant skills and also improve better relationships with the other employees which support minimize the employee turnover in the piling industry in Sri Lanka. The management of piling industry in Sri Lanka has to develop the relationships with immediate supervisors and also co-worker should be understanding the organizational stability which minimize the employee turnover in the piling industry in Sri Lanka.

The management of piling industry in Sri Lanka has to design the on-the job training and off-the job training for the employees which will support for the employees to understand the current trend and the opportunities for the piling industry and also these strategies will support to minimize the employee turnover in the piling industry in Sri Lanka.

The management of piling industry in Sri Lanka has to arrange the proper and safety work environment for the employees.

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# THE IMPACT OF ORGANIZATIONAL CULTURE ON COGNITIVE EMPOWERMENT IN SELECTED BANKS IN COLOMBO DISTRICT IN SRI LANKA

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**Abstract**

Cognitive empowerment plays a critical role in the banking sector in Sri Lanka as well as in the global financial industry which may enhance customer experience, efficient operations, effective decision making, innovations as well as adaptability while gaining an edge over competition. This study investigates how organizational culture (Clan, Adhocracy, Market, and Hierarchy) can enhance cognitive empowerment of bankers in Sri Lanka. A quantitative approach was used whereas, initially a preliminary investigation was conducted to gain a general understanding of the culture of few leading banks in Sri Lanka and eventually cascading down to four banks that covers all four cultures. Further, 239 responses were received through a structured questionnaire from four leading banks covering all four cultures. Results showed higher levels of cognitive empowerment in entities with strong clan, adhocracy, and market cultures, while higher hierarchy culture was associated with lower levels of cognitive empowerment.

**Key words:** Adhocracy Culture, Clan Culture, Cognitive Empowerment, Hierarchy Culture, Market Culture, Organizational Culture.

**Introduction**

Cognitive empowerment is crucial in today's rapidly changing world, as it provides individuals with the cognitive abilities and mindset needed to thrive in uncertain times. It enhances corporate agility, competitiveness, and employee well-being, Peterson (2014). In the banking sector, cognitive empowerment fosters efficiency, creativity, and overall organizational success through decision-making, problem-solving, innovation, adaptability, excellent customer service, risk management, and digital transformation. The banking industry faces challenges due to the volatile economy and rapid technological advancements. This study aims to explore the relationship between organizational culture and cognitive empowerment in Sri Lanka's banking industry, focusing on the need for long-term functioning in the sector. It aims to address the empirical gap on psychological empowerment components and the association between cognitive empowerment subscales and predicting conceptually related factors, thereby fostering professional development and national prosperity.

*General objective:*

To investigate the impact of organizational culture on cognitive empowerment amongst the bankers of Sri Lanka.

*Specific Objectives:*

To investigate the impact of the Clan Culture on the Cognitive Empowerment of the selected four Sri Lankan banks.

To investigate the impact of the Adhocracy Culture on the Cognitive Empowerment of the selected four Sri Lankan banks.

To investigate the impact of the Market Culture on the Cognitive Empowerment of the selected four Sri Lankan banks.

To investigate the impact of the Hierarchy Culture on the Cognitive Empowerment of the selected four Sri Lankan banks.

**Methodology**

The study aimed to validate concepts about organizational culture and cognitive empowerment using a quantitative approach. A preliminary investigation was conducted on seven leading banks to identify four banks that cover clan, adhocracy, market, and hierarchy cultures. Cameron & Quinn's (2006) model categorizes organizational culture into these types, with indicators such as collaboration, employee development, open communication, innovation, entrepreneurial spirit, flexibility, decentralized decision making, result-oriented, competitive environment, customer focus, goal alignment, and structure and stability. The study focused on four banks: Commercial Bank of Ceylon plc, Sampath Bank of Ceylon PLC, Nations Trust Bank PLC, and Bank of Ceylon. A self-developed questionnaire was used to gather primary data, while secondary data was extracted from annual reports, journals, and related websites. A descriptive and statistical data analysis was conducted to achieve the study's objectives. The research findings were generalized to the population of banks in Sri Lanka, with executive and above grades considered as the most requiring cognitive skills. The study used cross tabulation, correlation analysis, regression analysis, chi square analysis, and hypothesis testing to analyze the data. SPSS 26.0 software was used for descriptive and statistical analysis.
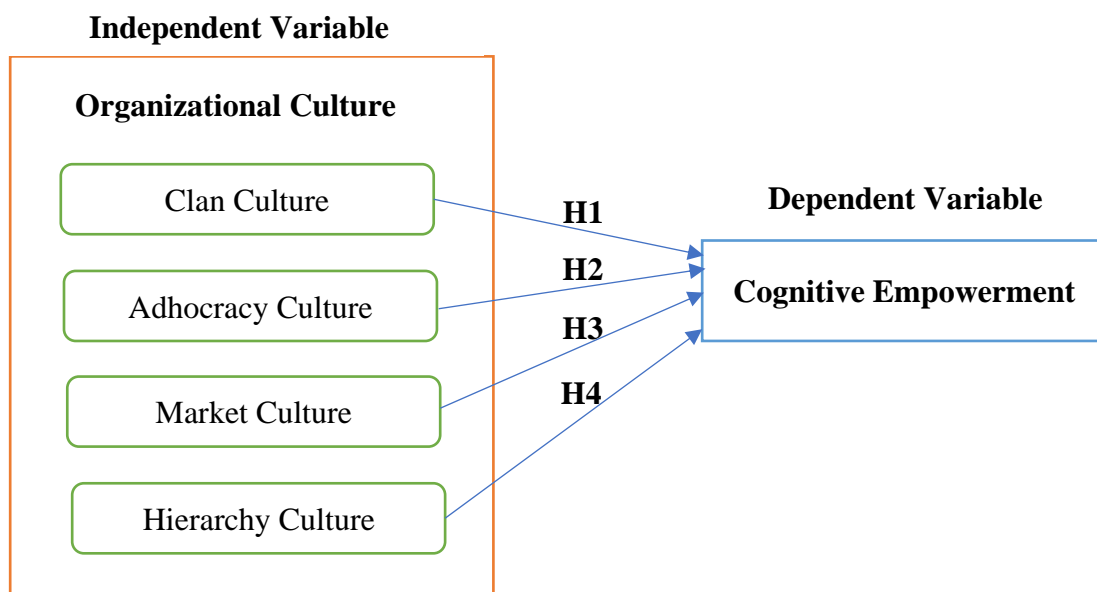
*Figure 01- Conceptual Framework*

Source: Author developed

H1: There is a significant impact of Clan Culture on Cognitive empowerment amongst the employees in the respective banks.

H2: There is a significant impact of Adhocracy Culture on Cognitive empowerment amongst the employees in the respective banks.

H3: There is a significant impact of Market Culture on Cognitive empowerment amongst the employees in the respective banks.

H4: There is a significant impact of Hierarchy Culture on Cognitive empowerment amongst the employees in the respective banks.

**Data Analysis and Discussion**
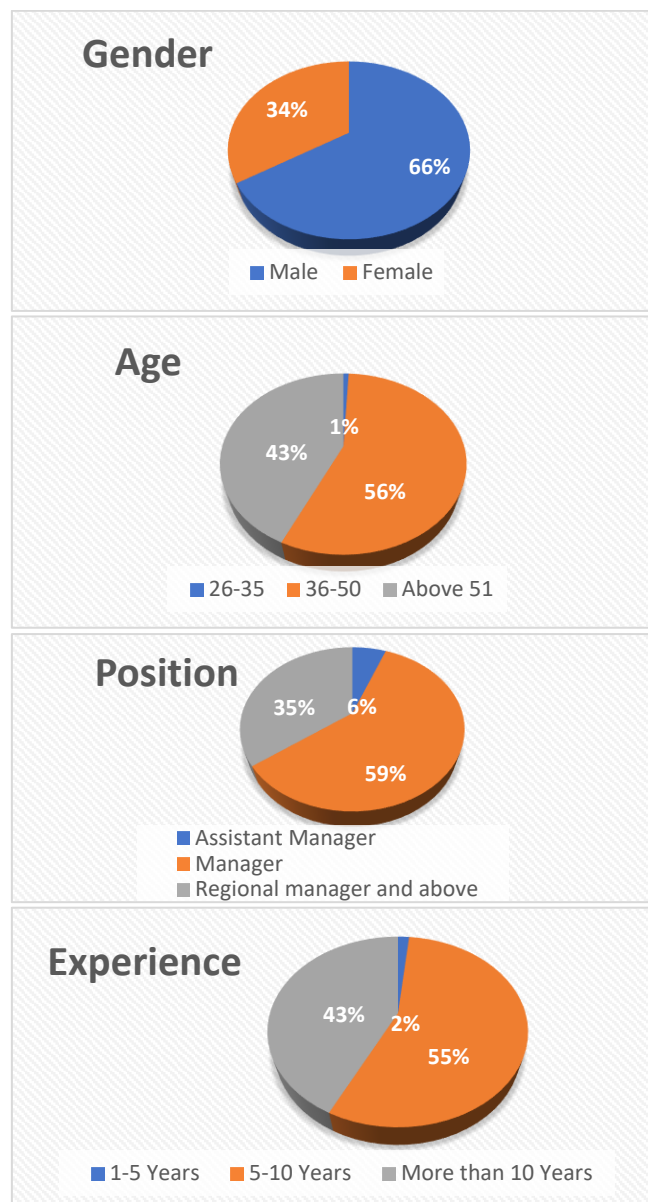


As per the demographic factors it is evident that the majority of the sample consist of males, while majority of respondents are of managerial category covering up 5-10 years of experience. This is beneficial for the study as the sample covers the personnel who are mostly utilizing the cognitive aspects while working.

Table 1: Reliability statistics (Cronbach's Alpha)

| Variable | Cronbach's Alpha |
|---|---|
| Clan Culture | .975 |
| Adhocracy Culture | .977 |
| Market Culture | .958 |
| Hierarchy Culture | .951 |
| Cognitive empowerment | .967 |

*Source:* Analyzed statistical output from field survey

The Cronbach's alpha values for all variables are high ranging from .951-.977. Therefore, these values indicate a strong internal consistency reliability.

Table 2: Validity statistics (KMO and Bartlett's Test)

| | Clan Adhocracy | | Market | Hierarchy | Cognitive Empowerment |
|---|---|---|---|---|---|
| Kaiser-Meyer-Olkin Measure of Sampling Adequacy. | .948 | .948 | .926 | .914 | .947 |
| Bartlett's Test of Sphericity Approx. Chi-Square | 3306.540 | 2383.190 | 1550.828 | 1916.783 | 3575.730 |
| df | 45 | 28 | 15 | 28 | 91 |
| Sig. | .000 | .000 | .000 | .000 | .000 |

*Source:* Analyzed statistical output from field survey

According to the above values, all KMO values are relatively high, implying that variables are related and share common underlying factors. Additionally, the significant Bartlett's test results support the presence of relationships between the variables.

**Correlations**

| | | Clan Culture | Adhocracy Culture | Market Culture | Hierarchy Culture |
|---|---|---|---|---|---|
| Cognitive Empowerment | Pearson Correlation | .598** | .648** | .553** | .262** |
| | Sig. (2-tailed) | .000 | .000 | .000 | .000 |
| | N | 239 | 239 | 239 | 239 |

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

**Model Summary$^b$**

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate | Durbin-Watson |
|---|---|---|---|---|---|
| 1 | .772$^a$ | .597 | .590 | .299 | 2.043 |

a. Predictors: (Constant), Hierarchy Culture, Adhocracy Culture, Clan Culture, Market Culture

b. Dependent Variable: Cognitive Empowerment

**Coefficients<sup>a</sup>**

| Model | | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. |
|---|---|---|---|---|---|---|
| | | B | Std. Error | Beta | | |
| 1 | (Constant) | 2.409 | .202 | | 11.944 | .000 |
| | Clan_Culture | .208 | .030 | .329 | 6.839 | .000 |
| | Adhocracy_Culture | .222 | .036 | .368 | 6.093 | .000 |
| | Market_Culture | .146 | .044 | .184 | 3.303 | .001 |
| | Hierarchy_Culture | -.206 | .038 | -.226 | -5.371 | .000 |

a. Dependent Variable: Cognitive_Empowerment

Cognitive Empowerment = 2.409+0.208*Clan Culture+0.222*Adhocracy Culture+0.146*Market Culture-0.206*Hierarchy Culture

The study found significant correlations between Cognitive Empowerment and various organizational culture types, with p-values less than 0.05 for all. Yet, it is important to note, even though a positive relationship can be identified between cognitive empowerment, clan, market and adhocracy cultures, correlation with hierarchy culture is weaker.

Based on the regression data, the model explains 59.7% ($R^2$=0.597) of the variance in cognitive empowerment, indicating a moderately strong fit. Since the adjusted $R^2$ is 0.590, the model suggests that 59% of the variance is explained, which accounts for potential overfitting. Based on the coefficient values, for one unit of increase in clan, adhocracy and market culture, the cognitive empowerment increases by 0.208, 0.222 and 0.146 units respectively. Yet, a unit increase in hierarchy culture is expected to decrease cognitive empowerment by 0.206 units which is a worthy fact to consider.

**ANOVA<sup>a</sup>**

| Model | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| 1 | Regression | 30.886 | 4 | 7.721 | 86.498 | .000<sup>b</sup> |
| | Residual | 20.888 | 234 | .089 | | |
| | Total | 51.774 | 238 | | | |

a. Dependent Variable: Cognitive_Empowerment

b. Predictors: (Constant), Hierarchy_Culture, Adhocracy_Culture, Clan_Culture, Market_Culture

*Source:* Analyzed statistical output from field survey

Based on the anova test, the overall model is highly significant (F=86.498  P=0.000) suggesting that at least one of the predictors significantly contributes to predicting cognitive empowerment. In general, the regression model which considered the clan, adhocracy, market and hierarchy cultures is statistically significant and explains substantial portion of the variance

in cognitive empowerment. It is eminent that cognitive empowerment is significantly affected by each cultural component; the most substantial effects are shown in the areas of clan and adhocracy cultures, and market culture to a lesser extent, while hierarchy impacting in a negative manner. The study indicates that organizational culture positively influences cognitive empowerment, suggesting that innovative and cooperative environments can boost employee empowerment, while hierarchical arrangements may have negative consequences.

**Conclusion and Recommendations**

This study aims to investigate the relationship between different organization cultural dimensions (clan, adhocracy, market, and hierarchy) and cognitive empowerment. Significant correlations were found using correlation analysis, emphasizing the role that company culture plays in shaping cognitive empowerment. The study revealed that the most significant positive relationships were found between clan, adhocracy and market cultures. Companies that prioritize market orientation, innovation, and cooperation tend to have higher levels of cognitive empowerment. However, a negative association was found between hierarchy culture and cognitive empowerment, suggesting that a hierarchical structure may hinder it. The regression analysis confirmed the statistical significance of the model, explaining a substantial portion of the variation in cognitive empowerment. The Durbin-Watson statistic confirmed its dependability.

*Limitations and future studies:*

The study on organizational culture and cognitive empowerment, based on cross-sectional data, faces challenges in establishing causal correlations. Future research should use longitudinal design to investigate changes over time. The data may be biased due to self-report bias, and additional measurements like observations or performance metrics may be included. The study's generalizability may be limited due to its focus on four cultural dimensions, and it is suggested that future studies explore a broader spectrum of cultural aspects. Additionally, mediating and moderating variables such as leadership styles, employee engagement, and organizational structure should be investigated to better understand the relationship between organizational culture and cognitive empowerment.

*Recommendations:*

Organizations should focus on cultivating clan, adhocracy, and market cultures to enhance employee cognitive empowerment. Initiatives like team building exercises, innovation programs, and customer-centric training can strengthen these cultural dimensions. Leadership programs should develop skills aligned with collaborative and innovative cultures, promoting employee participation and empowerment. Hierarchy negatively influences cognitive empowerment, so organizations with a more hierarchical structure should assess its impact. Introducing flexible structures, flattened hierarchies, or hybrid models can balance structure with employee empowerment. Regularly assessing the organization's culture and its impact on cognitive empowerment is crucial. Employee feedback is also essential for adaptation. Training programs should focus on enhancing cognitive skills, critical thinking, and problem-solving. A learning culture that supports ongoing development and empowerment is recommended.

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# INFLUENCES OF CORPORATE SOCIAL ACTIVITIES ON CONSUMER PURCHASE DECISION OF NESTLE LANKA

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**Abstract**

This study investigates at customer purchase intentions in the Sri Lankan food and beverage industry, focusing on the relationships between CSR efforts, brand image, and demographic characteristics. The study's goal is to examine consumer knowledge of CSR, especially within Nestle, and to investigate the relationship between CSR awareness, brand opinion, and purchase intention. The study used a mixed-methods approach, incorporating both qualitative and quantitative analysis. To assure demographic representation, simple and stratified random sampling are used. The results show a weak relationship between CSR awareness and purchase intention, which is impacted by economic situations in Sri Lanka. Nestle CSR, brand attitude, and purchase intention, on the other hand, show a substantial positive relationship, implying that Nestle's CSR initiatives significantly contribute to customer preferences and brand loyalty.

**Keywords:** CSR (Corporate Social Responsibility), Purchase intension, Consumer Behaviour, Brand attitude, Consumer research

**Introduction**

Corporate Social Responsibility (CSR) has transformed into a strategic necessity for businesses, going beyond simple philanthropy to become an essential component of their operational structures (Porter and Kramer 2007). The growing recognition of the diverse advantages stemming from CSR has established it as a crucial catalyst for financial success (Ajzen, 1991). Simultaneously, consumer behaviour has emerged as a pivotal factor influencing the success of CSR initiatives, as consumers increasingly exhibit discernment regarding the societal and environmental effects of their consumption decisions. (Lee, 2019) (Kim, 2014)

In the Sri Lankan context, the interest in CSR is palpable, particularly among large conglomerates employing it as a tool to communicate ethical considerations and a sense of belonging to society. Nestle Lanka, a local arm of a multinational conglomerate, stands out as a significant contributor to CSR activities in Sri Lanka.

This study addresses the nexus between CSR activities, brand image, and consumer purchase intention, focusing on Nestle Lanka. The research aims to explore the awareness of CSR among consumers, particularly within Nestle, and to understand the dynamics of brand attitude in influencing purchase decisions. The overarching objective is to unravel any existing correlation between Nestle's CSR initiatives and consumer preferences. The study's sub-objectives delve into the specifics of CSR awareness, Nestle's CSR perception, brand attitude, and the relationship between CSR and purchase intention.
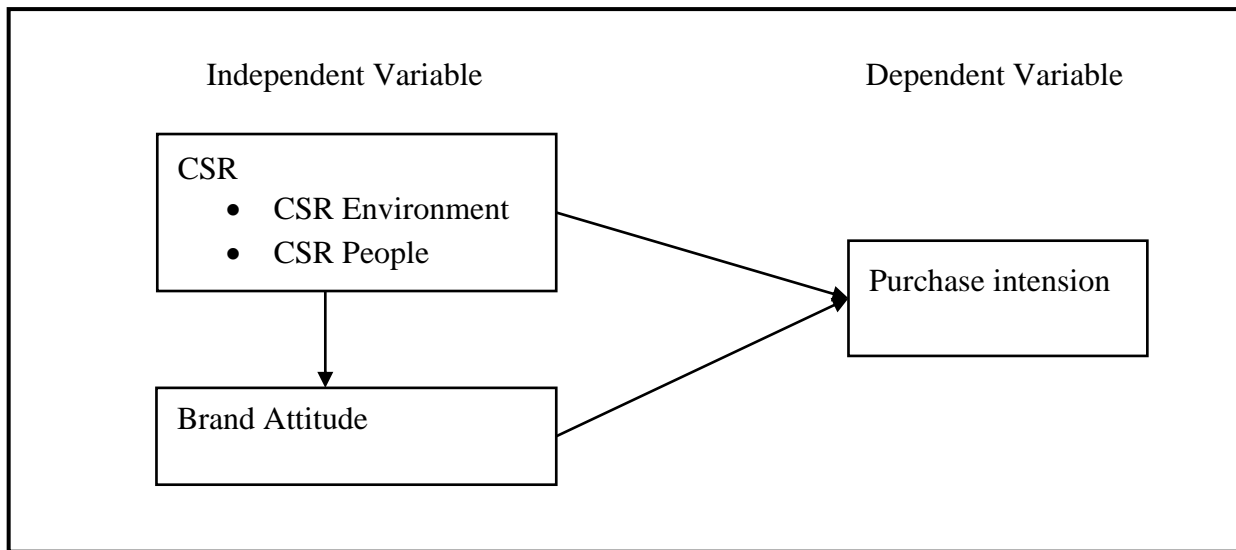
*Figure 1: Conceptual Framework*

Based on the discussion, the hypothesis development is as follows.

Table 1 Hypothesis Development

| Hypothesis | Independent variable | Dependent variable |
|---|---|---|
| H1$_a$ | Awareness of CSR people | Purchase intension |
| H2 $_a$ | Awareness of CSR Environment | |
| H3 $_a$ | Brand Attitude | |
| H4 $_a$ | Nestle CSR | |

The significance of this research is underscored by its potential contributions to business strategy effectiveness, enhancement of brand image, academic research advancement, and societal impact. Understanding how Nestle's CSR efforts influence consumer behaviour not only informs management strategies but also lays the groundwork for future research in the intricate interplay between CSR, purchase intention, and brand attitude. Ultimately, this study holds the promise of guiding corporate practices toward more impactful and beneficial societal contributions.

**Methodology**

The research methodology employed in this study involves a mixed-methods approach to comprehensively investigate the influence of corporate social responsibility (CSR) activities on consumer purchase intention, specifically focusing on Nestle Lanka. A quantitative method was utilized through an online survey and interviews targeting 384 participants, comprising English and Local language. The survey encompassed demographic analysis, including age, gender, location, education, occupation, monthly income, and product purchase frequency. Univariate and correlation analyses were conducted to examine the relationships between dependent and independent variables. Subsequently, regression and multiple regression analyses were employed to ascertain the impact of CSR components (awareness, brand attitude, and perceived CSR) on purchase intention. Furthermore, segmental analysis was undertaken to

explore specific demographic criteria. The comprehensive methodology aims to provide a nuanced understanding of the factors shaping consumer behaviour towards Nestle Lanka's CSR initiatives.

Table 2 Segmental analysis - Demographic criteria

| Demography | Category |
|---|---|
| Age | 27-35, 36-42 |
| Gender | Male, Female |
| District | Colombo, Gampaha, Kurunegala |
| Highest education | OL, AL, Bachelor Degree, Master Degree |
| Occupation | Employee, Entrepreneur |
| Monthly income | 50,000LKR-100,000LKR, 1000,000LKR-250000LKR, Above 250,000LKR |
| Product purchase frequency | Daily, once per week, more than once per week, monthly |

**Results**

*Descriptive data*

| Gender | Responses | % |
|---|---|---|
| Male | 228 | 59.38% |
| Female | 158 | 41.15% |
| Age | | |
| 20-26 | 42 | 10.94% |
| 27-35 | 119 | 30.99% |
| 36-42 | 113 | 29.43% |
| Above 43 | 52 | 13.54% |
| below 20 | 58 | 15.10% |
| District | | |
| Colombo | 107 | 27.86% |
| Gampaha | 91 | 23.70% |
| Kurunegala | 91 | 23.70% |
| Puttalam | 28 | 07.29% |
| Kalutara | 21 | 05.47% |
| Negambo | 8 | 02.08% |
| Other | 38 | 09.90% |
| Education Level | | |
| AL | 55 | 14.32% |
| Bachelor's Degree | 134 | 34.90% |
| Doctoral Degree | 1 | 00.26% |
| Master's Degree | 31 | 08.07% |
| OL | 126 | 032.81% |
| Undergraduate | 37 | 09.64% |
| Occupation | | |

| | | |
|---|---|---|
| Employee | 221 | 57.55% |
| Entrepreneur | 36 | 09.38% |
| Home | 22 | 05.73% |
| Retired | 22 | 05.73% |
| Student | 83 | 21.61% |
| Monthly income | | |
| Below 50,000 LKR | 246 | 64.06% |
| Between 100,000LKR - 250,000LKR | 31 | 08.07% |
| Between 50,000LKR - 100,000LKR | 95 | 24.74% |
| More than 250,000LKR | 12 | 03.13% |
| Product purchase frequency | | |
| Daily | 76 | 19.79% |
| Monthly | 85 | 22.14% |
| More than once a week | 124 | 32.29% |
| Once a week | 99 | 25.78% |

### *Data Distribution*

Basis below univariate analysis, low standard deviation represent that more data is spread close to the mean of all dependent and independent variables.

Table 3 Univariant analysis of purchase intension

| Variable | Mean | Standard Deviation |
|---|---|---|
| Purchase Intension | 3.87 | 0.645992 |

### *Univariate Analysis*

Table 4 Univariate analysis of independent variables

| Indicator | Mean | Standard Deviation |
|---|---|---|
| Awareness on CSR People | 4.03 | 0.66734 |
| Awareness on CSR Environment | 3.99 | 0.575442 |
| Brand Attitude | 3.88 | 0.483774 |
| Perceived CSR | 4.02 | 0.594814 |

### *Correlation Analysis*

The dependent and independent variables for the study are as follows.

Table 5 Correlation analysis between dependent and independent variables

| Dependent variable | Independent variables | Sig value | Relationship | $R^2$ | Status | Relationship representation |
|---|---|---|---|---|---|---|
| Purchase Intension | CSR People | 0.000 | Exist | -0.08 | Weak | 0.6% |
| | CSR Environment | 0.000 | Exist | -0.08 | Weak | 0.8% |
| | Brand Attitude | 0.000 | Exist | 0.619 | Strong | 38.3% |
| | Nestle CSR | 0.000 | Exist | 0.644 | Strong | 41.5% |

*Segment Analysis*

Table 6 Segment Analysis between independent and dependent variables

| Dependent variable | Independent variables | Sig value | Relationship | $R^2$ | Status | Relationship representation |
|---|---|---|---|---|---|---|
| Purchase Intension | CSR People | 0.000 | Exist | 0.784 | Strong | 58.6% |
| | CSR Environment | | | | | |
| | Brand Attitude | | | | | |
| | Nestle CSR | | | | | |

**Discussion**

The demographic analysis reveals that a significant contribution to the study comes from employees in the 27-42 age group, earning less than 50,000 LKR per month, and residing in Colombo, Gampaha, and Kurunegala. While the majority of respondents have at least a graduate qualification, interestingly, the majority still make product purchases at least once a week.

Referring to the results, it is evident that the relationship between CSR people, CSR environment, and purchase intention is weak. This suggests that consumers, particularly those surveyed, may not prioritize CSR considerations when making product selections. The univariate analysis, however, highlights the existence of relationships between the perceived CSR and Brand Attitude and the independent variables as follows.

Purchase intension = 0.462 * Perceived CSR + 2.072

Purchase intension = 0.462 * Brand Attitude + 2.072

In the multiple regression analysis, considering only the strong relationships between purchase intention and Nestle CSR, and purchase intention and brand attitude, both independent variables collectively contribute to 50.7% of purchase intention. The remaining 49.3% may be influenced by other factors, and in the context of adverse economic conditions in Sri Lanka, the price factor may dominate in this portion.

The $R^2$ for the multiple regression analysis is 0.714, exceeding the threshold of 0.6, indicating the acceptance of the conceptual framework developed based on the available literature.

*Segmental Analysis*

The segmental analysis reveals a robust and strongly positive relationship, with an R value of 0.784, between all independent variables and purchase intention within a demographic segment. The adjusted $R^2$ value of 0.586 underscores the substantial impact of perceived CSR and brand attitude, explaining 58.6% of the variance in purchase intention. The selected demographic segment with high purchasing power, as indicated by a monthly income of more than 50,000 LKR, aligns with middle or rich socio-economic groups according to the survey by the Department of Census and Statistics (Statistics, 2019). However, since this study was not specifically designed for this segment, a more in-depth analysis is warranted, especially considering the limited data points (57) available for this subgroup.

**Conclusions**

This study sheds light on several critical aspects influencing consumer behaviour in the context of Nestle Lanka's corporate social responsibility (CSR) initiatives. The findings reveal a weak relationship between CSR people and CSR environment with purchase intention, signalling a lack of consumer interest in CSR when selecting products, possibly attributed to financial pressures faced by consumers, particularly those with incomes below 50,000 LKR. Contrary to global trends, economic conditions emerged as a dominant factor shaping consumer purchase intentions. Notably, Nestle CSR demonstrated a robust and positive correlation with purchase intention, emphasizing consumers' specific interest in Nestle's CSR activities, even at potentially higher prices. The study underscores the powerful impact of brand attitude on purchase intention, highlighting the importance of consistent brand strength. Furthermore, the strong positive relationship between Nestle CSR and brand attitude suggests that Nestle's CSR efforts contribute significantly to the positive growth of brand attitude.

**Recommendations**

Study proposes below recommendations.

Strengthen Brand Attitude: Nestle Lanka should continue and enhance in initiatives aimed at fortifying its brand image. Strategic marketing efforts highlighting the company's values and positive contributions can build trust and foster consumer loyalty, thereby positively influencing purchase intentions.

Engage in Ongoing Consumer Research: To stay responsive to evolving consumer preferences, Nestle Lanka should conduct regular and thorough consumer research. This proactive approach will provide valuable insights into changing attitudes and enable timely adjustments to marketing and CSR strategies, ensuring effective communication of initiatives to diverse segments.

Consumer Segmentation: Acknowledging variations in CSR program responses based on demographic factors, Nestle Lanka should tailor marketing tactics to specific consumer categories. Customized approaches aligned with the diverse needs and values of different segments can enhance the impact of CSR initiatives.

Maintain Consistency in CSR Commitments: Nestle Lanka must uphold a consistent and enduring commitment to CSR initiatives. Recognizing that consumer perceptions of CSR are built over time, sustained dedication to social and environmental responsibility will enhance trust and loyalty. Consistency is key to maximizing the long-term impact of CSR efforts on purchase intention.

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# SENSORY MARKETING ATTRIBUTES AND ONLINE IMPULSE BUYING BEHAVIOR OF MILLENNIALS IN SRI LANKA: WITH REGARDS TO FASHION PRODUCTS

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## Abstract

Online shopping platforms have reached a superior level of communication with the consumer, where, messages are communicated in a compelling and persistent manner urging the customer to impulsively buy the product. The objective of the study is to determine the relationship between the level of attraction of visual, auditory, haptic sensory marketing attributes and the online impulse buying behavior of SLM, when buying fashion products. A questionnaire was used to collect data from 352 respondents. Data was analyzed using descriptive statistics, correlation and multiple regression. The results showed that there is an average level impulse buying behavior among millennials. They have more planned impulse buying nature than pure impulse buying nature. Further, millennials are more attracted to visual and haptic sensory attributes. However, only haptic sensory marketing attributes has a positive relationship with online impulse buying behavior of Sri Lankan millennials when buying fashion products.

**Key Words:** Impulse Buying Behavior, Millennials, Online Marketing, Sensory Marketing,

## Introduction

Impulse buying behavior (IBB) is defined as a quick and compelling purchasing intention with no pre shopping intention (Stern, 1962)**.** Online impulse buying has reached beyond the typical marketing limits as a result of information technological and e- commerce advancements (Liu, et al., 2013).

Marketing that appeals to the senses of the consumer and influences their cognition, reasoning and conduct is referred to as sensory marketing (Krishna, 2012).Marketers purposefully expose consumers to a range of sensory cues target one or more of the five senses – taste, smell, vision, touch and sound (Fürst, et al., 2020). The main goal of sensory marketing is to communicate with the brain of the consumer in the purpose of generating interest, transforming their buying intention and leaving a lasting impression (Nadanyiova & Majerova, 2018).

The cluster of individuals referred as Millennials, who were born between 1980 and 2000 (Smith & Nichols, 2015). The current ages of these individuals span between 23 to 42 years, also known as Digital natives since they were born into the digital age (McClure & McAndrews, 2016).

Online marketing has reached mobile space as a result of Millennial preferences and the wide-spread adoption of technology (Erickson, 2008). Millennials in particular are being greatly targeted for sensory marketing due to the fact their involvement with technology (Singh, et al., 2023).

Although all five senses are equally important in physical settings, smell and taste cannot be instantly stimulated in the online environment. Therefore, online store environments are limited to visual, auditory and haptic senses (Shang, et al., 2023)

Visual cues are the most frequently used stimulus to engage consumers (Kaushik & Gokhale, 2021). Conumers highly trust the visual details or the image provided on the website and retail owners need to rethink on the methods of picturing the quality, essential information and colors in virtual shopping platforms (Gopura & Kothalawala, 2021). As Hulten (2013) explains, product related visual stimuli such as graphics, vivid colors, inner and outer layout can be incoperated in developing marketing strategies. Griffith (2020) argues, when building a website or an online platform to instantly sell products, it is important to personalize the space where the user is interacting as per the consumer requirement.

Sound is often merged with visual stimuli to increase the impact and highlight a concept or a message. The volume, rhythm, genre and arrangement of music stimulate the auditory senses and impact the online consumer experience (Ding & Lin, 2012). When a consumer enjoys music their brain generates Dopamine, which improves their propensity to purchase (Ferreri, et al., 2019). Adding Ambient music to the online retail environment can positively affect the mood of the consumer (Cheng, et al., 2009). The arrangement of sound in an online store environment is utterly important in sensory interaction (Bilgihan, et al., 2016).

Ishikawa et al. (2014) claim that one of the key areas in traditional shopping is the use of haptic or tactile sensation in building buyer confidence. The consumer gains the primary idea of a product through visual and auditory cues, that combined with the sense of touch, creates a multisensory consumer experience (Hultén, 2011). Press, spread, multiple tapping, scroll, zooming, drag and rotating are key functionalities of a digital device based on the sense of touch (Villamor, et al., 2010). Mobile shopping apps, on the other hand frequently support the consumer to feel the sense of touch by delivering engaging and collaborative product presentational functions (Shi & Kalyanam, 2018).

Fashion is an expressive tool for Millennial generation (Wanniarachchi, et al., 2017). Sri Lankans who actively involved in and interact with online purchasing platforms are progressively increased over the recent past and it will exceed 45% in 2027 (Statista, 2022).

Due to the research gap related to online IBB of Sri Lankan Millennials (SLM) in regards to fashion product purchasing, the research question of this study was developed as follows:

What is the relationship between the level of attraction of visual, auditory and haptic sensory marketing attributes and the online IBB of SLM in regards to fashion product purchasing?

***Research objectives:***

To identify factors influencing the online IBB of SLM

To analyze the relationship between the level of attraction to visual, auditory and haptic sensory marketing attributes and online IBB

**Methodology**

Based on avaialble literature following conceptual framework (figure 1) and hypothesis were developed. A deductive approach was used with quantitative data. The theoretical population was SLM who purchases fashion products online. Population in Sri Lanka is nearly 22.16 million and approximately 26.1% of it is Millennials (Kemp, 2022). As extremely limited sources available on deciding the exact size of the target population, it was considered as unknown. A Sample was obtained from the selected population using the convenience sampling method, a type of non-probability sampling. In this technique, the ability to become included in the sample depends on the reachability of the researcher to all categories of the population (Hair, et al., 2011). The participants were selected using online social media platforms and through emails. Overall, 430 questionnaires were distributed using the convenience sampling method and 352 responses were taken into the analysis. A validated questionnaire was adapted. Refer table 1 for indicators of variables. All the dimensions were measured with a 5-point Likert scale (1= strongly agree to 5= strongly disagree). Descriptive statistics, bivariate correlation and linear regression techniques were used to analyze the data set using IBM SPSS software.
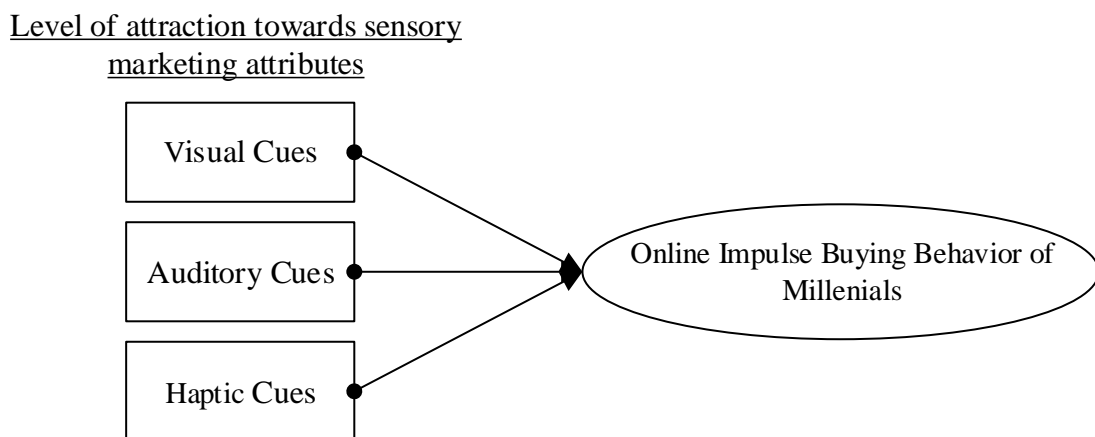


*Figure 1: Conceptual Framework*

**Hypothesis**

H1: There is a relationship in between the level of attraction of visual sensory marketing attributes and online IBB

H2: There is a relationship in between the level of attraction of auditory sensory marketing attributes and online IBB

H3: There is a relationship in between the level of attraction of haptic sensory marketing attributes and online IBB

Table 1: The Indicators of Variables

| Variable | Measurement indicator | Source |
|---|---|---|
| Online IBB | I make sudden, compelling decisions (Pure impulse buying)<br>The way the product is advertised made me buy the product (Reminder impulse buying)<br>When I see products for the first time, I visualize a need (Suggestion impulse buying)<br>I actively look for the product (Planned impulse buying) | (Stern, 1962) |
| Level of attraction of Visual sensory marketing attributes | I enjoy visually appealing website layouts | (Gopura & Kothalawala, 2021) |
| | I am attracted to colors and images | (Gopura & Kothalawala, 2021); (Hulten, 2013) |
| | A High-quality product image is very important | (Griffith, 2020); |
| Level of attraction of Auditory sensory marketing attributes | I enjoy listening to music while selecting and purchasing products | (Ferreri, et al., 2019) |
| | Good background music elevates my shopping mood | (Cheng, et al., 2009) |
| | Volume, rhythm and arrangement of music is very important to me. | (Ding & Lin, 2012); (Bilgihan, et al., 2016) |
| Level of attraction of Haptic sensory marketing attributes | I enjoy scrolling, tapping and zooming functions | (Ishikawa , et al., 2014) |
| | I am fascinated by the experience of scrolling, tapping and zooming functions | (Hultén, 2011) |
| | Scrolling, tapping and zooming functions are very important for me to read and understand the product properties clearly | (Villamor, et al., 2010); (Shi & Kalyanam, 2018) |

**Results and Discussions**

A pilot study was conducted to analyze the reliability using the Cronbach's alpha test and determined the alpha value of the design. Since the obtained values exceed the standard of 0.70 the dependability and authenticity of the survey instrument was validated.

Most respondents are female (58.5%), born between the years 1990 and 2000 (70.27%), employed (81.8%), graduates (54.65%).



**Education level**

- Secondary school education or below
- Diploma
- Bachelor's degree
- Masters or above

6.31%
14.41%
24.62%
54.65%
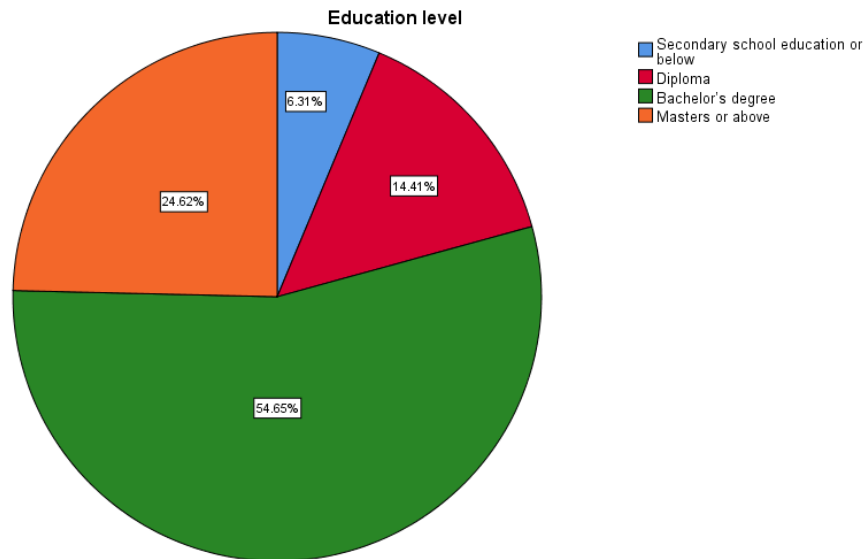
*Figure 2: Level of Education of Respondents*

According to table 2 there is an average level online impulse buying intention among Sri Lanakan Millennials (M=2.63, SD= 0.55). There is less pure impulse buying nature (M=3.14, SD= 1.04) but more towards planned impulse buying (M=2.10, SD= 0.96). Further, millennials are more attracted to visual (M=1.96, SD=0.65) and haptic (M=1.96, SD=0.68) sensory attributes.

Table 2 : Univariate Analysis

***Descriptive Statistics***

|  | N | Mean | Std. Deviation |
|---|---|---|---|
| Pure impulse buying | 352 | 3.14 | 1.038 |
| Reminder impulse buying | 352 | 2.70 | .970 |
| Suggestion impulse buying | 352 | 2.57 | 1.038 |
| Planned impulse buying | 352 | 2.10 | .955 |
| IBB_DV | 352 | 2.6278 | .54791 |
| Valid N (listwise) | 352 |  |  |

**Descriptive Statistics**

|  | N | Mean | Std. Deviation |
|---|---|---|---|
| IBB_DV | 352 | 2.6278 | .54791 |
| V_IV | 352 | 1.9583 | .65481 |
| A_IV | 352 | 2.6676 | 1.04003 |
| H_IV | 352 | 1.9593 | .67697 |
| Valid N (listwise) | 352 |  |  |

According to table 3, there are no statistical evidences to prove above-mentioned Hypothesis1 (p=0.66) and Hypothesis2 (p=0.12). However, there are statistical evidences to prove above Hypothesis3 (p=0.04). That means there is no correlation in between visual and auditory sensory marketing cues with online IBB of millennials. Only haptic sensory attributes are positively correlated (r=0.11) with IBB of SLM when buying fashion products online.

Table 3: Bivariate Analysis

**Correlations**

|  |  | IBB_DV | V_IV | A_IV | H_IV |
|---|---|---|---|---|---|
| IBB_DV | Pearson Correlation | 1 | .023 | .084 | .111<sup>*</sup> |
|  | Sig. (2-tailed) |  | .660 | .118 | .038 |
|  | N | 352 | 352 | 352 | 352 |

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

The achieved outcome of the study can vary due to the level of computer literacy and digital proficiency among SLM. Similarly, the individual personality characteristics of the participants can fluctuate the buying decisions of SLM.

**Conclusions and Recommendation**

Studying IBB of SLM in regards to online fashion product purchasing is important as online shopping has a rapid growth. Although the results of the study can vary as the tendency to higher biasness of the selected sample, the generated outcome indicated that there is an average level IBB among millennials. They have more planned impulse buying nature than pure impulse buying nature. Further, out of three sensory attributes available for online marketing called visual, auditory and haptic, millennials are more attracted to visual and haptic sensory attributes. However, only haptic sensory attributes are correlated with IBB of SLM when buying fashion products online. There is a considerable tendency of SLM to purchase fashion products online based on haptic sensory attributes, contrary to the traditional visual and auditory sensory interactions. Awareness on these variations can benefit marketers in adapting their online marketing tools as per the taste of their end users. Marketers should purposefully

expose consumers to a range of haptic sensory cues in online platforms. Further studies can be designed to identify other factors which affects online IBB of SLM.

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# EFFECT OF STRATEGIC CHOICES ON THE ORGANIZATIONAL GROWTH OF THE TECHNOLOGY INDUSTRY IN QATAR

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**Abstract**

This research study explores the intricate relationship between strategic choices made by organizations within the technology industry in Qatar with special reference to Prime Solutions and their subsequent effect on organizational growth. The dynamic nature of the technology sector, coupled with the unique socio-economic landscape of Qatar, presents a compelling context for examining the strategic decision-making processes and their implications for industry players.

In this descriptive research study, a sample of employee from different departments in the Prime Solutions were studied, to analyse. A total of 30 employees' data were collected according to Morgan table rules and essential statistical analyses were executed using SPSS software. From the findings of the research study, it was able to exposed those strategic choices, have significant effect on organizational growth. Considering the findings of the research study, it is recommended that the Prime Solutions to focus more on the implementation of suitable organizational strategies. Further, the support from the staff should be taken to enhance organizational performance.

**Keywords:** Strategic Choices, Strategic Formulation, Organizational Growth, Organizational Culture, Organizational Performance,

## Introduction

The rapid evolution of the technology industry has positioned itself as a driving force behind economic growth and innovation on a global scale. As nations strive to harness the potential of technology, Qatar, with its dynamic economy and strategic vision, has emerged as a notable player in this transformative landscape. This study researches into the elaborate relationship between strategic choices made by technology organizations in Qatar and their consequential effect on organizational growth. Strategic choices encompass decisions related to market positioning, innovation, partnerships, investment priorities, and overall business direction.

Qatar, a nation known for its economic diversification efforts, has witnessed a substantial rise in the prominence of its technology sector. With a keen focus on becoming a knowledge-based economy, Qatar has invested heavily in technology infrastructure, research and development, and fostering a conducive business environment. This backdrop sets the stage for an in-depth exploration of the strategic decisions that technology companies operating in Qatar including Prime Solutions make and their implications on organizational growth.

Qatar's National Vision 2030 outlines ambitious goals for economic development, sustainability, and technological innovation, underscoring the pivotal role of the technology sector in achieving these objectives. Understanding the strategic choices made by technology

organizations in Qatar is crucial for aligning industry practices with national aspirations and fostering sustainable growth.

Recent publications highlight the significant strides Qatar has made in developing its technology landscape. The "Qatar Digital Government Strategy 2020-2025," published by the Ministry of Transport and Communications, emphasizes the government's commitment to leveraging technology for enhanced public services, underscoring the role of strategic decisions in advancing the nation's digital agenda (Ministry of Transport and Communications, 2020).

An article by David J. Teece (2022) in the "Journal of Management" discusses the dynamic capabilities required for strategic management in technology-intensive industries. The author argues that organizations need to adapt quickly to technological changes, emphasizing the critical role of strategic choices in achieving and sustaining competitive advantage.

On another recent research by Ahmed A. Al-Emadi (2023) analyzes the impact of government policies on technology adoption in Qatar. The study reveals that government initiatives, such as the Qatar National Research Fund, play a crucial role in shaping strategic decisions by providing financial incentives for research and development in technology companies.

Organizational growth is the development of the organization in its life cycle is known as organizational growth (Graehler, et al., 2019). Organizational strategies are implemented within the organizational context to enhance organizational performance. Strengths of an organization are the strategic capabilities that are important for the growth of the organization. The main objective of the study is to identify the effect of strategic choices on the organizational growth of the technology industry in Qatar with special reference to Prime Solutions and Services company.

The research study is of practical significance because of the benefits that the outcomes of the research study provide to the parties such as Prime Solutions Company and the technology industry of Qatar.

*Conceptual framework*

| Independent variables | Dependent variable |
|---|---|
| **Strategic Management** | |
| Strategic choices | |
| Strategic capabilities | Organizational growth |
| Strategic implementation | |
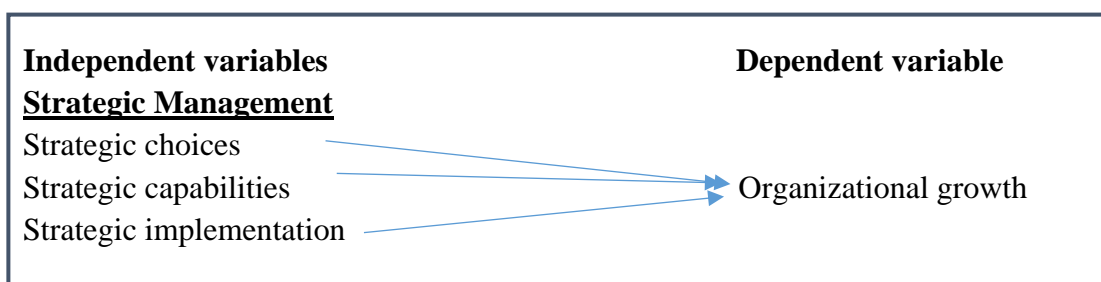
*Source: (Researcher's original work, 2023)*

*Independent Variables*
**Strategic choices –** The choice of the strategies by the organization to manage organizational performance (Gatersleben and Uzzel, 2017).
**Strategic capabilities -** The organizational strengths which are useful to improve organizational performance are known as strategic capabilities (Gatersleben and Uzzel, 2017).
**Strategic implementation -** The process of implementing the strategies within the organizational context is known as strategic implementation (Gatersleben and Uzzel, 2017).

*Dependent Variables*

Organizational growth - The development of the organization in its life cycle is known as organizational growth (Graehler, et al., 2019).

*Development of Hypotheses*

Based on the relationship between independent and dependent variables, three hypotheses have been developed. Under each of the hypotheses, there is an alternative hypothesis and a null hypothesis. In order to test these hypotheses, the independent variables and dependent variables are compared to determine whether there is a significant relationship between them.

**Hypothesis 1**

$H1_0$: There is no impact of strategic choices on the organizational growth of technology industry in Qatar.

$H1_1$: There is an impact of strategic choices on the organizational growth of technology industry in Qatar

**Hypothesis 2**

$H2_0$: There is no impact of organizational capabilities on the organizational growth of technology industry in Qatar.

$H2_1$: There is an impact of organizational capabilities on the organizational growth of technology industry in Qatar.

**Hypothesis 3**

$H3_0$: There is no impact of strategic implementation on the organizational growth of technology industry in Qatar.

$H3_1$: There is an impact of strategic implementation on the organizational growth of technology industry in Qatar.

*Operationalization table*

| Dimension | Indicators | Measurement | Question No | Source |
|---|---|---|---|---|
| Strategic choices | strategy of the business | 5 Point Likert scale | B.1.1 | Liu and Jiang (2011) |
| | Strategy of the corporate | | B.1.2 | |
| | international strategies | | B.1.3 | |
| | Developing innovative and entrepreneurial capabilities | | B.1.4 | |
| | An alliance and an acquisition | | B.1.5 | |
| Strategic capabilities | Impact of the environment | | B.2.1 | Lubin and Esty (2010) |
| | organizational goals | | B.2.2 | |
| | stakeholders | | B.2.3 | |
| | Corporate Social Responsibility (CSR) | | B.2.4 | |
| | organizational culture | | B.2.5 | |
| Strategic implementation | the strategy performance and evaluation | | B.3.1 | |

| | the process of the development of strategy | | B.3.2 | (Gatersleben and Uzzel, 2017). |
| | organizing | | B.3.3 | |
| | leadership and strategic change | | B.3.4 | |
| | strategy practice | | B.2.5 | |
| Organizational growth | Creation, survival | | C.1.1 | (Graehler, et al., 2019). |
| | pride and reputation | | C.1.2 | |
| | uniqueness and adaptability | | C.1.3 | |
| | stability | | C.1.4 | |
| | contribution | | C.1.5 | |

*Source: (Researcher's original work, 2023)*

**Methodology**

The study was undertaken among the total of 30 employees from the Prime Solutions company in Qatar. Questionnaires were circulated among the selected employees from the different departments in operations, software, hardware and finance to analyse effect of strategic choices on the organizational growth of the technology industry in Qatar. And required statistical analysis was performed using SPSS software.

**Results and Discussion**

The Content validity was ensured by conducting a comprehensive literature review, aligning research objectives with established theories, and incorporating inputs from industry experts during the development of the survey and interview questions. This ensured that the study's instruments captured the breadth and depth of strategic choices in the Qatari technology context.

The reliability of the study's instruments, such as surveys and interview protocols, was assessed using Cronbach's alpha. High alpha values were obtained for key constructs, indicating strong internal consistency and reliability of the measures used in the study.

In conclusion, the final results of this study stand on a foundation of validity and reliability. The robustness of the research design, the thoroughness of data collection and analysis, and the transparency in reporting contribute to the clarity and credibility of the study's findings on the impact of strategic choices on the organizational growth of the technology industry in Qatar.

Table 1 presents the demographic profile of the employees. Majority of respondents were males (86.7%), Aged between 31 to 35 years old. Based on the research results, 40% of the employees had less than 5 years of experience and 66.7% had less than one year of experience at Prime Solutions. Most of them are hold jobs position that fall outside of the senior categories such as Senior executives, Project Managers, and Divisional Heads. A total of 43.33% of the employees at Prime Solutions work in the Hardware department.

Table 1. Demographic variable

| Variable Components | Frequency | Percent | Valid Percent | Cumulative Percent | Mean | Mode | Std. Deviation |
|---|---|---|---|---|---|---|---|
| **Gender of the respondent** | | | | | | | |
| Male | 26 | 86.70% | 86.70% | 86.70% | 1.13 | 1 | 0.346 |
| Female | 4 | 13.30% | 13.30% | 100.00% | | | |
| **Age** | | | | | | | |
| 25 to 30 | 8 | 26.70% | 26.70% | 26.70% | 2.5 | 2 | 1.408 |
| 31 to 35 | 10 | 33.30% | 33.30% | 60.00% | | | |
| 36 to 40 | 6 | 20.00% | 20.00% | 80.00% | | | |
| 41 to 45 | 2 | 6.70% | 6.70% | 86.70% | | | |
| 46 to 50 | 3 | 10.00% | 10.00% | 96.70% | | | |
| above 50 | 1 | 3.30% | 3.30% | 100.00% | | | |
| **Years of experience in the technology industry of Qatar** | | | | | | | |
| below 5 years | 12 | 40.00% | 40.00% | 40.00% | 2.17 | 1 | 2 |
| 6 to 10 years | 8 | 26.70% | 26.70% | 66.70% | | | |
| 1 to 15 years | 4 | 13.30% | 13.30% | 80.00% | | | |
| 16 to 20 years | 5 | 16.70% | 16.70% | 96.70% | | | |
| above 20 years | 1 | 3.30% | 3.30% | 100.00% | | | |
| **Years of experience in Prime Solutions and Services** | | | | | | | |
| below 1 year | 20 | 66.70% | 66.70% | 66.70% | 1.77 | 1 | 1.278 |
| 1 to 2 years | 3 | 10.00% | 10.00% | 76.70% | | | |
| 3 to 4 years | 3 | 10.00% | 10.00% | 86.70% | | | |
| 4 to 5 years | 2 | 6.70% | 6.70% | 93.30% | | | |
| above 5 years | 2 | 6.70% | 6.70% | 100.00% | | | |
| **Job Position** | | | | | | | |
| Senior Executives | 5 | 16.70% | 16.70% | 16.70% | 3.07 | 4 | 1.172 |
| Project Manager | 4 | 13.30% | 13.30% | 30.00% | | | |
| Divisional Head | 5 | 16.70% | 16.70% | 46.70% | | | |
| Other | 16 | 53.30% | 53.30% | 100.00% | | | |
| **Working Department** | | | | | | | |
| Operations | 2 | 6.67% | 6.67% | 6.67% | 2.9 | 3 | 0.885 |
| Software | 7 | 23.33% | 23.33% | 30.00% | | | |
| Hardware | 13 | 43.33% | 43.33% | 73.33% | | | |
| Finance, HR and Admin | 8 | 26.67% | 26.67% | 100.00% | | | |

*Source: (Researcher's original work, 2023)*

Table 2 demonstrate the correlation between organizational growth and strategic choices is 0.955 which is very close to +1, It illustrates that there is a strong positive correlation between the two variables of Transformed strategic choices and transformed organizational growth.

This also further proves that by the significance p-value is less than 0.01 (p<0.01) this is clear evidencing to reject H0, null hypothesis and accept H1, alternative hypothesis between transformed strategic choices and transformed organizational growth relationship.

The evidence presented from previous research further supports this study's findings. Kawa et al (2013) stated that the success of an organization is based on the suitable strategy selection, formation, and implementation where strategic choice is most important in the first place.

Table 2. Results of Correlation between Strategic choices and Organizational growth

| Components | | Transformed Strategic Choices | Transformed Organizational Growth |
|---|---|---|---|
| Transformed Strategic Choices | Pearson Correlation | 1 | .955** |
| | Sig. (2-tailed) | | <.001 |
| | N | 30 | 30 |
| Transformed Organizational Growth | Pearson Correlation | .955** | 1 |
| | Sig. (2-tailed) | <.001 | |
| | N | 30 | 30 |
| **. Correlation is significant at the 0.01 level (2-tailed). | | | |

*Source: (Researcher's original work, 2023)*

Table 3 validates that Correlation analysis results between organizational growth and strategic capabilities is 0.936 at 1% significant level which was suggested by the Pearson correlation coefficients. this result indicates that there is a positive strong correlation relationship between these two variables of Strategic capabilities and Organizational growth. The significance value is 0.001 which was less than 0.01 (p<0.01) it is suggesting to reject H0 and accept H1.

By presenting adequate evidence from previous research findings, further strengthens this research finding as well. As stated in the previous study by Liu and Jiang (2011) a better organizational culture is a strategic capability that is beneficial for improving the organizational performance.

Table 3. Results of Correlation between Strategic Capabilities and Organizational growth

| Components | | Transformed Strategic Capabilities | Transformed Organizational Growth |
|---|---|---|---|
| Transformed Strategic Capabilities | Pearson Correlation | 1 | .936** |
| | Sig. (2-tailed) | | <.001 |
| | N | 30 | 30 |
| Transformed Organizational Growth | Pearson Correlation | .936** | 1 |
| | Sig. (2-tailed) | <.001 | |
| | N | 30 | 30 |
| **. Correlation is significant at the 0.01 level (2-tailed). | | | |

*Source: (Researcher's original work, 2023)*

Table 4 indicates a correlation value of 0.943 at 1% significance level for this dimension. It shows that it has strong positive relationship between organizational growth and strategic implementation. Since the sig. value is less than 0.01 (p<0.01) there is enough indication that to reject H0 and accept H1.

Additionally, this research finding is further supported by the adequate evidence presented by previous research findings. Madeeha and Imran (2014) stated that the strategic choices makes a significant effect on the organizational growth where the implementation of suitable organizational strategies such as business, corporate, and marketing is supportive of the improvement of the organizational growth in terms of increasing the market share, customer base, and reputation.

Table 4. Results of Correlation between Strategic implementation and Organizational growth

| Components | | Transform. Strategic Implementation | Transform. Organizational Growth |
|---|---|---|---|
| Transformed Strategic Implementation | Pearson Correlation | 1 | .943** |
| | Sig. (2-tailed) | | <.001 |
| | N | 30 | 30 |
| Transformed Organizational Growth | Pearson Correlation | .943** | 1 |
| | Sig. (2-tailed) | <.001 | |
| | N | 30 | 30 |
| **. Correlation is significant at the 0.01 level (2-tailed). | | | |

*Source: (Researcher's original work, 2023)*

### *What is the effect of strategic capabilities on the organization growth in the technology industry?*

Based on the analysis presented in this study it is revealed that there is a strong positive effect of strategic capabilities on organizational growth. The correlation analysis uncovered those strategic capabilities positively correlated with organizational growth by demonstrating the result of beta coefficient as 0.936 at p = 0.001 <α = 0.05 and t = 14.071 which was proven there was strong positive effect had between strategic capabilities and the organizational growth.

The study concluded with the findings uncovered based on the analysis that the effect of strategic capabilities on the organization's growth in the technology industry had a strong positive effect.
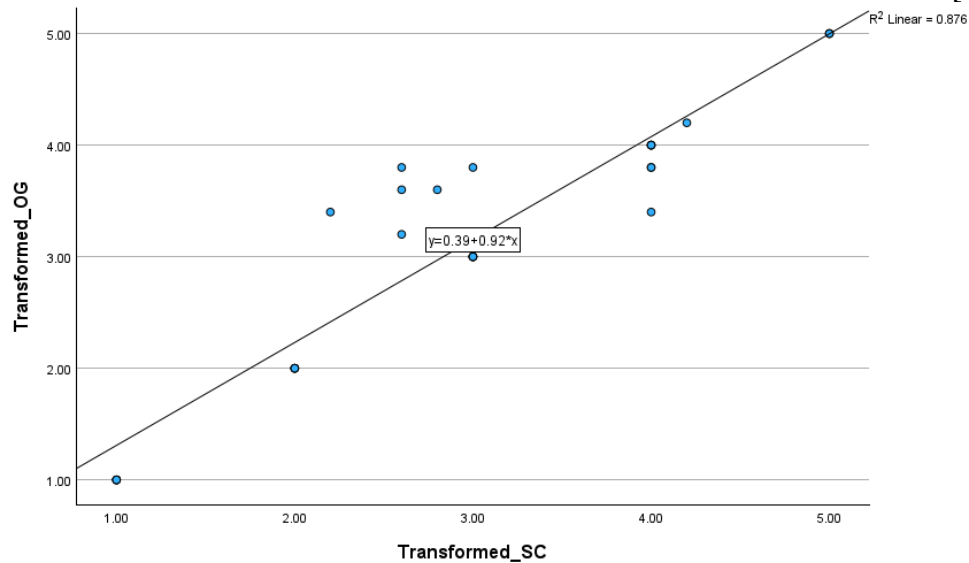
*Figure: 1 Strategic capabilities and Organizational growth scatter diagram*
**Source: (Researcher's original work, 2023)**

An upward slanting line on the scatter plot as per the figure 1 indicates that a positive relationship between the variables of capabilities and Organizational growth.

### What is the effect of strategic choice on the organization growth in the technology industry?

As per the calculations and figures carried out on this study exposed that the strategic choices were strongly affected on organizational growth. The correlation analysis revealed that strategic choices positively correlated with organizational growth by representing the result outcome of beta coefficient as 0.955 at $p = 0.001 < \alpha = 0.05$ and $t = 17.022$ which was proven there was strong positive effect had between strategic capabilities and the organizational growth.

Based on the findings of the study, it was determined and concluded that strategic choices had a strong positive effect on the company's growth in the technology industry,
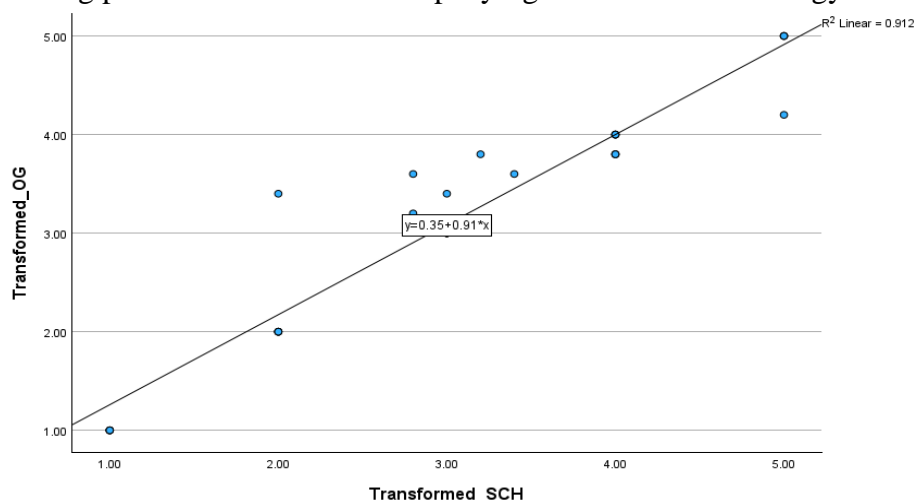


*Figure: 2 Strategic choices and Organizational growth scatter diagram*
**Source: (Researcher's original work, 2023)**

A positive correlation can be seen in the above Figure 2 represents in the points on the scatter plot slant upward from left to right.

***What is the effect of strategic implementation on the organization growth in the technology industry?***

It is concluded from this study that the strategic implementation had a positive effect on organizational growth. According to the correlation analysis, strategic implementation positively correlated with organizational growth by demonstrating a beta coefficient value of 0.943 at $p = 0.001 < \alpha = 0.05$ and $t = 15.033$, It has been proven the above argument.
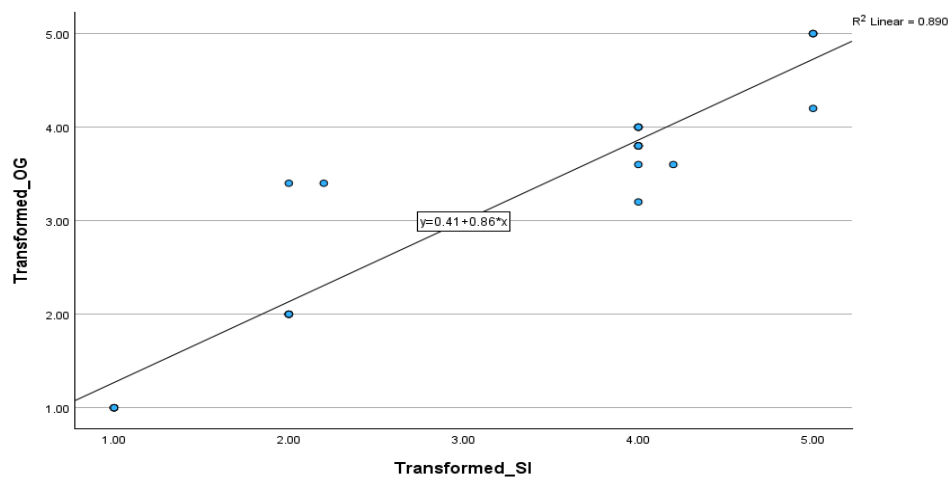


*Figure: 3 Strategic implementation and Organizational growth scatter diagram*
**Source: (Researcher's original work, 2023)**

Slanting lines on the scatter plot reference to the Figure 3 indicate a positive relationship between variables of Strategic implementation and Organizational growth.

**Conclusions and Recommendations**

The conclusion has been made based on the research sub questions developed in this study under three dimensions presented in the Table 2,3 and 4, based on the analyzed data findings and their outcomes. Also, the previous researches findings presented to support and strengthens this research findings.

In overall as stated the relationship between in the above three dimensions which was demonstrate and concluded that the main objectives of strategic choices and organization growth of the Prime Solutions and Services had a strong positive effect. Thus, it is finally concluded that there is a positive strong effect of strategic choices on the organizational growth of the Prime Solutions and Services technology industry in Qatar.

The study successfully analyzed a diverse set of strategic choices made by technology organizations in Qatar. Through interviews, surveys, and case studies, a comprehensive understanding of market positioning, innovation, collaborations, government policy alignment, talent management, cybersecurity, adaptability, sustainability, digital transformation, and customer-centric approaches was achieved.

The study provides empirical evidence supporting theoretical frameworks in strategic management, innovation, and organizational growth. This contribution strengthens the

theoretical foundation by aligning academic concepts with real-world practices in the Qatari technology context.

Considering the findings of the research study, it is recommended that the Prime Solutions should focus more on the implementation of suitable organizational strategy choices. To make strategic choices, the company can assess by doing a SWOT analysis in order to identify the strengths and weaknesses Internally and the opportunities and threats from the external environment in the technology industry in Qatar. When implementing organizational strategies, the company has to consider how the corporate strategies will contribute to accomplishing the organizational vision and growth of the company in the industry.

The objectives of the research study include the identification of impact of strategic capabilities, strategic choices, and strategic implementation on the organizational growth in the technology industry of Qatar. From the findings, I was able to identify those three independent variables have strong positive impact on the organizational growth in the technology industry of Qatar. I was able to gain better outcomes from the completion of my research study. I learnt in a systematic method how to handle research studies. Further, MBA completion going to supportive for me to enhance my business administration knowledge and it will allow me to achieve my career goals by giving me an added value credentials to the current profile where I expect a higher position in the senior management as GM Finance, Finance Director, VP Finance or even for a CEO of a reputed organization.

In summary, the achievements of the objectives and knowledge contributions of this study provide a holistic perspective on the interplay between strategic choices and organizational growth in Qatar's technology industry. The insights garnered serve as a valuable resource for industry stakeholders, policymakers, and researchers seeking to navigate and contribute to the growth of the technology sector in the region.

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# FACTORS THAT INFLUENCING ENGINEERS' JOB SATISFACTION; WITH EMPHASIS ON THE MECHANICAL, ELECTRICAL AND PLUMBING ENGINEERING CONSULTANCY FIELD IN COLOMBO DISTRICT, SRI LANKA

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**Abstract**

Employee job satisfaction is a crucial factor for employees' productivity as well as effectiveness. Therefore, identifying the influencing factors can be beneficial for both employees and employers. The Mechanical, Electrical, and Plumbing Engineering consultancy field can be taken as one of the major consultancy fields in the field of the building services industry. Therefore, this study was conducted to identify factors that influence the engineers' job satisfaction in the mentioned field. The study employed a deductive research approach. It conducted quantitative research involving 102 engineers in Colombo District, Sri Lanka, with distributed questionnaires for data collection. Data analysis was conducted using Statistical Package for the Social Sciences software and Microsoft Excel. The analysis employed reliability, correlation coefficients and multiple regression analyses. The proposed model's significance value was less than 0.05, indicating acceptance of the model.

**Key Words:** Job Satisfaction, MEP Engineering Consultancy Field, Sri Lanka

## Introduction

### *Background of the study*

Job satisfaction is one of the most important outcomes of ethical human resource management, and it can also be defined as the evaluation of one's professional experiences that may lead to a positive emotional state(Robert L. Mathis, 2009). Therefore, understanding the factors that contribute to employees' job satisfaction is crucial. This study specifically focused on engineers working in the Mechanical, Electrical and Plumbing (MEP) engineering consultancy field, where they are responsible for designing, installing, and maintaining mechanical, electrical, and plumbing systems, which are essential aspects construction consulting.

### *Research problem identification*

The MEP engineering consulting industry in Sri Lanka does not have the same history as other consulting industries, and engineer scarcity has become a growing issue. As a result, the workload for engineers is high, and managing this workload results in a decrease in the quality of project deliverables, followed by poor performance and decreased productivity. Staff turnover also occurs as a result of engineers' tendency to quit their jobs in search of career fulfilment. Due to an increase in turnover costs, these circumstances result in a decline in the growth and development of the MEP engineering consulting company, which primarily affects the employer as well as the employee. Therefore, the results of this study will be used to identify the crucial measures that can be taken to attract and retain engineers in the field of MEP consulting.

Despite the fact that there have been numerous studies on job satisfaction, it has been challenging to locate research on engineers' job satisfaction in MEP engineering consultancies.

In light of these circumstances, the research question that emerges is, "What are factors influencing engineers' job satisfaction, with emphasis on the MEP engineering consultancy in Colombo district, Sri Lanka?".

### *Objectives of the study*
- To identify factors that affect engineers' job satisfaction in the MEP engineering consultancy profession, specifically with relation to the Colombo district.
- To determine the study population's demographic traits.
- To offer suggestions for improving engineers' job satisfaction in the MEP Engineering Consultancy Field.

### *Significance of the study*
Focusing on the job satisfaction component, it is possible to lower employee turnover rates, which will support industry growth, and most of the MEP engineering consulting firms in Sri Lanka are presently working on international contracts that will help the country import foreign currency. Therefore, improving this industry will help to reduce outsourcing MEP services from foreign countries for local projects, and through international contracts, foreign currencies can be generated. Therefore, it is crucial to take into account the economic impact of this consulting profession, considering the current situation of the nation's economy.

### *Limitations of the study*
One of the main limitations of this study is that it is based on MEP engineers in the Colombo district of Sri Lanka. The MEP engineering consultant industry involves various professionals beyond engineers, like draughtsman and accountants. By concentrating solely on engineers, the study may miss insights from other key stakeholders.

### Methodology
### *Conceptual Framework*
Due to the deductive nature of this study's (Sooriyapperuma & Nawarathna, 2021), the research's conceptual framework was developed with the help of a literature review, and five variables were chosen as shown in Figure 2.1. The independent factors are supervision, financial compensation, autonomy, and training opportunities. The dependent variable is job satisfaction.
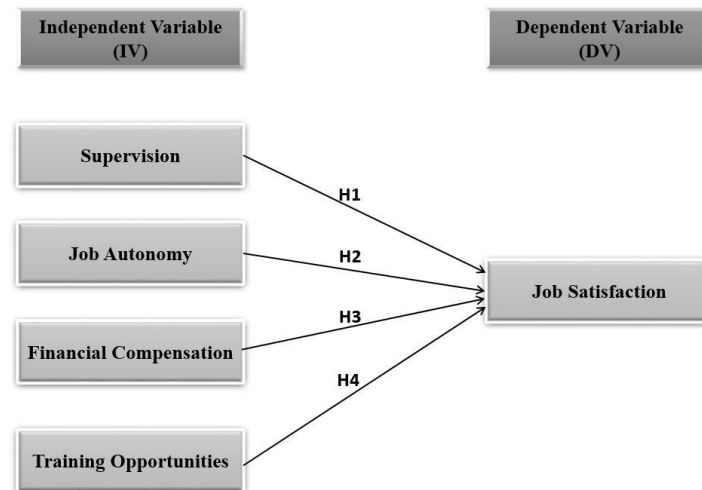
*Figure 1: Conceptual Framework (Source : Data Complied by the author)*

### Development of Hypotheses

The following hypotheses were selected for testing in the research study based on the conceptual framework and prior literature:

Table 1: Hypotheses of the Research Study (Source : Data Complied by the author)

| Null Hypothesis | Alternative Hypothesis |
|---|---|
| H0: There is no relationship between supervision and job satisfaction of engineers in MEP Engineering Consultancy Field. | H1: There is a relationship between supervision and job satisfaction of engineers in MEP Engineering Consultancy Field. |
| H0: There is no relationship between job autonomy and job satisfaction of engineers in MEP Engineering Consultancy Field. | H2: There is a relationship between job autonomy and job satisfaction of engineers in MEP Engineering Consultancy Field. |
| H0: There is no relationship between financial Compensation and job satisfaction of engineers in MEP Engineering Consultancy Field. | H3: There is a relationship between financial Compensation and job satisfaction of engineers in MEP Engineering Consultancy Field. |
| H0: There is no relationship between training opportunities and job satisfaction of engineers in MEP Engineering Consultancy Field. | H4: There is a relationship between training opportunities and job satisfaction of engineers in MEP Engineering Consultancy Field. |

*Research Design*

The field sample design method was selected as a stratified random sampling method in order to uncover factors influencing job satisfaction at MEP Engineering Consultancy. Data was collected from about 102 engineers for this study from twelve MEP engineering consulting companies. Mechanical, electrical, and plumbing specializations were selected for potential strata, along with other characteristics like gender, age, marital status, and working specialization.

Primary data collection was done by using a Google Form questionnaire issued to a sample of the population. Respondents' responses were graded on a 5-point Likert scale from strongly agreed to strongly disagreed, and decisions were determined by the results of the data analysis. The Statistical Package for the Social Sciences (SPSS) was used to assess the data that has been gathered. Pearson correlation analysis, coefficient analysis, and multiple regression were employed as statistical methods for data analyses. Coefficient analysis and Pearson correlation analysis were used to evaluate the influence or representation of independent variables. ANOVA regression analysis was used to evaluate the validity of the model.

**Results**

*Descriptive Statistics of the Collected Data*
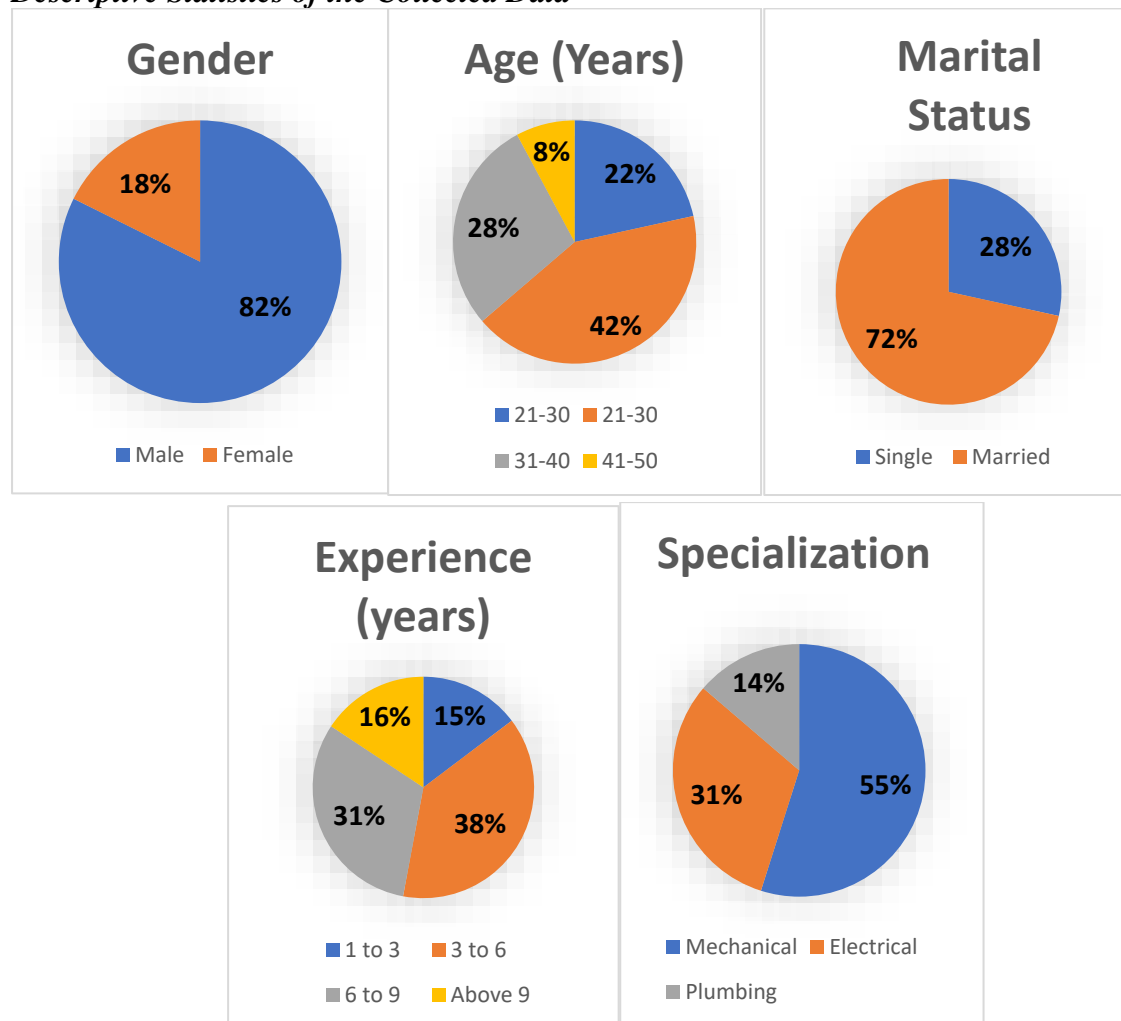


*Figure 2: Descriptive Statistics of Demographic Factors (Source : Survey Results)*

Table 2: Descriptive Statistics Independent variables and Dependent variable (Source : SPSS Results)

**Descriptive Statistics**

|  | Mean | Std. Deviation | N |
|---|---|---|---|
| Supervision | 3.9681 | .43039 | 102 |
| Job_Autonomy | 3.9730 | .48096 | 102 |
| Financial_Compensation | 3.8382 | .49583 | 102 |
| Training_Opportunities | 3.6005 | .41515 | 102 |
| Job_Satisafaction | 3.5858 | .56452 | 102 |

*Reliability Analysis*
Table 3: Cronbach's Alpha value for total data (Source : SPSS Results)

**Reliability Statistics**

| Cronbach's Alpha | N of Items |
|---|---|
| .873 | 5 |

Table 4: Cronbach's Alpha value for variables (Source : SPSS Results)

**Item-Total Statistics**

|  | Scale Mean if Item Deleted | Scale Variance if Item Deleted | Corrected Item-Total Correlation | Cronbach's Alpha if Item Deleted |
|---|---|---|---|---|
| Supervision | 14.9975 | 2.824 | .565 | .876 |
| Job_Autonomy | 14.9926 | 2.480 | .737 | .837 |
| Financial_Compensation | 15.1275 | 2.416 | .756 | .832 |
| Training_Opportunities | 15.3652 | 2.631 | .760 | .836 |
| Job_Satisafaction | 15.3799 | 2.284 | .717 | .846 |

*Analysis of correlation coefficient and hypothesis validation*
Table 5: Summary of Analysis (Source : SPSS Results)

| Independent Variables | Pearson Correlation (r) | R Square Value (%) | Significance Value (P) |
|---|---|---|---|
| Supervision | +0.483 | 23.3% | 0.000 |
| Job Autonomy | +0.642 | 41.2% | 0.000 |
| Financial Compensation | +0.634 | 40.2% | 0.000 |
| Training Opportunities | +0.610 | 37.2% | 0.000 |

*Multiple Regression Analysis*

Table 6: Multiple Regression Analysis Model Summary (Source : SPSS Results)

**Model Summary**

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate |
|---|---|---|---|---|
| 1 | .722[a] | .522 | .502 | .39843 |

a. Predictors: (Constant), Training_Opportunities, Supervision, Job_Autonomy, Financial_Compensation

Table 7: ANOVA Test (Source : SPSS Results)

**ANOVA[a]**

| Model | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| 1 | Regression | 16.788 | 4 | 4.197 | 26.439 | .000[b] |
| | Residual | 15.399 | 97 | .159 | | |
| | Total | 32.187 | 101 | | | |

a. Dependent Variable: Job_Satisafaction

b. Predictors: (Constant), Training_Opportunities, Supervision, Job_Autonomy, Financial_Compensation

**Discussion**

*Descriptive Analysis*

Five items on a Likert scale were included in the questionnaire that was used to gather the data and A Likert scale of 1 to 5 implies strongly disagreeing or strongly agreeing. According to Table 1, the mean score for job satisfaction was 3.5858 out of 5, meaning that the respondents either agreed with the job's description or were satisfied with it. The average score for supervision, job autonomy, financial compensation, and training opportunities ranged from 3.6 to 3.9 out of 5, which denotes agree or satisfaction, because all questions were related to positive aspects and levels of satisfaction related to engineers in the MEP engineering consultancy field.

*Reliability Analysis*

Table 2 indicates that the overall data set's Cronbach's alpha value is 0.873, and Table 3 shows that the supervision category has the highest value of 0.876 and the financial compensation category has the lowest of 0.832. This indicates that Cronbach's alpha values for both the total data and the variable are both higher than 0.7. The data can therefore be regarded as acceptable and trustworthy

*Correlation Coefficient analysis*

According to Table 4, it was evident that three independent variables have a strong positive relationship with the dependent variable, which means the Pearson correlation value is between 0.6 and 1. They are job autonomy, financial compensation, and training opportunities. The highest coefficient value among independent variables belongs to job autonomy, and it explains that job satisfaction has a representation from job autonomy, which has a representation value

of 41.2% and 58.8% of other unknown factors, and all alternative hypotheses were accepted because the significance value was lower than 0.05 as mentioned in Table 4.

*Multiple Regression*

The findings demonstrate that the dependent variable job satisfaction has a representation in the independent variables supervision, job autonomy, financial pay, and training opportunities, which have a representation value of 50.2%, according to the adjusted R square value of 0.502 in the study. Other elements that were not taken into account in this study accounted for the remaining 49.8%.

The model is accepted since the significance value in this case is less than 0.05, which indicates that all independent variables towards the dependent variable are accepted.

**Conclusions and Recommendations**

*Conclusion of the study*

Males represent the majority of the gender, with a percentage value of 82. And the highest percentage of engineers have between 3 and 6 years of experience. Furthermore, the mechanically specialised engineering workforce received the greatest percentage, a score of 55, under the element of field of specialisation. Above all, demographic queries are permissible in the context of MEP engineering consultation. In their journals, Alzubi et al. (2021), Paudel et al. (2020), and Sun et al. (2022) discovered comparable results connected to demographic aspects in the field of engineering construction.

Table 8: Status of Hypothesis (Source : SPSS Results)

| Independent Variables | Significance Value (P) | Hypothesis Status |
|---|---|---|
| Supervision | 0.000 | Alternative hypothesis Accepted |
| Job Autonomy | 0.000 | Alternative hypothesis Accepted |
| Financial Compensation | 0.000 | Alternative hypothesis Accepted |
| Training Opportunities | 0.000 | Alternative hypothesis Accepted |

All four alternative hypotheses were accepted considering the significance value, which is less than 0.05, and all null hypotheses were rejected. Furthermore, according to Table 6, the ANOVA test results indicated that the research model was accepted, considering significance value.

According to Table 5, the results of the multiple regression analysis indicate that all independent variables towards the dependent variable have a strong positive correlation, with a value of 0.722. Additionally, the table shows that there is a 50.2% representation of all independent variables contributing to job satisfaction. Which means 49.8% are other unknown factors, which we did not take into account for this research.

*Recommendations*

The job autonomy factor can vary according to the phase of the project and the early stage. For example, in the design stage, engineers need to make decisions regarding the design with their

expertise and knowledge. Therefore, providing freedom to complete the design will lead to successful outcomes.

In this field, normally there are mainly two types of engineers: junior engineers and senior engineers. If junior engineers can get regular performance assessments that provide feedback and acknowledgement as well as conduct mentorship programmes, it will help enhance their confidence.

The engineering field is a highly technical field, and data related to this field, especially standards, is updated often. And also, there is more software involved in this field, especially in the design stage, and therefore, engineers and others who are related to this field need to know about it. Therefore, encouraging engineers to participate in training sessions will be beneficial for the company, the client, and the engineers who work on a project.

The company needs to make suitable financial compensation policies considering factors like experience, education and qualifications, project complexity, and economic conditions. After job autonomy, financial compensation had the highest correlation with job satisfaction. Therefore, a company can make policies that are beneficial for both parties, the company and its employees, which ultimately lead to satisfying both employees and employers.

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# EMPLOYER RECOMMENDED STRATEGIES TO PROMOTE EMPLOYMENT FOR PERSONS WITH DISABILITIES (PWDs) IN THE PRIVATE SECTOR OF SRI LANKA (SL)

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**Abstract**

Despite robust disability reforms, low number of Persons with Disabilities (PWD) are employed in the private sector of Sri Lanka (SL). Thus, this study explored the employer-recommended strategies to promote employment opportunities for PWDs, and the benefits of employing PWDs in the private sector organisations of SL. A multiple case study research strategy was used and semi-structured interviews were conducted to collect primary data from nine participants who were purposively sampled among nine private companies which have been employing PWDs for more than five years. Cross-case data analysis technique and thematic analysis was used to analyse the different perspectives of these participants, without injecting the researcher's preconceptions and biases into the inferences. The key findings were, private sector organisations can immensely benefit from employing PWDs and it is very crucial to sensitise non-disabled society to ensure sustainable disability employment in the private sector, with the support of the State, non-governmental organisations and other interested stakeholders.

**Keywords:** Diversity management, Inclusive culture, Persons with Disabilities, Private sector employers, Equal employment opportunity

**Introduction**

Disability is a global emerging issue because, according to the World Health Organisation (WHO), approximately 16% of the global population possesses some type of disability, making them the largest minority in the world (WHO, 2023). Disability-related trends also predict that the number of PWDs will further increase due to chronic diseases, a rising ageing population, and accidents (Sachinthana & Samaraweera, 2021; WHO, 2011).

Moreover, the sustainable development goals (SDG) developed by the United Nations (UN) ensure a sustainable future for all, which must be achieved by 2030. The eighth SDG is about decent work and economic growth, emphasising the importance of promoting inclusiveness and employment for all, including disability (International Labour Organisation [ILO], 2019). Further, many employers are giving importance to diversity, equity, and inclusion (DEI) strategies to expand their talent pool, covering broader dimensions such as age, gender, and disability (Henry, et al., 2014).

Against this backdrop, disability-related statistics are not updated frequently in SL (Mendis, 2003; Sachinthana & Samaraweera, 2021). Although the private sector in SL has contributed immensely to increasing employment opportunities when compared to other sectors (Salih, 2001), the highest number of PWDs aged 15 and above were employed as own account workers

(45.7%) followed by private sector employment (32.8%) and government sector employment (8.9%) (Census of Population and Housing [CPH], 2012 as cited in Arunatilake, 2016). Thus, low number of PWDs are employed in the private sector of SL.

Past studies revealed that PWDs perform better when compared with their non-disabled colleagues on productivity, safety measures, loyalty, and attendance (Ang, 2017; Bonaccio et al., 2019). Thus, private-sector employers can immensely benefit from this untapped pool of unique talent, which consists of people with unique abilities.

Consequently, the purpose of this study was: "Employer Recommended Strategies to Promote Employment for PWDs in the Private Sector of SL. The research objectives were as follows: (1) to identify employer-recommended strategies which can promote employment opportunities for PWDs, and (2) to explore the benefits of employing PWDs in the private sector organisations of SL.

This research is original about the SL context and can be a wealth of information to identify their recommended strategies as there are very few studies considering the SL context regarding the private sector employer-recommended strategies for sustainable disability employment.

**Methodology**

The researchers chose an *interpretivism* research philosophy and an *inductive research approach* for this *qualitative study*. A *multiple case study research strategy* was chosen as this was often used in *exploratory research* (Saunders et al., 2019; Yin, 2017).

Table I: Number of PWDs Employed – Total

| Company Code | Type of Workplace | Respondents | No. of PWDs Employed | No. of Years – of Employing PWDs |
|---|---|---|---|---|
| A | Beauty Salon – Service Sector | Director (Overseeing overall HR) | 2 [a] | 25+ Years |
| B | Tea Manufacturing & Exporter | HR Manager (Overseeing overall HR) | 13 | 20+ Years |
| C | Bank | Assistant HR Manager – Talent Acquisition | 6 | 10+ Years |
| D | Quick Food Restaurant | CSR Head | 59 | 5+ Years |
| E | Bank | Vice-President Group HR | 3 [a] | 10+ Years |
| F | Diversified Conglomerate (Sectors: Hospitality, FMCG, Packaging, Manufacturing) | Executive Director – CSR | 11 [a] | 10+ Years |
| G | Bank | Chief Manager - HR | 16 | 33+ Years |
| H | Retail – Supermarket | Compensation Manager – Retail Cluster | 5 | 15+ Years |
| I | Apparel Manufacturer & Exporter | Head of Sustainability | 456 | 25+ Years |

*Source: Researcher's interviews.*

[a] Although Company A, E & F show very low numbers of PWDs employed at present, they had previously employed higher numbers of PWDs.

Cases include *nine private sector companies* which were selected based on a *purposive sampling strategy* and the principle of data saturation. To choose the sample, the following criteria were decided based on the researchers' expertise.

*Must Have Been Employing PWDs For More Than Five Years:*

For an organisation to reap the benefits of employing PWDs, it should at least employ PWDs for more than five years.

*Must Be a Private Organisation that Employs PWDs:*

The participants must be in senior positions and/or have direct exposure to employing and managing PWDs in private sector organisations.

All nine organisations in the sample have been employing PWDs for more than five years (see Table I), thereby complying with the above criteria.

*Semi-structured interview method* was chosen to collect primary data. Each interview lasted for about one hour, recorded with the consent of the participants and thereafter transcribed verbatim. Open-ended questions were finalised based on extensive literature and feedback from disability-related experts.

For data analysis, cross-case data analysis technique (Yin, 2017) was used based on two stages:

*Stage 1:* 'W*ithin-case analysis'* - **Six-steps of Thematic analysis** (Braun & Clarke, 2006) was used where the transcribed interview data were arranged in data segments and analysed to understand contextual variables within nine cases.

*Stage 2: 'Cross-case analysis'* - '**Grounded-up strategy** (Yin, 2017) where relevant phrases from each of the participant's responses were included under the identified themes and sub-themes, based on the node hierarchies.

As disability is a sensitive topic, research ethics were adhered to when accessing organisations, data collection, analysis, and reporting stages. Based on the ethical principles of social research (Saunders et al., 2019), all nine participants confirmed in writing that they were willing to participate and their participation was voluntary. Pseudonyms were used to replace companies' & participants' names to ensure confidentiality. Ethical approval was also obtained from the university, affiliated with this study.

**Results & Discussions**

The employer-recommended strategies were analysed under four themes (see Figure I). 89% of respondents emphasised that it is very crucial to sensitise non-disabled society and organisational members to ensure sustainable disability employment in the private sector of SL which concurred with Henry et al. (2014). Moreover, 89% also elaborated that the Government, NGOs, and stakeholders must also coordinate with the private sector to sensitise non-disabled community.

To change the negative mindset of the co-workers and supervisors of PWDs, 67% of the participants specifically indicated that it's important to conduct regular disability awareness training to reduce unconscious bias & negative attitudes they have against PWDs.

This is because non-disabled society will show negative dispositions toward PWDs because of negative myths about PWDs' abilities and unawareness in dealing with PWDs (Ang, 2017) which was transpired as the major barrier to promote employment opportunities for PWDs.

Moreover, the findings also concurred with Henry et al. (2014) which emphasised that it is paramount to share success stories of PWDs who are employed in mainstream employment and interested stakeholders need to continuously challenge other employers to hire more PWDs.
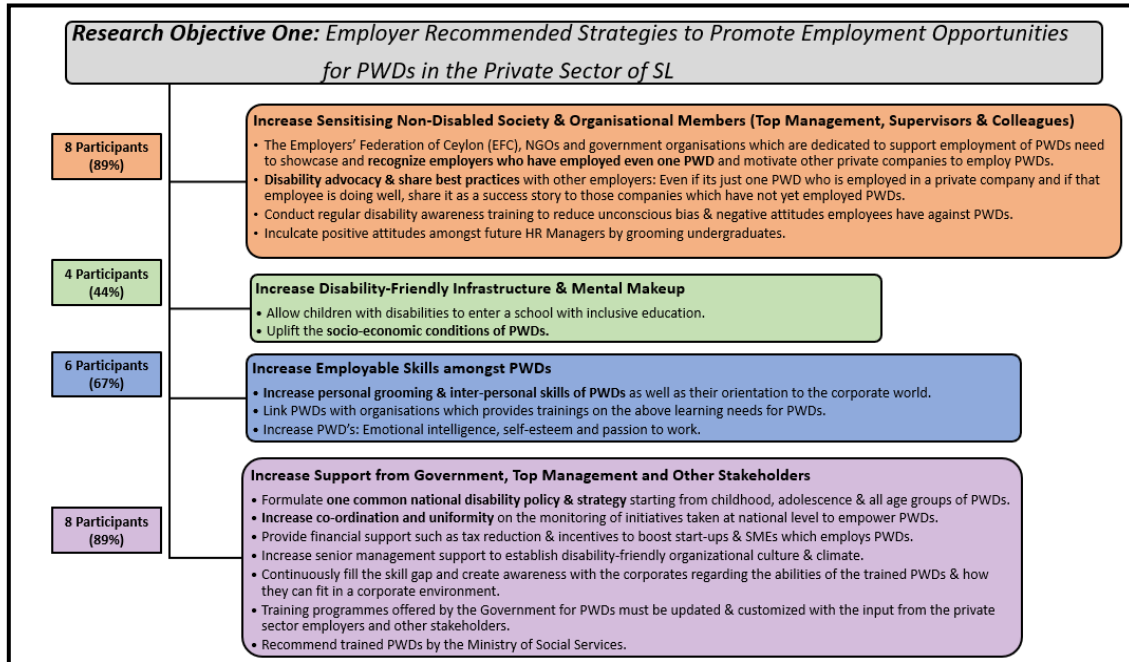


*Figure I: Summary of Findings for Research Objective One*

Source: Researcher's original context.
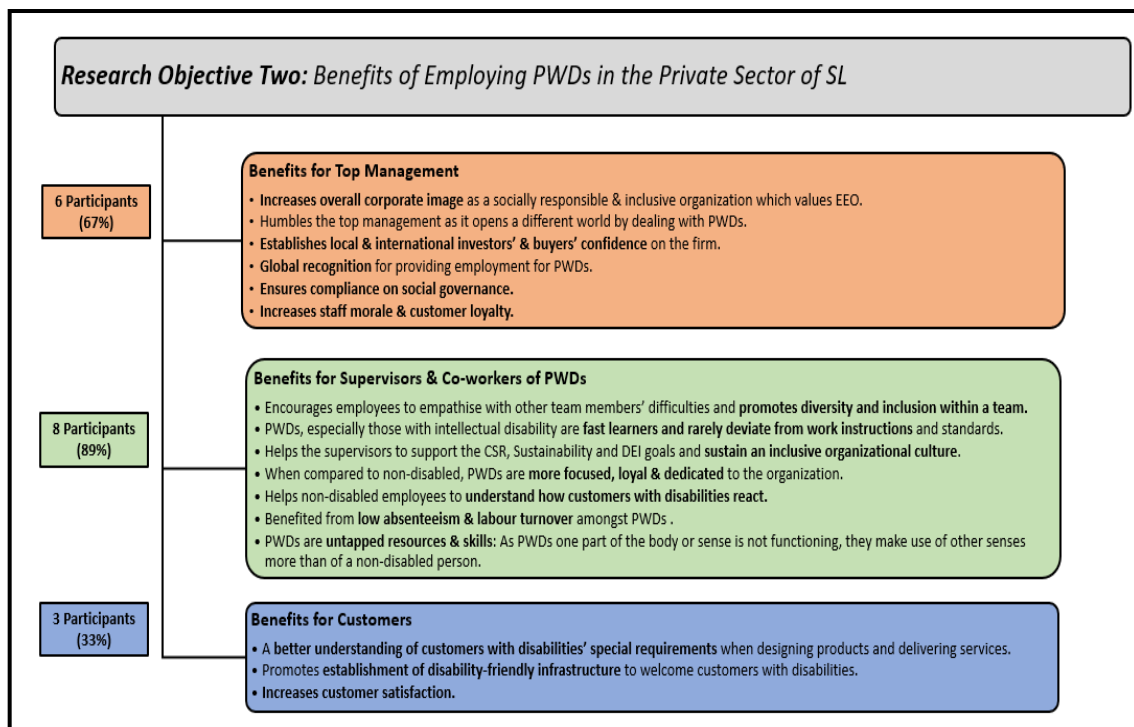


*Figure II: Summary of Findings for Research Objective Two*

Source: Researcher's original context.

Another key interesting finding from this study was that financial incentives from the Government can be beneficial only for start-ups or small-scale organisations and not for large organisations as they are already investing huge amounts in other CSR projects and few of the participants were of the notion that the SL Government is unable to financially support due to the present economic crises.

This supports Moore et al.'s (2017) study in Australia, which found that financial incentives from the State may not be valued by well-resourced and large organisations. Yet, it is not parallel with some literature that recommends that the Government should provide incentives to *all employers* to hire PWDs (Arunatilake, 2016; Henry et al., 2014).

The researcher supports Moore et al.'s (2017) argument that financial incentives alone will not promote employment opportunities for PWDs in the private sector. It is only when employers adopt a rights-based approach to disability that will help employers to change their negative attitudes toward a PWD so that they will focus on PWDs' unique abilities.

Moreover, the benefits of employing PWDs in the private sector were analysed under three themes (see Figure II). Majority of the respondents (89%) highlighted that the PWDs' supervisors and co-workers greatly benefitted from employing PWDs.

These findings concurred with past studies which revealed that PWDs perform better when compared with their non-disabled colleagues on productivity, safety measures, loyalty, and attendance (Ang, 2017; Bonaccio et al., 2019).

**Conclusion & Recommendation**

The success of the study depends on the achievement of the research objectives which were mainly to identify the private sector employers' recommended strategies to promote employment for PWDs and explore the benefits of employing PWDs in the private sector of SL.

Figure III summarises the employer recommended strategies based on the key findings of this study and literature review. The boxes highlighted in red are unique to the SL context as some of the employer-recommended strategies, were not found in past studies specific to the SL private sector context.

The employer-recommended strategies from the literature review in Figure III (highlighted in yellow) were based on Henry et al.'s (2014) focus group study with 74 public and private employers in the US. Although the research context is different from the present study, Henry et al.'s (2014) recommendations will also be useful in promoting disability employment in the private sector of SL.

Moreover, the findings concurred with past studies which revealed that PWDs perform better when compared with their non-disabled colleagues on productivity, safety measures, loyalty, and attendance (Ang, 2017; Bonaccio et al., 2019). The most common benefit was that the organisations were able to establish a strong corporate image that values DEI, which led to establishing robust confidence amongst their employees, prospective top talent, investors, buyers, and customers. These findings supported literature which revealed that employing PWDs will result in achieving competitive advantage as the employers will be considered as equal employment opportunity provider who values DEI in the workplace (Bonaccio et al., 2019).
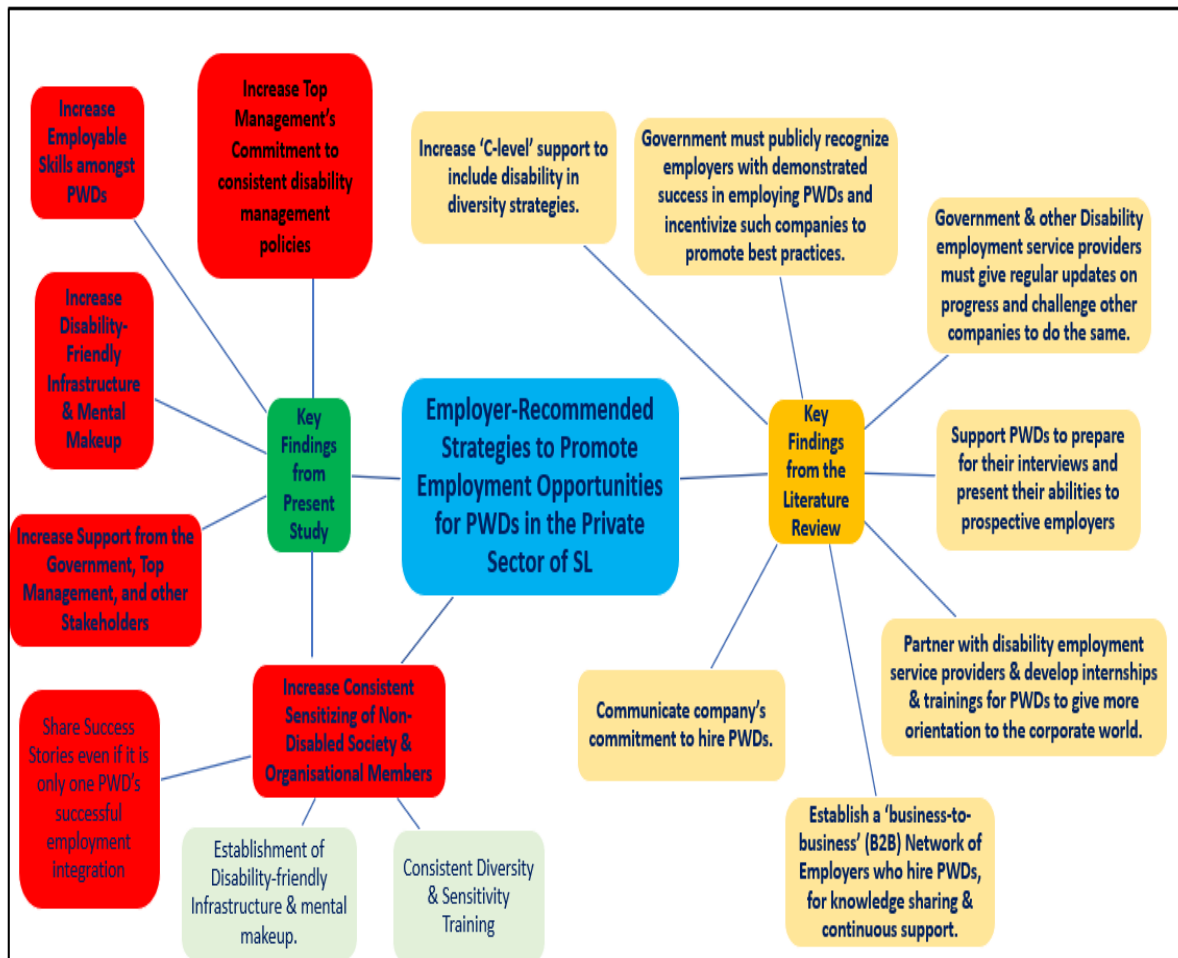
*Figure III: Employer-Recommended Strategies to Promote Employment Opportunities for PWDs in the Private Sector*

Source: Researcher's original construct.

Hence, the researchers emphasise all private sector employers to consider the recommendations shown in Figure III and promote employment opportunities for PWDs, with support from the State, NGOs, and other stakeholders, without neglecting PWDs who possesses unique abilities and not 'disabilities'.

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# THE IMPACT OF SPIRITUAL INTELLIGENCE ON INNOVATIVE WORK BEHAVIOUR: A MEDIATOR, MODERATOR MODEL OF ORGANIZATIONAL CULTURE AND PSYCHOLOGICAL EMPOWERMENT IN SELECTED BANKS IN COLOMBO DISTRICT IN SRI LANKA

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**Abstract**

Sri Lanka is viewed as a spiritual nation due to its religious background; yet, this has not received much domestic focus to improve the urgently required advances. Therefore, the main purpose of this study is to identify the relationship between Spiritual Intelligence (SI) and Innovative Work Behavior (IWB), while identifying the level of influence of Organization Culture (OC) Psychological Empowerment (PE) as the mediator and moderator respectively. The research uses a mixed approach, with 287 responses from employees in two leading private sector commercial banks and ten employees for qualitative analysis. The quantitative analysis shows a moderate influence of SI on IWB, with Organization Culture (OC) acting as a partial mediator. Psychological Empowerment (PE) strengthens the relationship but not significantly. The qualitative analysis validates the quantitative findings, highlighting the importance of fostering an innovative work culture for business success and long-term sustainability.

**Keywords:** Innovative Work Behaviour, Organizational Culture, Psychological Empowerment, Spiritual Intelligence.

**Introduction**

Creativity and innovation are crucial in today's VUCA environment (De Jong & Den Hartog, 2010), with entities like banks investing heavily in research and development to satisfy customers. Spiritual intelligence can inspire the integration of innovative work behavior into organizational culture, leading to outstanding outcomes (Afsar & Badir, 2017). Additionally, Daft (2014) claims that by including the psychological component, empowerment, which is typically understood to be the transfer of authority and power to subordinates, is given a fresh perspective. This study focuses to bridge an empirical gap with regard to the relationship between SI and IWB, having culture as the mediator and psychological empowerment as the moderator, mainly with the focus of the banking sector in Sri Lanka.

*General Objective*

This study investigates the relationship between Spiritual Intelligence (SI) and Innovative Work Behaviour (IWB) among executive officers of Commercial Bank of Ceylon PLC and Hatton National Bank PLC, examining the influence of Organizational Culture and Psychological Empowerment.

*Specific Objectives*

To identify the current level of Spiritual Intelligence (SI) on the executive officers of Commercial Bank PLC and Hatton National Bank PLC.

To examine the current level of the Innovative Work Behaviour (IWB) on the executive officers of Commercial Bank PLC and Hatton National Bank PLC.

To evaluate the level of influence of Spiritual Intelligence (SI) on Innovative Work Behaviour (IWB).

To assess the mediating effect of organizational culture on Spiritual Intelligence (SI) and Innovative Work Behaviour (IWB).

To assess the moderating effect of Psychological Empowerment (PE) on Spiritual Intelligence (SI) and Innovative Work Behaviour (IWB)

**Methodology**

This study used a mixed method of quantitative and qualitative analysis to investigate a problem in the Commercial bank and Hatton National Bank. Primary data was collected through self-administered questionnaires, face-to-face and telephone interviews, and secondary data from annual reports, journals, and websites. The research findings were generalized to the total population, with a sample of Junior Executive Officers and above. The study selected Colombo district branches of Western province from the selected banks to gather reliable information. Cluster sampling and simple random sampling techniques were used to identify branches and employees. A descriptive analysis was conducted on 287 responses, considering mean, median, standard deviation, and mode. Statistical analysis included cross-tabulation, correlation analysis, and regression analysis. SPSS 26.0 was used for statistical analysis, and a Thematic approach was used for qualitative analysis. The study aimed to provide a realistic solution for the identified problem and provide valuable insights into the problem.
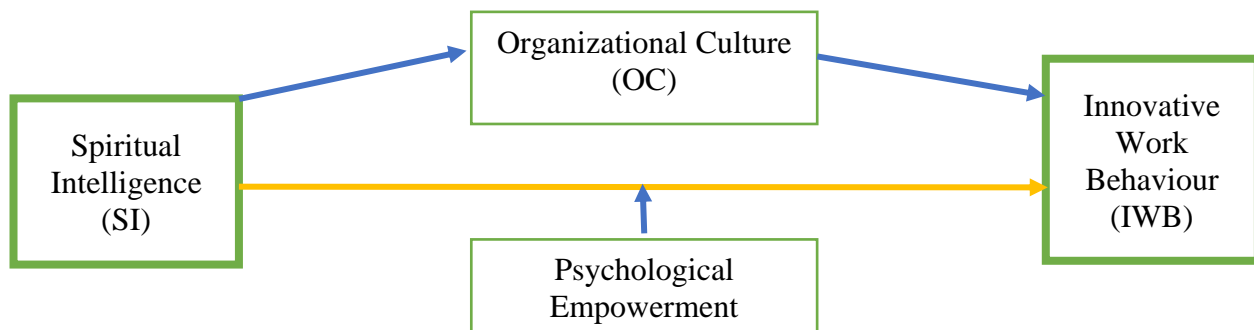


H1: There is a significant positive impact of spiritual intelligence and innovative work behavior.

H2: Organizational Culture has a mediating effect on the influence of SI on IWB.

H3: Psychological empowerment significantly strengthens the influence of SI on IWB.

**Results**

*Quantitative Analysis*

Table 1: Reliability, validity statistics of the independent variable (SI) and dependent variable (IWB)

| Variable | Statistic | Value |
|---|---|---|
| SI | Cronbach's Alpha | 0.918 |
| SI | N of Items | 20 |

| SI | KMO Measure | 0.881 |
| SI | Bartlett's Test Chi-Square | 3551.338 |
| SI | Bartlett's Test df | 190 |
| SI | Bartlett's Test Sig. | 0.000 |
| IWB | Cronbach's Alpha | 0.947 |
| IWB | N of Items | 11 |
| IWB | KMO Measure | 0.933 |
| IWB | Bartlett's Test Chi-Square | 2602.581 |
| IWB | Bartlett's Test df | 55 |
| IWB | Bartlett's Test Sig. | 0.000 |

Table 2: Descriptive Statistics

| | N | Minimum | Maximum | Mean | Std. Deviation | Skewness | | Kurtosis | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | Statistic | Statistic | Statistic | Statistic | Statistic | Statistic | Std. Error | Statistic | Std. Error |
| SI_MEAN | 287 | 2.50 | 4.85 | 3.8828 | .44751 | -.252 | .144 | .392 | .287 |
| IWB_MEAN | 287 | 1.91 | 5.00 | 3.7510 | .60712 | -.669 | .144 | 1.224 | .287 |
| OC_MEAN | 287 | 2.07 | 5.00 | 3.8430 | .58815 | -.879 | .144 | 1.121 | .287 |
| PE_MEAN | 287 | 1.83 | 5.00 | 3.8002 | .67920 | -.648 | .144 | .593 | .287 |
| Valid N (listwise) | 287 | | | | | | | | |

*Statistical analysis for hypothesis 1 (SI and IWB)*

Table 3: Correlations

| | **SI_MEAN** | **IWB_MEAN** |
| --- | --- | --- |
| SI_MEAN | **1** | **0.612**\** |
| IWB_MEAN | **0.612**\** | **1** |

Table 4: Regression Analysis - Model Summary

| **Model** | **R** | **R Square** | **Adjusted R Square** | **Std. Error** | **Durbin-Watson** |
| --- | --- | --- | --- | --- | --- |
| 1 | 0.612 | 0.374 | 0.372 | 0.48116 | 1.834 |

Table 5: Coefficients

| **Model** | **Unstandardized Coefficients** | **Standardized Coefficients** | **t** | **Sig.** |
| --- | --- | --- | --- | --- |
| 1 | (Constant) | 0.529 | | 0.034 |
| 1 | SI_MEAN | 0.830 | 13.052 | 0.000 |

Equation: IWB= 0.529 + 0.830*SI

*Statistical analysis for hypothesis 2*
*Relationship between SI and OC*

Table 6: Correlations

|  | SI_MEAN | OC_MEAN |
|---|---|---|
| SI_MEAN | 1 | 0.603** |
| OC_MEAN | 0.603** | 1 |

Table 7: regression analysis- Model Summary

| Model | R | R Square | Adjusted R Square | Std. Error | Durbin-Watson |
|---|---|---|---|---|---|
| 1 | 0.603 | 0.363 | 0.361 | 0.47018 | 1.941 |

Table 8: Coefficients

| Model | Unstandardized Coefficients | Standardized Coefficients | t | Sig. |
|---|---|---|---|---|
| 1 | (Constant) | 0.768 |  | 0.002 |
| 1 | SI_MEAN | 0.792 | 12.748 | 0.000 |

Equation: OC=0.768+0.792*SI

*Relationship between OC and IWB*

Table 9: Correlation

|  | OC_MEAN | IWB_MEAN |
|---|---|---|
| OC_MEAN | 1 | 0.853** |
| IWB_MEAN | 0.853** | 1 |

Table 10: Regression Analysis- Model Summary

| Model | R | R Square | Adjusted R Square | Std. Error | Durbin-Watson |
|---|---|---|---|---|---|
| 1 | 0.853 | 0.727 | 0.726 | 0.31769 | 2.057 |

Table 11: Coefficients

| Model | Unstandardized Coefficients | Standardized Coefficients | t | Sig. |
|---|---|---|---|---|
| 1 | (Constant) | 0.368 |  | 0.003 |
| 1 | OC_MEAN | 0.880 | 27.559 | 0.000 |

Equation: IWB= 0.368+0.880*OC

*Mediation effect statistics*

Table 12: Model Summary-OC_MEAN (Outcome variable)

| R | R-sq | MSE | F | df1 | df2 | p |
|---|---|---|---|---|---|---|
| 0.6026 | 0.3631 | 0.2211 | 162.5111 | 1.0 | 285.0 | 0.0000 |

Table 13: Coefficients- OC_MEAN Model

| Variable | Coefficient | Std. Error | t | p | LLCI | ULCI |
|---|---|---|---|---|---|---|
| constant | 0.7679 | 0.2428 | 3.1625 | 0.0017 | 0.2900 | 1.2458 |
| SI_MEAN | 0.7920 | 0.0621 | 12.7480 | 0.0000 | 0.6697 | 0.9143 |

Table 14: Model Summary- IWB_MEAN (Outcome variable)

| R | R-sq | MSE | F | df1 | df2 | p |
|---|---|---|---|---|---|---|
| 0.8615 | 0.7421 | 0.0957 | 408.7070 | 2.0 | 284.0 | 0.0000 |

Table 15: Coefficients- IWB_MEAN Model

| Variable | Coefficient | Std. Error | t | p | LLCI | ULCI |
|---|---|---|---|---|---|---|
| constant | -0.0733 | 0.1625 | -0.4512 | 0.6522 | -0.3933 | 0.2466 |
| SI_MEAN | 0.2083 | 0.0512 | 4.0660 | 0.0001 | 0.1074 | 0.3091 |
| OC_MEAN | 0.7847 | 0.0390 | 20.1340 | 0.0000 | 0.7080 | 0.8614 |

Table 16: Total effect model- IWB_MEAN

| R | R-sq | MSE | F | df1 | df2 | p |
|---|---|---|---|---|---|---|
| 0.6116 | 0.3741 | 0.2315 | 170.3427 | 1.0 | 285.0 | 0.0000 |

Table 17: Total, Direct, and Indirect effects of X on Y (IWB_MEAN)

| Effect | se | t | p | LLCI | ULCI | c_cs |
|---|---|---|---|---|---|---|
| Total effect | 0.8298 | 0.0636 | 13.0515 | 0.7046 | 0.9549 | 0.6116 |
| Direct effect | 0.2083 | 0.0512 | 4.0660 | 0.1074 | 0.3091 | 0.1535 |
| Indirect effect | 0.6215 | 0.0473 | 0.0000 | 0.5238 | 0.7104 | - |

Table 18: Completely standardized indirect effects of X on Y

| Variable | Effect | BootSE | BootLLCI | BootULCI |
|---|---|---|---|---|
| OC_MEAN | 0.4581 | 0.0338 | 0.3854 | 0.5188 |

*Statistical analysis for hypothesis 3 (Moderating effect -statistics)*
Table 19: Model summary – IWB_MEAN (Outcome variable)

| R | R-sq | MSE | F | df1 | df2 | p |
|---|---|---|---|---|---|---|
| 0.7328 | 0.5370 | 0.1725 | 109.4181 | 3.0 | 283.0 | 0.0000 |

Table 20: Coefficients- IWB_MEAN model

| Variable | Coefficient | Std. Error | t | p | LLCI | ULCI |
|---|---|---|---|---|---|---|
| constant | 2.0866 | 0.8168 | 2.5547 | 0.0112 | 0.4789 | 3.6944 |

| SI_MEAN | -0.0391 | 0.2215 | -0.1766 | 0.8599 | -0.4751 | 0.3969 |
| PE_MEAN | 0.0379 | 0.2229 | 0.1699 | 0.8652 | -0.4009 | 0.4766 |
| Int_1 | 0.1118 | 0.0570 | 1.9615 | 0.0508 | -0.0004 | 0.2241 |

Table 21: Test of Interaction

| R2-chng | F | df1 | df2 | p |
|---|---|---|---|---|
| 0.0063 | 3.8474 | 1.0 | 283.0 | 0.0508 |

Table 22: Conditional effects of SI_MEAN at values of PE_MEAN

| PE_MEAN | Effect | Std. Error | t | p | LLCI | ULCI |
|---|---|---|---|---|---|---|
| 3.1667 | 0.3151 | 0.0777 | 4.0555 | 0.0001 | 0.1621 | 0.4680 |
| 3.9167 | 0.3990 | 0.0735 | 5.4310 | 0.0000 | 0.2544 | 0.5436 |
| 4.4100 | 0.4541 | 0.0835 | 5.4395 | 0.0000 | 0.2898 | 0.6185 |

*Qualitative Analysis*

*Demographics*

| Demographics | N |
|---|---|
| Gender | |
|   Male | 5 |
|   Female | 5 |
| Age | |
|   Between 31-40 | 5 |
|   Between 41-50 | 3 |
|   Above 50 | 2 |
| Level of experience | |
|   Between 10- 15 | 5 |
|   Between 16-25 | 4 |
|   More than 25 | 1 |
| Designation | |
|   Executive | 10 |
|   Non-executive | 0 |

Upon reviewing the insightful reviews of the respondents in the qualitative analysis, it is important to emphasize that the qualitative discussion further verified the statistical analysis's conclusions, adding even more value to the study. The respondents demonstrate characteristics associated with spiritual intelligence on a more substantial level. Although there were some opposing viewpoints, it is noteworthy that most employees support innovation and creativity when it comes to innovative work behavior. Based on the respondents' views, it is evident that culture is seen as a crucial element that provides a competitive advantage in the ever-changing modern world. it is also evident that employees do, in fact, have a certain degree of psychological empowerment. It would be extremely advantageous to capitalize further on this idea for the benefit of both the banking sector and its workforce.

**Discussion**

According to the study findings, employees of Commercial bank and Hatton National Bank currently have moderately high levels of SI and IWB. Prior to analyzing the mediation effect through SPSS, a comprehensive statistical analysis was carried out independently to identify the relationship between SI vs OC and OC vs IWB. Positive linear relationships were identified. Mediation effect with the use of SPSS affirmed this finding and it turned out to be a 'partial mediation' which means, IWB can be either directly influenced by SI or indirectly influenced through OC. While there's little research on the mediating role of OC on SI and IWB, the study's conclusion appears consistent with the statement made by (Khan, et al., 2020), that culture serves as a binding agent tying together personnel and organizational processes. According to the findings, PE was found to slightly but not significantly improve the relationship between SI and IWB and this could only be improved by 45% even with the full presence of PE. This implies the existence of numerous other variables that improves the relationship which affirms the findings of (Ranasinghe & Samarasinghe, 2019). Based on the in-depth interviews, with the chosen bankers, this conclusion could be regarded as applicable since, in their opinion, PE has little significance because all employees have to essentially follow the Central Bank's and numerous other regulatory bodies strict rules and regulations, which are crucial in the banking industry given its high-risk component.

**Conclusion & Recommendation**

The purpose of this study is to identify ways to improve IWB in the banking sector. The study revealed that bankers from selected banks have moderately high SI and IWB levels, with a high standard deviation for IWB, indicating diverse viewpoints on innovation and creativity. Further, a moderately significant relationship was identified between SI and IWB. When analyzing the mediating effect, the influence of SI on OC was found to be moderately significant, while OC's influence on IWB was found to be highly significant where the $R^2$ value 72.7% of the total variation in IWB can be explained by variation in OC. On the other hand, only 37% of the total variation of IWB can be explained by the variation of SI. The study identified a mediation effect between SI vs OC and OC vs IWB, which was confirmed through SPSS analysis where a 'partial mediation' was identified, along with a moderator effect, which is not considered significant.

*Limitations and future studies*

The study focused on bankers and only two banks, but could be expanded to other sectors. Future research should explore innovative work practices of blue- and white-collar employees, SI's influence on IWB focusing managerial levels, and other factors impacting IWB, and the impact of organizational culture on IWB in the banking sector.

*Recommendations*

(Bowell, 2004)'s seven steps for spiritual intelligence include awareness, meaning, evaluation, being centered, vision, and projections and it's advisable to consider these steps. To cultivate spiritually intelligent bankers, employee assistance programs, diversity programs, wellness programs, yoga, flexible schedules, and reduced travel time can be implemented. This fosters a spiritually enriched culture, promoting innovative work behavior in Sri Lankan banks.

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# IMPACT OF HYBRID WORKPLACE MODELS ON EMPLOYEE PRODUCTIVITY OF CONTENT CREATION COMPANIES IN COLOMBO DISTRICT, SRI LANKA

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**Abstract**

The study aimed to address a gap in the literature by investigating the impact of hybrid workplace models on the productivity of content creators during an economic crisis in Sri Lanka. Motivated by the challenges posed by the COVID-19 pandemic and the country's economic situation, the research focused on understanding how organizations could effectively manage remote and on-site work arrangements to maintain employee productivity. Conducted the research in collaboration with five prominent Sri Lankan content creation companies. The study used a quantitative approach with 157 respondents selected through simple random sampling method. The three dimensions of hybrid workplace models; job autonomy, supportive leadership, and digital skills were explored using a self-administrated questionnaire. The findings indicated that there is an impact of job autonomy, supportive leadership and digital skills on employee productivity in a hybrid workplace.

**Keywords:** Employee productivity, Hybrid workplace models, Job autonomy, Supportive leadership, Digital skills

**Introduction**

The COVID-19 pandemic has rapidly shifted remote work from a luxury to a necessity for many organizations, leading to the emergence of hybrid workplace models that combine remote and in-office work. The content creation companies, like others, have adapted to this trend, implementing a hybrid workplace model to balance in-office presence with remote flexibility. While remote work offers advantages such as flexibility and cost reduction (Farrer, 2022), it also presents challenges like decreased collaboration and increased isolation (Wigert and White, 2022). Hybrid models aim to address these issues by emphasizing in-office work.

Research on the impact of hybrid work on employee productivity has been conducted across various industries, but more specific investigations into hybrid workplace models are needed. This study focuses on content creation companies, aiming to understand the model's effects on productivity and guide effective work environment structuring. Productivity is similarly defined in scientific literature as the link between production and input, between outcomes and sacrifices (Björkman, 1992). Existing research on hybrid models shows mixed results, with some studies indicating increased productivity (PwC, 2021) and others finding no significant difference (Sun, Liu, and Wang, 2022). This study seeks to fill a gap in the literature by examining the effects of hybrid workplace models on employee productivity at content creation companies, providing context-specific insights. The results will be valuable for management and stakeholders interested in optimizing remote and in-office work for productivity and employee well-being.

This research holds considerable importance in academia due to the nascent nature of hybrid workplace models and the limited existing research on them, particularly regarding their impact on employee productivity. By exploring the relationships between job autonomy, supportive leadership, digital skills, and employee productivity in a hybrid setting, the study significantly contributes to the expanding body of knowledge in this field. It provides crucial insights for organizations seeking to optimize their hybrid work settings for enhanced employee productivity, especially pertinent in the context of the current economic crisis affecting 95% of respondents.

### Research Question

What it is the impact of hybrid workplace models on employee productivity of content creation companies in Colombo district, Sri Lanka?

### Objectives

MAIN OBJECTIVE

To examine the impact of hybrid workplace models on employee productivity of content creation companies in Colombo district, Sri Lanka

SECONDARY OBJECTIVES

To study the impact of job autonomy on employee productivity of content creation companies in Colombo district, Sri Lanka

To study the impact of supportive leadership on employee productivity of content creation companies in Colombo district, Sri Lanka

To study the impact of digital skills on employee productivity of content creation companies in Colombo district, Sri Lanka

To identify the most important factor in terms of hybrid workplace models on employee productivity of content creation companies in Colombo district, Sri Lanka

## Methodology

### Research Strategy

This study follows a positivist philosophy, using deductive reasoning to identify causal relationships between variables. A quantitative research approach was used, emphasizing the collection and statistical analysis of numerical data.

### Sampling and Data Collection

The population this study population is 262 employees who are working in five content creation companies in Colombo district in Sri Lanka. The study carried out sample basis and the sample content of 157 respondents who have been selected through simple random sampling technique.

This research utilized both primary and secondary data collection methods. For the primary data, a structured questionnaire employing a five-point Likert scale was distributed among 157 employees, garnering responses from 150 individuals, resulting in an 95.5% response rate, which was deemed satisfactory for the research. The collected data underwent analysis using

the IBM SPSS data analysis program. Various techniques, including Frequency analysis, Central tendency measures, Correlation analysis, and Regression analysis, were employed to analyze the data comprehensively.

### *Conceptual Framework*

According to Swaen and George (2022), a conceptual framework is a visual representation of the link between the variables being studied as well as the characteristics or properties the investigator is particularly interested. The elements in below conceptual framework were chosen after reviewing an extensive amount of literature. These three dimensions (job autonomy, supportive leadership, and digital skills) have been selected as the dimensions of the independent variable of hybrid workplace models. The following conceptual framework includes a graphical representation of the relationship between these factors.

**Independent variables**
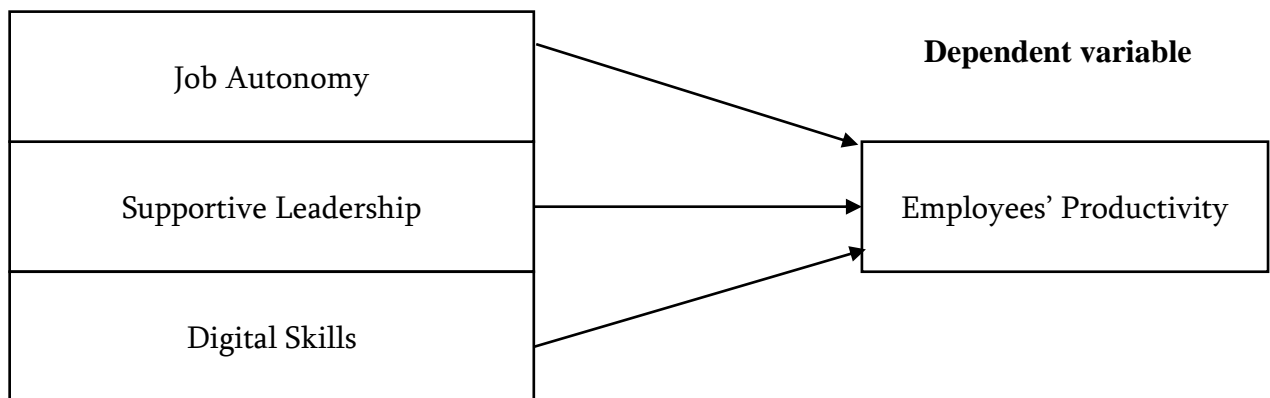


*Figure 1: Conceptual framework*

Source: Author constructed (2023)

### *Hypotheses*

H1: There is an impact of job autonomy employee productivity of content creation companies in Colombo district, Sri Lanka

H2: There is an impact of supportive leadership on employee productivity of content creation companies in Colombo district, Sri Lanka

H3: There is an impact of digital skills on employee productivity of content creation companies in Colombo district, Sri Lanka

**Results**

Table 1: Reliability of the variables

| Variable | Dimension | Cronbach's Alpha | Reliability |
|---|---|---|---|
| **Independent Variable** | Autonomy | 0.906 | Extremely Reliable |
| | Supportive leadership | 0.939 | Extremely Reliable |
| | Digital skills | 0.890 | Extremely Reliable |
| **Dependent Variable** | Employee productivity | 0.903 | Extremely Reliable |

Source: Researcher's original work (2023)

Cronbach's alpha values for autonomy, supportive leadership, digital skills, and employee productivity were exceptionally high at 0.906, 0.939, 0.890 and 0.903, respectively exceeding the standard cutoff of 0.7. This indicates strong associations within each scale, affirming the reliability and internal consistency of the study's measures and bolstering the validity and accuracy of the research findings.

Table 2: Validity of the variables

| KMO and Bartlett's Test | | |
|---|---|---|
| Kaiser-Meyer-Olkin Measure of Sampling Adequacy. | | 0.694 |
| Bartlett's Test of Sphericity | Approx. Chi-Square | 5175.266 |
| | df | 1770 |
| | Sig | <.001 |

Source: Researcher's original work (2023)

The KMO value for this research project is 0.694, which is regarded as good. The KMO analysis results thus indicate that the dataset is suitable for factor analysis to investigate the underlying constructs of this study.

*DESCRIPTIVE STATISTIC*

In the research, 157 participants were involved, with 77% being men and 23% women. The majority, representing 56.3%, belonged to the millennial category, followed by Gen Z participants at 33.3%. Gen X and boomers constituted 8% and 2.3%, respectively. Regarding marital status, 41.4% were married, while 58.6% were unmarried. In terms of housing, 23% lived in rented accommodations, 62.1% owned their homes, and 14.9% stayed with relatives.

Public transportation was the primary mode of commuting for 51.7%, while 43.7% used their vehicles. Most respondents (32.2%) traveled less than 20 kilometers to work. Senior executives (39.1%) and coordinators (42.5%) were the majority, with only one participant from the head and above category.

*CORRELATION ANALYSIS*

Table 3: Results of Pearson Correlations between Dimensions of Hybrid workplace models and Employee Productivity

| No | Independent variables (Dimensions) | Dependent Variable (EP) | p-value |
|----|-----------------------------------|-------------------------|---------|
| 1 | Autonomy | 0.509** | <0.001 |
| 2 | Supportive leadership | 0.544** | <0.001 |
| 3 | Digital Skills | 0.412** | <0.001 |

**. Correlation is significant at the 0.01 level (2-tailed)
Source: Researcher's original work (2023)

Pearson correlation analysis reveals a positive relationship between hybrid workplace models and employee productivity. Autonomy and productivity have a correlation coefficient of 0.509, and Supportive Leadership and Digital Skills show coefficients of 0.544 and 0.412, respectively. All correlations are statistically significant ($p < 0.001$), indicating a genuine relationship between the variables.

*REGRESSION ANALYSIS*

Table 4: Regression summary of autonomy, supportive leadership, and digital skills

| Measurements | Value |
|--------------|-------|
| R | 0.706 |
| Adj. R Square | 0.480 |
| p-value | 0.001 |
| F | 27.493 |
| B-Constant | 0.404 |

Source: Researcher's original work (2023)

Adjusted R square of 0.480 indicates that autonomy, supportive leadership, and digital skills explain 48% of the variability in employee productivity. The significant F value of 27.493 ($p < 0.001$) in Table 4.6 confirms the model's statistical significance, supporting its ability to predict employee productivity using the specified independent variables.

Table 5: beta coefficient, t and p values of autonomy, supportive leadership, and digital skills

| Dimension | beta coefficient | t value | p-value |
|---|---|---|---|
| Autonomy | 0.302 | 3.289 | 0.01 |
| Supportive Leadership | 0.466 | 5.863 | <0.01 |
| Digital Skills | 0.221 | 2.452 | 0.016 |

Source: Researcher's original work (2023)

The regression analysis underscores the significant impact of supportive leadership on employee productivity, evidenced by a strong positive relationship (beta coefficient = 0.466). Autonomy follows closely in influence, while digital skills, although statistically significant (beta coefficient = 0.221), contribute to a comparatively smaller effect size. These findings highlight the importance of supportive leadership and autonomy in predicting and enhancing employee productivity.

Table 6: Summary of hypothesis testing

| | Hypothesis | Accept/Reject |
|---|---|---|
| H1 | There is an impact of job autonomy employee productivity of content creation companies in Colombo district, Sri Lanka | Accepted |
| H2 | There is an impact of supportive leadership on employee productivity of content creation companies in Colombo district, Sri Lanka | Accepted |
| H3 | There is an impact of digital skills on employee productivity of content creation companies in Colombo district, Sri Lanka | Accepted |

Source: Researcher's original work (2023)

**Discussion**

The study, focusing on the hybrid workplace at content creation companies which are operated in Colombo district during a financial crisis, confirms the importance of job autonomy for enhancing employee productivity, aligning with findings by Deloitte (2020), Jaafar and Rahim (2022), Vasudevan et al. (2021), Reisinger et al. (2022), George-Clinton (2021), Cárdenas (2022), and Amin (2018). Additionally, the research affirms the positive influence of supportive leadership on productivity, consistent with studies by Bloom et al. (2015), Almaamari and Alaswad (2021), Madaan (2015), and Radwan (2017). In exploring the impact of digital skills on employee productivity during an economic downturn, the study aligns with earlier literature by Anthony (2005), Liddell (2022), and Saputra et al. (2021). These collective insights contribute empirical evidence to the existing knowledge, emphasizing the multifaceted factors influencing productivity in contemporary work environments.

**Conclusion and Recommendations**

The research confirms the substantial impact of job autonomy, digital skills, and supportive leadership on employee productivity within content creation companies operating in a hybrid workplace. It does not only underscore the positive correlation between job autonomy and productivity but also advocates for substantial investments in digital skills training to augment overall productivity levels. Moreover, the study accentuates the pivotal role of supportive leadership in cultivating successful outcomes within a hybrid work environment.

To further delve into the impact, it is crucial to recognize that job autonomy empowers employees, enabling them to make independent decisions and fostering a sense of ownership. This empowerment directly translates into increased productivity, as individuals feel a greater sense of responsibility and engagement in their tasks. Similarly, investing in digital skills contributes to a workforce that is not only adaptable to technological advancements but is also equipped to handle varied tasks efficiently. This, in turn, has a direct positive impact on overall organizational productivity. Supportive leadership, as highlighted in the study, plays a critical role in shaping the work environment. Leaders who provide guidance, encouragement, and a conducive atmosphere for collaboration can significantly impact employee morale and productivity. The influence of leadership extends beyond immediate task management, contributing to an organizational culture that values innovation, collaboration, and individual growth.

Therefore, the management of content creation companies is strongly recommended to implement policies that prioritize job autonomy, invest in comprehensive digital skills training programs, and foster supportive leadership. These proactive measures are anticipated not only to enhance employee productivity but also to fortify overall organizational performance, particularly during economic challenges and within the dynamic landscape of a hybrid work setting.

In conclusion, organizations aspiring to boost productivity in a hybrid workplace should strategically prioritize aspects such as job autonomy and supportive leadership, creating an environment that is both transparent and flexible. Simultaneously, the integration of comprehensive digital skills training initiatives, including online programs and knowledge-sharing platforms, is deemed crucial. These recommendations provide actionable steps for organizations aiming to optimize employee performance in the evolving dynamics of a hybrid work environment.

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# FACTORS AFFECTING OBTAINING MARGIN TRADING FACILITY BY INVESTORS OF ACUITY GROUP.

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**Abstract**

This study is conducted with the objective of identifying critical factors that affect the investors in obtaining a Margin Trading Facility (MTF) in Sri Lanka.

The hypotheses were developed based on above objectives and the quantitative research method was followed to test them and purposive sampling method used to select the sample. A questionnaire was used to collect primary data

The most significant finding from the study is that the MTF management style by the individual margin providers is having a higher impact towards the investors decision to obtain an MTF. It was also observed that the main three factors tested in the study has an impact of only 45.8% towards an investor obtaining a MTF and therefore it is important to draw attention towards other factors also.

**Keywords:** Margin Trading Facility, Margin percentages, Margin Limits Negative Leeway, Margin call

## Introduction

### *Background of the Study*

An investor in the Colombo Stock Exchange (CSE) can obtain a Margin Trading Facility (MTF) as a funding option. It is a facility provided by holding an investor`s share portfolio as a collateral and charging interest as a fee. Initial MTF requirements set by the regulator must be adhered by the investor and the MTF provider (Hardouvelis & Theodossiou, 2002).The MTF providers also implement margin control measures to safeguard themselves from any losses (Rytchkov, 2014). The utilization of MTF in a share market is always carry a high level of risk (Lin, et al., 2015). The investors with higher overconfidence in investment literacy are more likely to make share purchases on margin (Kim, et al., 2022).The application of different type of margin percentages based on the type of the shares is a common practice among margin providers (Rytchkov, 2016).It is a widely accepted concept that the liquidity level of a stock would get increased when they are being identified as a marginable stock (Kahraman & Tookes, 2017).

### *Margin Trading Landscape in Sri Lanka*

At present, the margin providers of Sri Lanka offer various margin percentages to the listed shares at the time of obtaining an MTF, subject to keeping the overall limit within 50% of the total value of marginable share portfolios.

*The Cost factors related to MTF*

The MTF is utilized by investors to manage their share portfolio in cost effective manner and therefore the cost incurred on a MTF is one of the crucial factor that would impact on a decision with regards to obtaining a MTF.

*Follow up and recovery actions related to MTF*

The investors who utilize MTF are required to be concerned with the type of shares that they would transact with, since it will have an impact to their margin limits when market prices fluctuate. The MTF would assist lower the risk of crashing of future stock prices via purchased induced liquidity (Alexander, et al., 2004). The regulators also structure the mandatory limits to safeguard the interest of both MTF clients and the MTF providers (Wang, Cheng, & Chou, 2016). In contrary to that, it was also argued that the margin calls may increase the declining market sentiment and thereby it would increase the possibility of a future market crash (Thurner, et al., 2012).

### Research Problem & Objectives

The margin percentages allocated on listed shares may get amended in time to time by the MTF provider. Since the MTF are provided by charging an interest the investors are required to monitor the movement in market interest rates. These factors make it challenging task to an investor to move in to an MTF. Therefore, the impact from following three aspects to an investor, at the point of obtaining an MTF, have been identified as research questions & the research objectives.

1. Do the margins percentages allocated to listed shares by the margin provider?
2. Do the interests Rates and the formula of Interest rate calculation applicable to MTF?
3. Do the margin account balance management styles by the margin provider?

### Significance of the Study

A study in to the critical factors that affect investors in obtaining an MTF will assist the margin trading providers to further strengthen their strategies towards promoting and growing their businesses. In addition to that the investors would also be able to gain an insight into the aspects that they should draw attention when they are evaluating an MTF.

### Limitations of the Study

There are several research papers published in various countries in relation to the topic of this study. (Ladley, et al., 2020) discuss that the impact to investors from margin call collateral requirements and (Bian, et al., 2021) elaborate on how margin driven stock portfolios have an impact to investor returns. (Lv & Wu, 2019) discuss the impact that margin trading has on future stock price crashes.

There are no adequate past research materials in relation to Sri Lankan margin trading industry is one of the main limitations. The selected sample for the research was comprises of investors who were representing ABC company only. Therefore, it may not fairly represent the entire population of share trading investors trading with borrowed funds in CSE.

**Methodology**

*Conceptual Framework (CF) of the Research*

The independent & dependent variables were identified as per below given figure i.

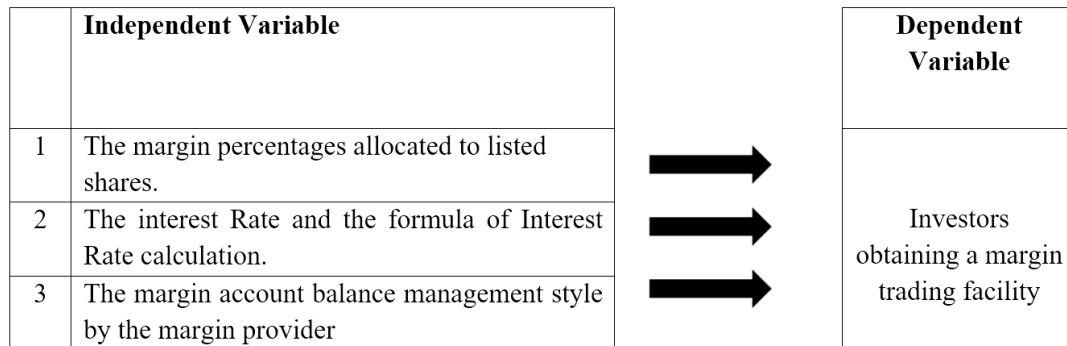| | Independent Variable | | Dependent Variable |
|---|---|---|---|
| 1 | The margin percentages allocated to listed shares. | → | Investors obtaining a margin trading facility |
| 2 | The interest Rate and the formula of Interest Rate calculation. | → | |
| 3 | The margin account balance management style by the margin provider | → | |

*Figure i-Conceptual Framework of the Research*

*Development of Hypothesis*

The following hypothesis (Table i) were developed in line with the above-mentioned variables.

Table i- Development of Hypothesis

| **Based on the conceptual framework the following hypothesis have been developed.** |
|---|
| **H1:** The margin percentages allocated to listed shares have a relationship with Investors obtaining an MTF. |
| **H2:** The interest Rate and the formula of Interest Rate calculation have a relationship with Investors obtaining an MTF. |
| **H3:** The margin account balance management style by the margin provider has a relationship with Investors obtaining an MTF. |

The Operationalization of the variables in to questionnaire were done according to the table iii.

Table ii- Operationalization Table

| Concept | Variable | Measuring Dimension | Measurement Method | Relevant Question |
|---|---|---|---|---|
| Independent Variable 1 | The margin percentages allocated to listed shares. | • Application of Margin Percentages | Likert Scale 1-5 | Q-6 |
| | | • Effect from application of margin percentages to the marginable shares | | Q-7 |
| | | • Comparison of the margin Percentages | | Q-8 |
| | | • Application of maximum margin percentage | | Q-9 |
| | | • Comparison of margin percentages time to time | | Q-10 |
| Independent Variable 2 | The interest Rate and the formula of Interest Rate calculation. | • Awareness on Interest Rate | Likert Scale 1-5 | Q-11 |
| | | | | Q-12 |
| | | • Awareness towards Interest Rate formula | | Q-13 |
| | | • Comparison of interest rates | | Q-14 |
| | | • Interest settlement methods | | Q-15 |
| Independent Variable 3 | The margin account balance management style by the margin provider. | • Minimum margin Limit | Likert Scale 1-5 | Q-16 |
| | | • Maintenance margin Limit | | Q-17 |
| | | • Forced sale option | | Q-18 |
| | | • Settlement options | | Q-19 |
| Dependent Variable | Investors obtaining a margin trading facility | • Factors influencing when obtaining a margin trading facility | Likert Scale 1-5 | Q-20 |

## Research Design, Sampling Design & Population

The quantitative research method was followed and the purposive sampling method was used to select the sample. Total of 108 investors were selected in to the sample from a population of 151 clients with debtor balances in ABC Company and the data collection was carried out by forwarding a questionnaire.

## Discussion

### Analysis of Demographic Factors

Information was collected in relation to the Age group, Gender, Number of years involved in share trading, Source of funds utilized to invest in the share market & Method of engaging in share trading. It was observed that 92 out 109 participants were male and 44% of participants were belong to the age category of 25-34 years.

### R-squared value

As indicated in the diagram i, the margin account balance management style by the MTF provider indicated the highest R squared value of 0.378 (37.8%)while the margin percentages allocated to listed shares indicated the lowest R squared value of 0.235(23.5%) (Diagram ii). The interest rate and the interest rate calculation formula indicated a R squared value of 0.368(36.8%)(Diagram iii). These R squared values indicate the dependency of the dependent variable on the independent variables respectively.

*Correlation Analysis between independent variables and the dependent variable*

Table iii- Analysis of correlation

**Correlations**

| | | Margin_ percentages allocated_ to listed_ shares | Interest_Rate _and_the_ formula_of_ Interest_Rate _calculation | Margin_ account_ balance_ management_ style_by_the_ margin_ provider | Investors_ obtaining_a_ margin_ trading_ facility |
|---|---|---|---|---|---|
| Margin percentages_ allocated_to_listed_shares | Pearson Correlation | 1 | .675** | .443** | .485** |
| | Sig. (2-tailed) | | .000 | .000 | .000 |
| | N | 109 | 109 | 109 | 109 |
| Interest_Rate_and_the_ formula_of_Interest_Rate_ calculation | Pearson Correlation | .675** | 1 | .597** | .606** |
| | Sig. (2-tailed) | .000 | | .000 | .000 |
| | N | 109 | 109 | 109 | 109 |
| Margin_account_balance_ management_style_by_the_ _margin_provider | Pearson Correlation | .443** | .597** | 1 | .615** |
| | Sig. (2-tailed) | .000 | .000 | | .000 |
| | N | 109 | 109 | 109 | 109 |
| Investors_obtaining_a_ margin_trading_facility | Pearson Correlation | .485** | .606** | .615** | 1 |
| | Sig. (2-tailed) | .000 | .000 | .000 | |
| | N | 109 | 109 | 109 | 109 |

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

As per the table iii, the Margin facility, being the dependent variable, is having a correlation of 0.485 with the margin percentages independent variable and it is a positive but weak correlation. The P value between margin facility and the margin percentages is 0.000. Since it is below the significant level of 0.05 the first null hypothesis is rejected.

The correlation between the margin facility and the Interest is 0.606 and it is a positive strong correlation. The P value between these two variables is 0.000 and thereby the second null hypothesis is rejected. The correlation between the margin facility and the account management is 0.615 and it is a positive & strong correlation and the P value between the same variables is 0.000 and since it is below 0.05, the 3<sup>rd</sup> null hypothesis is rejected.

*Model Summary & ANOVA Table Analysis*

Table iv-Model Summary

| | | | **Model Summary** | | |
|---|---|---|---|---|
| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate |
| 1 | .688ª | .473 | .458 | .49453 |
| a. Predictors: (Constant), Margin_account_balance_management_style_by_the_margin_provide r, Margin_percentages_allocated_to_listed_shares, Interest_Rate_and_the_formula_of_Interest_Rate_calculation | | | | |

The model summary table (Table iv) indicates that the adjusted R square value is 0.458 and it is defined as all three independent variables are having an impact of 45.8% towards the dependent variable.

Table v-ANOVA Table

| ANOVAᵃ | | | | | |
|---|---|---|---|---|---|
| Model | Sum of Squares | df | Mean Square | F | Sig. |
| 1   Regression | 23.079 | 3 | 7.693 | 31.457 | .000ᵇ |
| Residual | 25.679 | 105 | .245 | | |
| Total | 48.758 | 108 | | | |
| a. Dependent Variable: Investors_obtaining_a_margin_trading_facility | | | | | |
| b. Predictors: (Constant), Margin_account_balance_management_style_by_the_margin_provider, Margin_percentages_allocated_to_listed_shares, Interest_Rate_and_the_formula_of_Interest_Rate_calculation | | | | | |

The ANOVA table (Table v) gives a significance value of 0.000. It is below the 0.05 and it can be determined that the model tested through the research has been accepted.

Show multiple regression table and show hypothesis testing for that.

**Conclusion of the Study**

As the data analysis indicated that all three factors identified through the objectives are significant when an investor is obtaining an MTF, but the margin account balance management style followed by the margin providers have the highest impact to a client when they are to obtain a MTF. It indicates that in general the investors are keen on how they can manage their margin debt with respective MTF providers. The investors may shift between MTF providers depending on their experience that they observed at the point of managing the MTF facility. Therefore, this study shows that the investors who may enter in to MTF in future should carefully evaluate the MTF balance management style of a MTF provider prior to obtaining a one. On the other hand, the MTF facility provider cans also can draw more attention to their style of managing MTF balances with the clients, in order to grow their client base or at least to retain their existing client base.

*Recommendations*

The margin providers could draw more attention to the identified three variables to grow their MTF client base. Further, they may gain added advantage by adopting an effective approach towards margin account balance methods, since it has the highest positive and strong correlation towards the dependent variable.

The MTF providers could further expand their options of providing competitive interest rates to the investors and the investors are also required much broader way the Interest options offered by the MTF providers.

Further, the data analysis indicated that the impact from all unknown factors other than the three independent variables is 54.2%. Therefore, the MTF providers could explore in to those unknown factors and it might provide further options for them to grow their business.

*Suggestions for Future Research*

The entire population of investors who trades on borrowed funds can be in the range of 20000 to 25000. The sample size for a population of 20000 is approximately 380 (Krejcie & W, 1970).Therefore, conducting a similar nature study with much larger sample size may help to arrive at a conclusion with much higher confidence levels.

The data analysis indicated that the three independent variables are having only a 45.8% impact on the movement of the dependent variable. Therefore, the number of objectives of this study can be expanded and it will allow in future researchers to collect more broader data relevant to other critical factors that would have an impact when the investors are obtaining an MTF.

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## *Chapter 02:*
## CONSTRUCTION

# APPLICABILITY OF BIM TO REDUCE CONSTRUCTION PROJECT DELAYS IN THE WESTERN PROVINCE OF SRI LANKA

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**Abstract**

This research focuses on evaluating the applicability of Building Information Modelling (BIM) in addressing construction project delays within Sri Lanka's Western Province. To investigate the potential benefits, challenges, and strategies for implementing BIM in this context, a random sample of contractors in the Western Province was surveyed through an online questionnaire survey. Among previous studies, this study is distinctively original, supported by robust scientific evidence. While other studies have studied comparable research regarding BIM and how to reduce project delays in several parts of the world, this study offers fresh views on the practical application of Building Information Modelling (BIM) to efficiently reduce building project delays in the peculiar setting of Sri Lanka's Western Province. The findings reveal a low level of BIM adoption among contractors, primarily due to limited experience, training gaps, resistance to change, and financial constraints. The research provides recommendations to promote BIM adoption, such as government regulations, knowledge-sharing platforms, training initiatives, and awareness campaigns. delays.

**Keywords:** Building Information Modelling, Construction Project Delay, Sri Lanka, Western Province

**Introduction**

Sri Lanka construction industry. Once it was a biggest contributor to the country's GDP and the generation of employment is now facing the biggest downfall in history. According to the Central Bank of Sri Lanka (2020), the GDP of Sri Lanka's construction industry was measured at around 4-8% at end of 2019, making it the 4th largest contributor to the GDP of Sri Lanka. But according to Global Data, the Sri Lanka construction industry which was projected to have a growth of 9.2% is now forecasted to have a contraction of 4.6% (McLoughlin, 2022).

Even before the financial crisis, evidently, the Sri Lankan construction industry wasn't a sustainable industry when considering the delay aspect of a project. Therefore, it is very important that the construction industry adheres to new technologies and techniques which have been used in other parts of the world to mitigate problems such as project delays. Such techniques and technologies can be identified as lean construction and building information modelling (Tauriainen et al. 2016).

BIM is a method for creating and handling information on a building job throughout its whole life span. As part of this process, a coordinated digital representation of every element of the built object is created using suitable technology. BIM does this by increasing the efficiency, productivity, and level of management whole throughout the life cycle of a construction

process. (Hamil, 2021; Jiang et al., 2022). This digital description most likely combines structured data with information-rich 3D models, such as details about the construction project, the execution, and the handover. Though it is evident that, countries like Singapore and Australia use BIM to reap various benefits out of it, Sri Lanka still hasn't adapted to BIM. Therefore, this study plays a vital role since it covers significant gaps in existing knowledge about building project delays in Sri Lanka's Western Province. The research investigates the usability of BIM as a Lean Construction Technique, providing practical ways to overcome problems and important insights for increasing project efficiency in the Western Province of Sri Lanka.

***Objectives***

- To find out how BIM can reduce construction project delays in western province of Sri Lanka.
- To identify the perception and knowledge among Sri Lankan construction industry professionals regarding BIM.
- To identify the barriers to implementing BIM in Sri Lankan construction industry.
- To provide recommendations based on the findings.

**Methodology**

This research follows a positivist research philosophy, utilizing quantitative methods to gather observable and measurable data. Internet-based questionnaire surveys were employed to efficiently collect data from construction contractors in Sri Lanka's Western Province. In conjunction with the chosen positivist research philosophy and quantitative methodology, a snowball sampling strategy was implemented for participant selection. This method was particularly relevant within the intricate network of the construction industry in Sri Lanka, where existing industry connections facilitated the identification and inclusion of suitable respondents for the internet-based questionnaire surveys. The survey encompassed two sections, one for demographic information and another for insights on construction project delays, Building Information Modelling (BIM) knowledge, and barriers to BIM implementation. Likert scale questions were used, along with an open-ended query to capture respondents' opinions. Data analysis was performed using IBM SPSS Version 26, enabling a comprehensive examination of BIM's potential in addressing construction delays in the region.

**Results and Discussion**
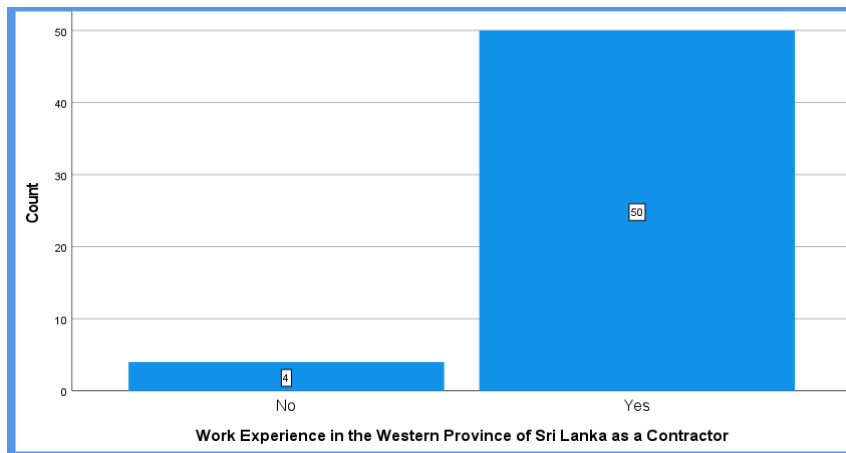


*Figure i - Work Experience of the Respondents in the Western Province as a Contractor*
*(From SPSS Analysis)*

A total of 54 anonymous surveys were collected through the questionnaire surveys that was distributed online. However, four of the surveys has to be discarded from the analysis because as seen from the

Figure *i* 4 number of respondents has no experience in the Western Province of Sri Lanka as a contractor.

***BIM As a Tool to reduce Construction Project Delays in Western Province of Sri Lanka***

Table i - The Average Agreement Level of the Respondents Regarding the Common Delay Causes in the Western Province of Sri Lanka (From SPSS Analysis)

| # | **Common Delay Causes in the Western Province of Sri Lanka** | **Mean Agreement Level** |
|---|---|---|
| 1 | Construction project delays occur due to improper planning and scheduling in the Sri Lanka construction industry | 3.78 |
| 2 | Construction project delays occurs due to errors and reworks in the Sri Lanka construction industry | 3.83 |
| 3 | Construction project delays occurs due to poor communication in Sri Lankan construction industry | 3.67 |
| 4 | Construction project delays occurs due to improper design changes in the Sri Lankan construction industry | 3.76 |
| 5 | Construction project delays occurs due to not having proper updated shop drawings in the Sri Lankan construction industry | 3.64 |

Table shows the average level the respondents of the Western Province of Sri Lanka have agreed to the common delay causes in the Sri Lankan construction industry. The agreement level was tested on 1 – 5 Likert scale and the average of each delay cause falls well over 3, meaning that respondents have agreed that these factors cause delays in the Sri Lankan

construction sector. However, fortunately, through the literature review it was identified that almost all the causes above can be mitigated through BIM.

***Perception and Knowledge of the Contractors in Western Province in Sri Lanka Regarding BIM and Barriers in Implementing BIM***
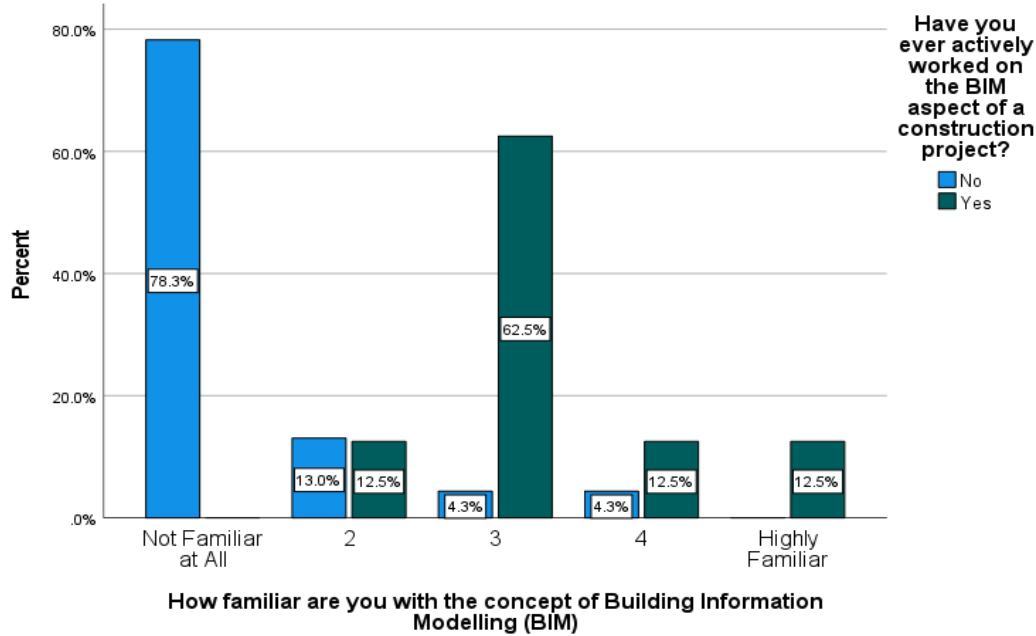


*Figure ii - Familiarity to Concept with BIM, Clustered by Weather the Respondent has Actively Worked in the BIM Aspect of a Project (From SPSS Analysis)*
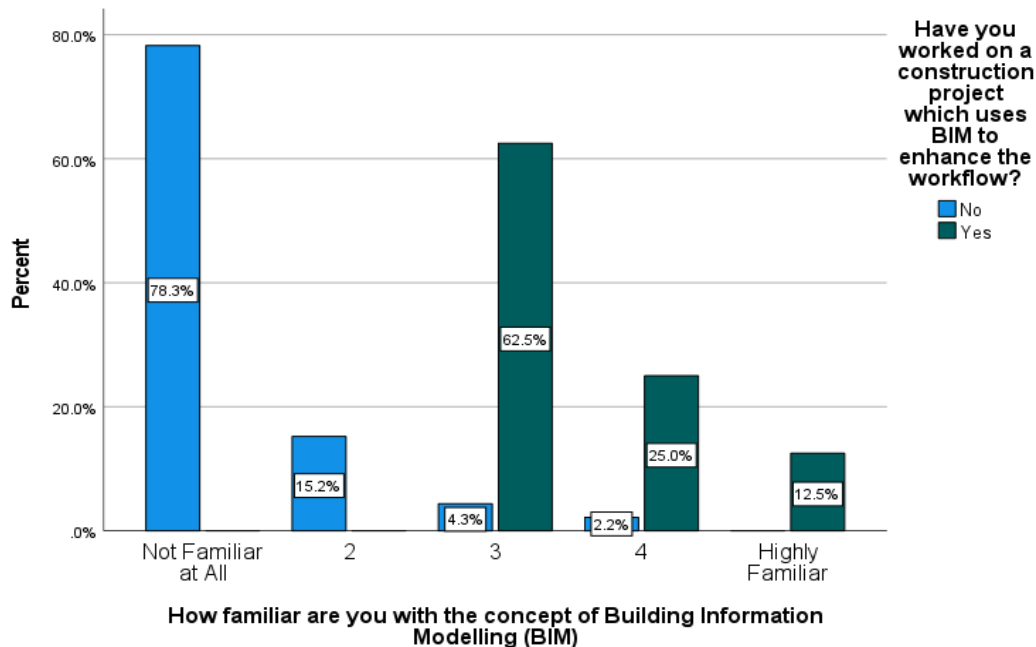


*Figure iii - Familiarity to Concept with BIM, Clustered by Weather the Respondent has Worked on a Construction Project Which Uses BIM (From SPSS Analysis)*

Familiarity to BIM is proportionate to the fact that whether a contractor has worked on the BIM aspect of a project or whether a contractor has worked on a construction project which uses BIM. According to results, it is evident that the majority of the contractors in the western province has not worked in the BIM aspect of a project nor worked in a construction project which uses BIM to enhance the workflow. This is reflected in the contractor's familiarity with the concept of BIM as seen by the Figure ii and Figure iii.

When discussing the individual's knowledge towards BIM, it is important discuss the competency of the individual regarding BIM. The competency of each category shown in the Table  was identified through a 1 – 5 Likert scale. The average overall competency was measured at 1.50. Therefore, it can be seen that competency level of the contractors in the Western Province of Sri Lanka is very low, and hence proportionately the knowledge of BIM.

Table ii - Average Competency in BIM (From SPSS Analysis)

| # | Competency Category | Average Competency |
|---|---|---|
| 1 | Competency with 3D modelling? (3D BIM) | 1.68 |
| 2 | Competency with planning the project with coordinated 3D models (4D BIM) | 1.50 |
| 3 | Competency with extracting schedules and managing resources with coordinated 3d models? (5D BIM) | 1.30 |
| 4 | Overall Competency of BIM | 1.50 |

There are several reasons identified for why this knowledge gap and the competency gap exist within the contractors in the Western Province of Sri Lanka. The main reasons can be identified as lack of awareness and understanding regarding BIM. The benefits and possibilities of BIM are not well known or understood in Sri Lanka because it is a fairly recent concept in Sri Lanka and the limited industry adoption and implementation of BIM as indicated by Figure iv.
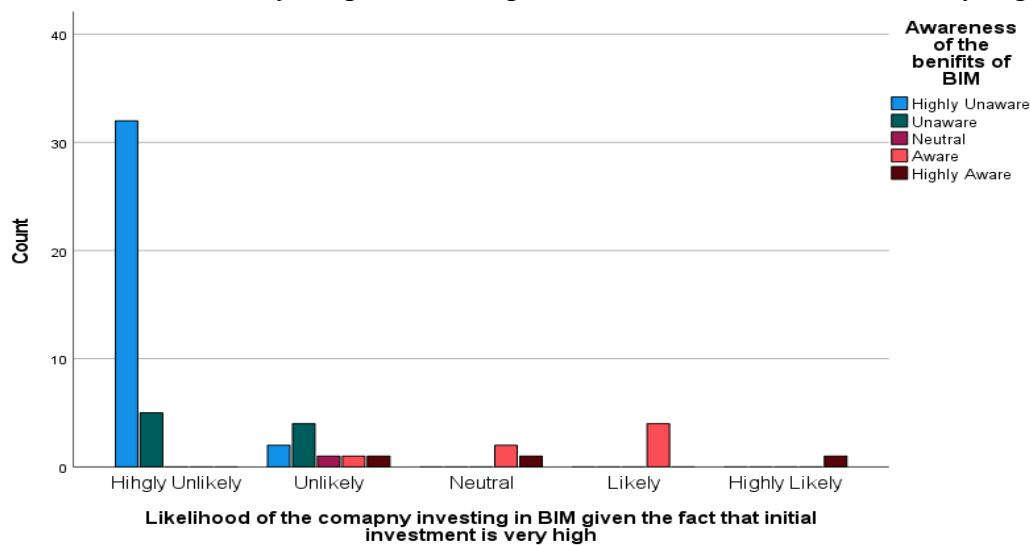


*Figure iv - Likelihood of the Company Investing in BIM and the Awareness if Benefits of BIM (From SPSS Analysis)*

Furthermore, reluctance of the company to invest in BIM , is also due to the Lack of knowledge and skills regarding BIM in Sri Lanka. BIM is a difficult process that needs expert knowledge and abilities.

Figure v shows the major software that has been used by the respondents in their respective construction projects. It can be seen that nearly 78% of the respondents have only used Autodesk AutoCAD in their projects, which is essentially a 2D software. As AutoCAD only supports manual updates, collaboration and coordination amongst project stakeholders might be more difficult. Therefore, lack of 3D software knowledge can cause a huge barrier in implementation of BIM.
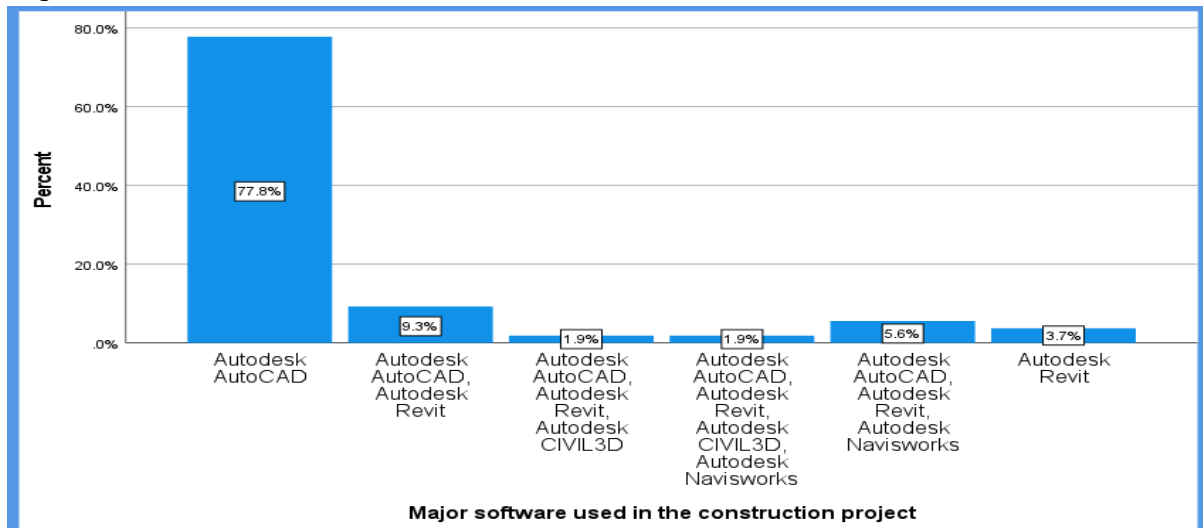


*Figure v - Major Software used by the Respondents in their Construction Projects (From SPSS Analysis)*

The final barrier that was identified in the course of the survey was identified as the insufficient academic institutional support and the lack of training regarding BIM. The degree of support provided by academic institutions, professional organizations, and governmental organizations can have a significant influence on the acceptance and advancement of BIM expertise. lack of institutional support, such as an absence of BIM-related education, certifications, and industry standards, may hinder the development of BIM capability in Sri Lanka. There aren't many official education programs or BIM-specific training courses offered in Sri Lanka. This is evidenced by Figure vi.
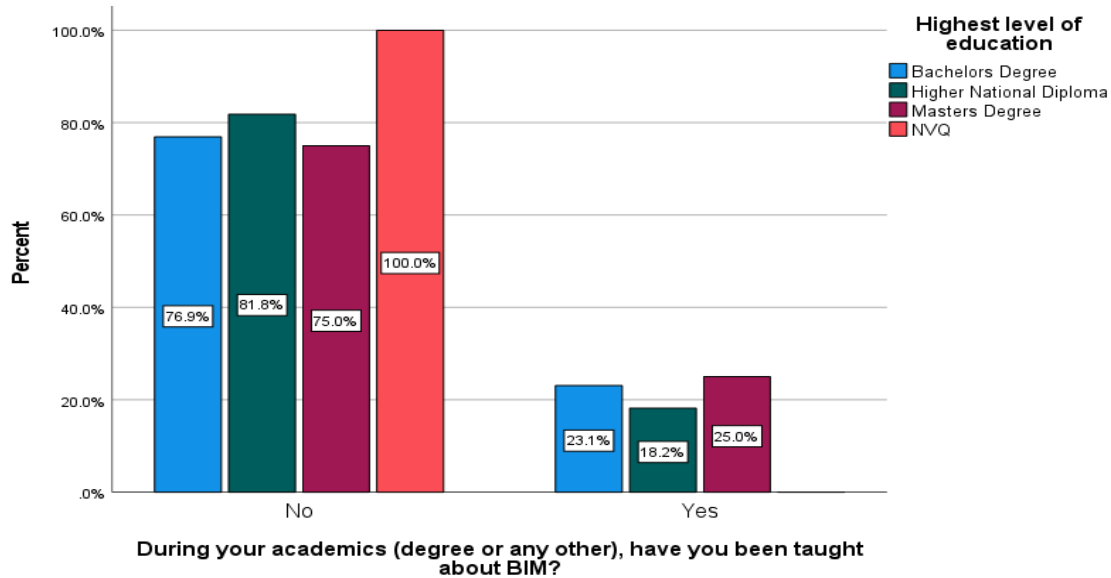
*Figure vi - BIM Taught as Part of the Academic Curriculum in the Academic Institutions
(From SPSS Analysis)*

**Conclusion and Recommendations**

*Conclusion*

This research explored the potential of Building Information Modelling (BIM) to mitigate construction project delays in Sri Lanka's Western Province. Aligning with key objectives of the research, this study identified the challenges leading to project delays, such as poor management and communication and these delays impact project costs and overall success. Through the analysis of literature, BIM was identified as a promising technology for reducing delays through improved coordination, visualization, cost estimation, and sequencing. Through an extensive data analysis, research revealed varying levels of BIM awareness among contractors and identifies obstacles, including a lack of understanding and resistance to change. Overcoming these challenges requires collaborative efforts, including education, regulation, and public-private cooperation, to enhance Sri Lanka's construction sector and address project delays.

*Recommendations*

To enhance the implementation of Building Information Modelling (BIM) in Sri Lanka's Western Province for mitigating construction project delays, several key recommendations are proposed. These include raising awareness through education programs, establishing industry standards, introducing government mandates, providing financial incentives for BIM adoption, and delivering comprehensive training programs tailored to contractors' needs. These efforts can foster BIM utilization, improve collaboration, communication, and project management, ultimately reducing delays and enhancing the efficiency of the construction sector in Sri Lanka.

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# THE IMPACT OF STRESS MANAGEMENT ON THE JOB PERFORMANCE OF QUANTITY SURVEYORS IN THE CONSTRUCTION INDUSTRY

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## Abstract

Employees are an organization's most valuable asset in overcoming competitors by developing competitive advantages. As a result, organizations have been struggling to control workplace stress to improve employee performance. Hence, the study was primarily concerned "to investigate relationship between stress management and job performance among quantity surveyors in the Sri Lankan construction industry". The study employed a deductive approach with quantity research choice and a survey research strategy. Moreover, the study sample included 85 quantity surveyors from the Sri Lankan construction industry, and data was gathered using simple random sampling. Hence, the study's findings demonstrated that stress management was positively associated to job performance among quantity surveyors in Sri Lanka. As a result, it can be stated that managing the stress of the quantity surveyor will result in greater employee job performance.

**Keywords :** Construction Industry, Job performance, Quantity Surveyor, Stress Management

## Introduction

Work-related stress is a major issue in organizations since it can hinder employee performance and work satisfaction across the entire organization (McVicar, 2003). Furthermore, work-related stress harmed employees' psychological, social, and physiological well-being (Ng, Skitmore and Leung, 2005), and it reduced production quality and quantity (Kawshalya and Pathirana, 2019). Hence, controlling workplace stress is one of the most challenging duties within the context of the organization.

The Sri Lankan construction industry expected 0.9% annual growth, but encountered obstacles such as COVID-19, foreign currency scarcity, tourism downturn, tax policy changes, and foreign loans, resulting in decreased investment and construction sector growth collapsed in 2022 (Research And Markets.com, 2022). The construction industry has provided more than 650,000 job opportunities, but the economic crisis is caused to job losses, with 100,000 predicted in 2022. Moreover, construction companies are transitioning to project-based recruiting (Wijerathana, 2022). Hence, job uncertainty led to higher work-related stress (Caridade *et al.*, 2022) and lower employee performance. The construction market is predicted to rise by 5.5% between 2023 and 2026, drawing investments in transportation, housing, renewable energy, industrial zones, and tourism. Furthermore, in order to satisfy market expansion, the construction business must manage financial resources as well as time. Furthermore, due to rising demand from consumers and officials, quantity surveyors encounter difficulty in adjusting material pricing and shortages. Hence, it creates job-related stress and performance loss of quantity surveyor. Moreover, there has been no study undertaken in the Sri Lankan context to examine the relationship between quantity surveyor managing stress and

its impact on job performance following the Covid-19 and economic crisis. Hence, because of the theoretical and practical gap the study focused to answer "Does stress management impact the job performance of quantity surveyors in the Sri Lankan construction industry?" as the research question. The findings of this study are critical for stakeholders in the construction sector, including HR executives, government agencies, quantity surveyors, and academics. It can aid in the identification of stress management factors which leads to improvement of employee job performance and the expansion of the existing literature on stress management in human resources. Government policies can also be designed to protect the well-being of employees.

**Methodology**

The study mainly focused on "to investigate relationship between stress management and job performance among quantity surveyors in the Sri Lankan construction industry". Hence, existing theory and knowledge on stress management and job performance were employed in the study. Furthermore, the research problem and findings will be defined using current knowledge rather than own perspectives and ideas. As a result, this study concentrated on positivist research philosophy. Furthermore, hypotheses were constructed based on existing theories to fulfill the research purpose, and numerical data was collected and evaluated using statistical software. Hence, the study was quantitative based deductive nature research work, and followed a cross-sectional temporal horizon. The study population included all of Sri Lanka's quantity surveyors, and 120 questionnaires were delivered to a randomly selected sample and collected 85 valid questionnaires. As a result, the study sample consisted of 85 quantity surveyors from Sri Lanka, and data was collected using a simple random sampling technique via structured questionnaires.

**Results and Discussion**
**Results**

*Demographic Analysis*
The study sought to ascertain the association between quantity surveyors' stress management and job satisfaction in the construction industry. As a result, 120 structured questionnaires were delivered to randomly selected quantity surveyors in the Sri Lankan construction industry. Furthermore, 85 responses were declared valid, resulting in a 56% response rate. Moreover, the demographic variables were interpreted using frequency and percentage analysis in the study. Hence, the demographic analysis results for this study are summarized in the table below.

Table 1: Demographic analysis

| Demographic factor | | Frequency | Percentage |
|---|---|---|---|
| **Gender** | Male | 63 | 74.1 |
| | Female | 22 | 25.9 |
| **Age** | 25 years-34 years | 13 | 15.3 |
| | 35 years-44 years | 63 | 74.1 |
| | 45 years-54 years | 9 | 10.6 |
| **Experience** | <5 years | 18 | 21.2 |
| | 5-10 years | 67 | 78.8 |
| **Education Level** | Degree | 67 | 78.8 |
| | Post graduate | 18 | 21.2 |
| **Experience Stress at work** | Sometimes | 20 | 23.5 |
| | Often | 65 | 76.5 |
| **Reasons for stress at work** | Workload | 15 | 17.6 |
| | Conflict with co-workers or managers | 20 | 23.5 |
| | Insufficient support or resources | 22 | 25.9 |
| | Work-life balance | 18 | 21.2 |
| | Role ambiguity or conflict | 10 | 11.8 |
| **Strategies applied to management of stress** | Employee assistance programs | 6 | 7.1 |
| | Flexible work arrangements | 16 | 18.8 |
| | Wellness programs | 13 | 15.3 |
| | Stress management workshops or training sessions | 22 | 25.9 |
| | Regular employee feedback and communication channels | 18 | 21.2 |
| | Employee recognition and reward programs | 10 | 11.8 |

According to the findings of the study, the majority of quantity surveyors [74.1%] are men, and the majority of them [74.1%] are between the ages of 35 and 44. Furthermore, 78.8% of quantity surveyors claimed that they have five to ten years of construction experience. Furthermore, 78.8% declared that they have a bachelor's degree, while 21.2% have a postgraduate degree. Moreover, the majority of quantity surveyors reported that they frequently feel work-related stress. Further, 25.9% of quantity surveyors reported that a lack of resources or assistance contributes to significant stress in the workplace. Furthermore, 25.9 quantity surveyors stated that stress management workshops or training programs assist them manage their stress at work.

### Reliability Analysis

The reliability analysis aids in determining the internal consistency of questions about factors such as stress management and job performance. As a result, the study findings revealed that Cronbach's alpha values related to stress management and job performance were 0.881 and 0.907, respectively. Thus, given Cronbach's alpha is more than 0.7, it may be concluded that stress management and job performance have strong internal consistency.

### Descriptive Analysis

Table 2: Descriptive Statistics

|  | N | Minimum | Maximum | Mean | Std. Deviation |
|---|---|---|---|---|---|
| Stress Management | 85 | 2.78 | 4.86 | 4.0075 | .39982 |
| Job Performance | 85 | 2.78 | 4.86 | 3.9840 | .41539 |

The mean and standard deviation values in Table 2 were related to variables such as stress management and job performance. Hence, the majority of quantity surveyors feel that stress management is an important aspect in improving job performance, as the mean value for stress management is 4.0075. Furthermore, the mean value for job performance is 3.9840, indicating that the majority of participants believe that stress management practices can improve job performance. Moreover, the standard deviation values related variables such as stress management and job performance .39982 and .41539 respectively. As a result of the low standard deviation, data points from this study are grouped around the mean value.

### Correlation analysis

The correlation analysis shows that relationship between the variables such as stress management and job performance. Hence, according to analysis stress management has strong positive relationship [r=.779**] with the job performance of quantity surveyor in Sri Lankan construction industry at 0.01 levels.

Table 3: Correlation table

| | | Stress Management | Job Performance |
|---|---|---|---|
| Stress Management | Pearson Correlation | 1 | .779** |
| | Sig. (2-tailed) | | .000 |
| | N | 85 | 85 |
| Job Performance | Pearson Correlation | .779** | 1 |
| | Sig. (2-tailed) | .000 | |
| | N | 85 | 85 |
| **. Correlation is significant at the 0.01 level (2-tailed). | | | |

*Regression analysis*

The R value of the model summary analysis revealed that stress management had a 77.9% association with quantity surveyor work performance. Furthermore, the R square value revealed that stress management variation caused a 60.7% variation in job performance. Further, ANOVA analysis revealed that the study model is statistically significant at the 0.05 level [sig =.000]. Furthermore, at the 0.05 level, the coefficient table revealed that stress management has a favorable impact on the job performance [sig=0.000] of quantity surveyors in Sri Lankan construction industry.

**Discussion**

The correlation [r=.779**] and regression analysis [sig=0.000] results revealed that stress management had a favorable impact on quantity surveyor work performance in the Sri Lankan construction industry. Hence, the previous study used 170 employees who were on a banking organization to determine the association between stress management and job performance. Furthermore, the study results demonstrated a substantial association between stress management and employee performance level (Yılmaz, 2006). Moreover, another study was conducted as a secondary study to determine the association between stress management and job performance of individuals in various sectors. The study's findings demonstrated a negative relationship between stress management and job performance (Altindag, 2020). Furthermore, the prior study sought to ascertain the relationship between work-related stress and job performance among Mali employees. Furthermore, the study findings suggested that stress management practices can be used to improve employee job performance. According to the discussion, the findings of this study concurred and contrast with earlier expert findings.

**Conclusions and Recommendations**

The study mainly focused on "to investigate relationship between stress management and job performance among quantity surveyors in the Sri Lankan construction industry". Through answering the study research purpose, the correlation [r=.779**] and regression analysis [sig=0.000] results revealed that stress management had a strong positive impact on quantity surveyor work performance in the Sri Lankan construction industry. Thus, within the construction industry, it is recommended to implement stress management programs, regular wellness programs such as yoga, mediation sessions, and team-building exercises, create a

positive work environment, promote a healthy work-life balance, and provide adequate resources and supports to manage quantity surveyors stress levels and improve their job performance at construction industry.

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# INVESTIGATION ON CHARACTERISTICS OF PALMYRAH ASH, RICE HUSK & DEMOLISHED WASTE PARTIALLY REPLACED GRADE 30 CONCRETE

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## Abstract

This study investigated the potential of renewable, eco-friendly alternatives to replace conventional materials in concrete. The experimental approach was deployed by utilizing abundant PLA, RH, and DW waste resources in Sri Lanka. The optimum mechanical performance of grade 30 concrete was evaluated by partially replacing suitable mix proportions of PLA, RH, and DW. A concrete mix design of 1:1.5:3 was adopted with a 0.55 w/c ratio. 9 concrete mixtures were developed by partially replacing PLA in 2%, 4%, 6%, RH in 50%,100%, and DW in 20% including 0% (control). A total of 54 cubes were cast and cured for 7 and 28 days. Compressive strength, water absorption and density parameter variations in concrete specimens were observed along with their corresponding microstructural behavior. Mathematical connections were developed based on the patterns exhibited in the mechanical performance of concrete specimens and relationships were established between parameters gaining a better grasp of the alternatives' behavior in the concrete matrix. These findings will be helpful for the practitioners and researchers when exploring previous developments of concrete parameters relevant to their field of study.

**Keywords:** $CO_2$ emission, raw material consumption, green concrete, compressive strength, water absorption, optical microscopy

## Introduction

Concrete is a popular building material widely used in various applications in the construction industry due to its' good load-carrying capacity, long structural life cycle, fire resistance, moldability, and affordability. According to (Mishra & Singh, 2019), the properties of hardened concrete depend on the parameters such as homogeneity of the medium, porosity of concrete microstructure, density of the matrix, and characteristics of aggregates.

According to (Bheel, et al., 2021), more than 12 million tons of cement exhausts annually where annual concrete production exceeds 10 billion tons. (Sathiparan & De Zoysa, 2018) observed that the local sand demand had exceeded 17.37 million cubic meters by 2007. According to the records of GSMB, the annual production of crushed and broken stones is around 10 million cubic meters (Arulmoly, et al., 2021). According to (Kiambigi, 2021), the mining of raw materials exceeds 47 billion tons annually, and 68% - 85% percentage is accountable for sand and gravel mining. (Sivakrishna, et al., 2020) further stated that concrete production had become the main consumer of natural raw materials and fresh water. It's evident that concrete production affects the natural deposits of these raw materials therefore with the growth of population and urbanization, continuous extraction and consumption caused by the

increment in demand will lead to material scarcity which calls for the need to explore the potential of material alternatives.

Investigation carried out by (Bheel, et al., 2021) reported that the hydration process of cement causes severe $CO_2$ emission. He further stated that the cement manufacturing process contributes to 7% of annual global carbon emissions due to large quantities of greenhouse gases generation during production. According to (Fayomi, et al., 2019), 1kg production of cement causes 0.5-0.9 kg generation in $CO_2$ thus with the current annual production of cement, 3.24 billion tons of $CO_2$ emitted directly into the atmosphere therefore construction industry has become the third largest $CO_2$ emitting sector around the world with the heat and excessive emission of $CO_2$ caused by concrete production.

(Kajeevan, et al., 2023) observed that the palmyra leaves are a common waste product in Sri Lankan rural neighborhoods with no higher economic value than use as an organic fertilizer. According to (Christy , et al., 2022), Palmyra tree concentration in Sri Lanka surpasses 11 million. (Chithranayana & Punyawardena, 2014) stated rice is the main staple food in Sri Lanka, nearly occupying 29% of total agricultural lands therefore high volume of rice husk waste is generated annually as a consequence of large-scale rice production. (Srikanth, et al., 2022) reported 0.88 million metric tons of rice husk produced from rice cultivation as a waste product over the past two decades in Sri Lanka. According to (Liyanage, et al., 2019), the construction industry was identified as the main contributor to solid waste generation in Sri Lanka. Construction & demolition wastes (C & D waste) are generated in large quantities at the construction sites during renovation & construction projects. The applicability of industrial and agricultural wastes such as bagasse, silica fume, demolished waste, rice husk, coconut shell, and glass to partially replace conventional materials in concrete was investigated by previous researchers (Bheel, et al., 2021).

According to (Oad, et al., 2018), demolished waste had shown promising development as an aggregate alternative. According to (Zhang, et al., 2019), due to the presence of old cement paste on the surface of DW aggregate, the chemical reactions occur between old and new binding compounds hence the old paste influenced the bond development of concrete matrix in microstructural scale thus microstructural behavior of cement paste, aggregate and the interfacial transition zone (ITZ) between them significantly affect the strength parameters of concrete. (Dilbas & Çakır, 2020) reported that the inferior properties of demolished waste aggregate can be enhanced with the improvement of binder content. (Mohseni, et al., 2017) had observed the substitution of DW in 20% had diminished the potential structural impacts that can occur on the properties of concrete due to the inferior properties of DW. According to (Aravind, et al., 2020) and (Zhu, et al., 2015), DW and RH have good insulating properties that can be used to improve thermal insulation of composite material.

According to (Yuhazri, et al., 2020), researchers used CFRP with concrete to improve the mechanical properties of concrete as CFRP confinement was found to increase the tensile capacity and axial strength of concrete. (Arolkar, et al., 2021) stated rice husk has high potential as a fine aggregate alternative and further reported that the ease of placement and workability of concrete increased with the increment of RH. According to (Fapohunda, et al., 2017), $SiO_2$ in RHA reacted with $Ca(OH)_2$ in cement producing CSH gel that improved the porous structure. He further stated, that when $Fe_2O_3$, $Al_2O_3$, and $SiO_2$ contents in ash exceed 70% of its' content,

they can be categorized in class F fly ash that shows high pozzolanic characteristics. PLA exceeds >50% (Iorliam, et al., 2012), CaO and $SiO_2$ were found as the predominant oxides. He further observed considerable improvement in the binder with the addition of PLA. According to (Hilal, 2016), cement paste consists of hydration products such as fibrous crystals of C-S-H, needles of ettringite, and crystals of $Ca(OH)_2$ produced during pozzolanic reactions, unreacted cement grains, and pores. How dense the C-S-H structure develops, and its' uniformity influence the changes in the porosity of concrete.

The findings of the present research will help researchers and practitioners to understand the characteristics of the concrete which partially include Palmyrah Ash, Rice Husk, and demolished Waste to obtain suitable mix proportions for specific use.

**Methodology**

*Materials*

Two strength classes (32.5N and 42.5N) of Portland cement (cement type 1) are used in Sri Lanka for structural concrete. Ordinary Portland cement was obtained from Mahaweli MARINE cement under a strength class of 42.5 N. Further, fresh well water with a 5.97 pH value was used.

Palmyra leaves (PLA) waste generated in the paddy fields in the Chilaw was collected. Leaves were dried for 48 hours under direct sunlight to remove moisture presence then burned in an open area under uncontrolled combustion and allowed to cool to room temperature naturally. Fine ash particles were taken by sieving using 75-micron bs sieve.

Uncrushed river sand and crushed coarse aggregates with 20mm diameter were obtained from the local market. Also, Rice husks (RH) were collected from mills in Ragama, Western Province. Demolished concrete wastes (DW) were collected from a renovation project in Ragama and hammered. 20 mm maximum nominal-sized aggregates were obtained through sieving.



*Figure 1: Palmyrah (Dried leaves and Leaf ash)*

Table 1: Mix proportions of PLA, RH and DW
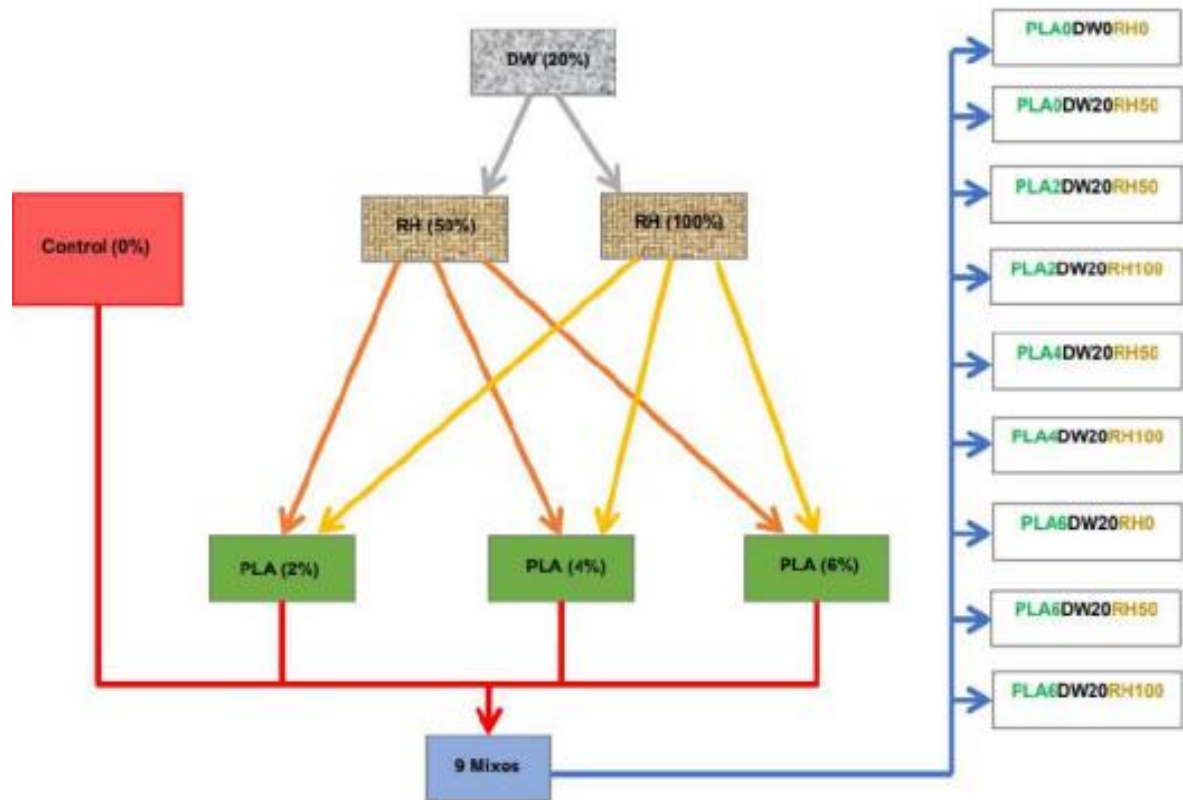


| Concrete Mixture | Palmyrah leaf ash (kg) | Cement (kg) | Water (kg or liters) | Rice husk (kg) | Fine aggregate (kg) | Demolished waste aggregate (kg) | Coarse aggregate (kg) |
|---|---|---|---|---|---|---|---|
| 1. PLA0DW0RH0 | - | 4.86 | 2.673 | - | 7.29 | - | 14.58 |
| 2. PLA0DW20RH50 | - | 4.86 | 2.673 | 3.645 | 3.645 | 2.916 | 11.664 |
| 3. PLA2DW20RH50 | 0.097 | 4.763 | 2.673 | 3.645 | 3.645 | 2.916 | 11.664 |
| 4. PLA2DW20RH100 | 0.097 | 4.763 | 2.673 | 7.29 | - | 2.916 | 11.664 |
| 5. PLA4DW20RH50 | 0.194 | 4.666 | 2.673 | 3.645 | 3.645 | 2.916 | 11.664 |
| 6. PLA4DW20RH100 | 0.194 | 4.666 | 2.673 | 7.29 | - | 2.916 | 11.664 |
| 7. PLA6DW20RH0 | 0.292 | 4.568 | 2.673 | - | 7.29 | 2.916 | 11.664 |
| 8. PLA6DW20RH50 | 0.292 | 4.568 | 2.673 | 3.645 | 3.645 | 2.916 | 11.664 |
| 9. PLA6DW20RH100 | 0.292 | 4.568 | 2.673 | 7.29 | - | 2.916 | 11.664 |
| Total | 1.458 | 42.282 | 24.057 | 36.45 | 29.16 | 23.328 | 107.892 |
| Total requirement for 7 & 28 days (x 2) | 2.916 | 84.564 | 48.114 | 72.9 | 58.32 | 46.656 | 215.784 |

*Figure 2: Mix proportions of PLA, RH and DW*

*Specimen Preparation*

Table 1 represents the Mix proportions of PLA, RH, and DW replaced for conventional materials in grade 30 concrete.150 mm x 150 mm x 150 mm sized concrete cubes were cast according to BS 1881: Part 108:1983 by partially replacing PLA for cement in 2%, 4%, 6%. RH for sand in 50% and 100%. DW was kept constant at 20%. A 1:1.5:3 mix design was adopted with a constant water-cement ratio of 0.55. Further, PLA0DW20RH50 and PLA6DW20RH0 mixtures were developed to critically observe the integrity performance of DW with RH and the influence of RH versus sand in the concrete matrix. 9 mixtures were prepared including the control (0%). A total of 54 cubes were cast and cured for 7 and 28 days.

*Testing*

*Compressive Strength*

Compressive strength of casted concrete cubes were tested at ages of 7 and 28 days using universal compression testing machine according to BS 1881: Part 116:1983 specifications. Peak values were obtained from the machine with a loading rate below 0.5 kN/s.

Compressive strength (P)
$$P = \frac{\text{Peak load value} \times 1000}{\text{Area of the cube}} \qquad \text{Eq - 1}$$



*Figure 3: Compressive Strength Test*

*Water Absorption*

According to BS 812: Part 2:1975 testing specifications, average water absorption rates of concrete specimens were determined at the age of 7 and 28 days according to the formula given below.

Water absorption (W)
$$W = \frac{Ww - Wd}{Wd} \times 100\% \qquad \text{Eq - 2}$$

*Density*

Density of concrete cubes were determined in accordance with BS 812: Part 2:1975 standards. Volume of the mold was obtained as 0.003375 m³ as per standard 150mm x 150mm x 150mm cube mold size. Calculations were carried out by following below equation.

Density (D)
$$D = \frac{\text{Dry weight of the cube}}{\text{volume of the cube}} \qquad \text{Eq - 3}$$

### *Optical Microscopy*

Optical microscopy, a non-destructive testing method was used to observe the microstructural surface of specimens to investigate the surface texture, distribution of components over the surface area and to identify the defects and their locations. Magnified images of the concrete specimens were obtained by MEIJI DK 5000 optical microscope.



*Figure 4: MEIJI DK 5000 - Optical Microscope*

### Data analysis and Discussion

Figure 5 illustrates the compressive strength variation of concrete specimens. Gradual increase was observed up to PLA6DW20RH0 (7) then further declined till PLA6DW20RH100 (9). The integrity performance of DW and RH had shown inadequate strength development in PLA0DW20RH50 (2).
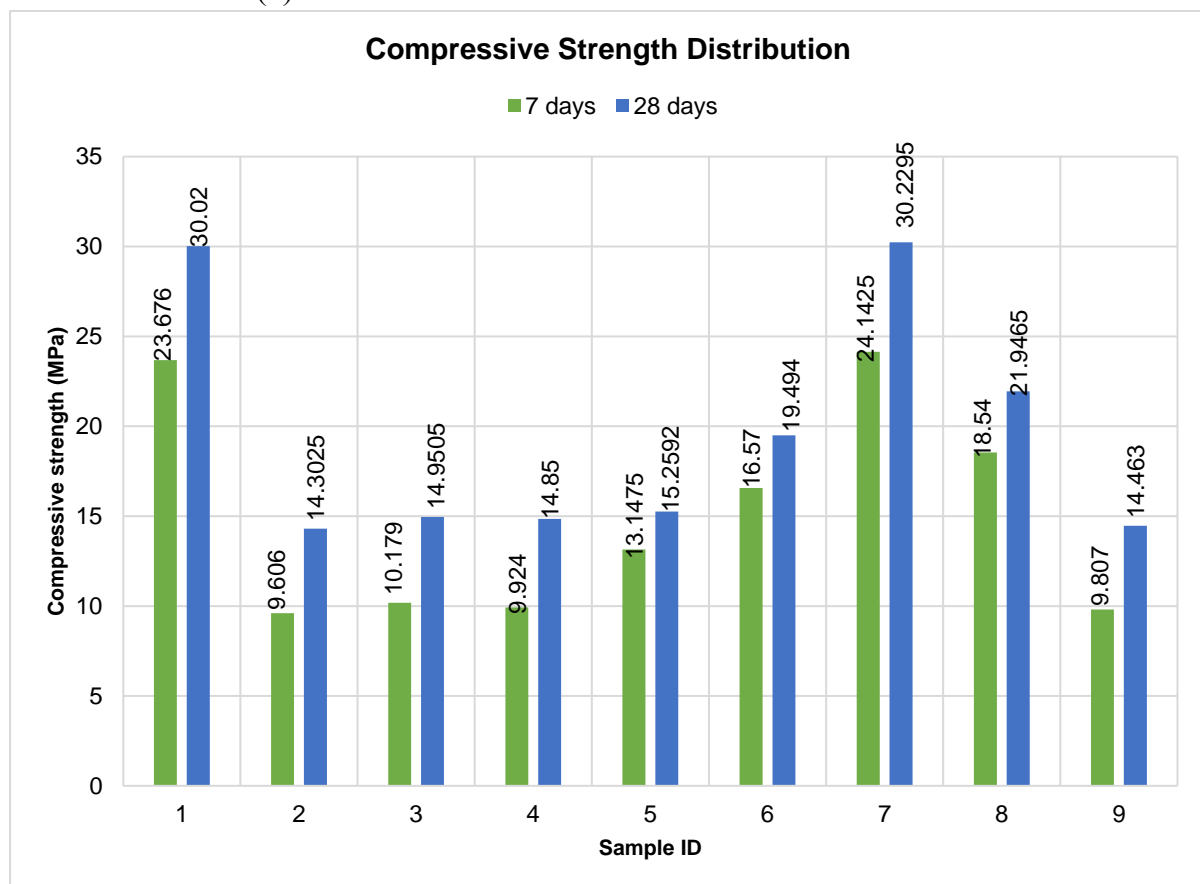


*Figure 5: Compressive strength distribution*

As expected, a significant increment in compressive strength was achieved in PLA2DW20RH50 (3) compared to the former with the addition of PLA in 2% hence it's evident that PLA contains enhancing properties to improve the quality of concrete. Incline and decline trends exhibited in PLA2DW20RH100 (4), PLA4DW20RH50 (5), PLA6DW20RH100 (6), PLA6DW20RH50 (8), and PLA6DW20RH100 (9) were caused by rice husk which was the predominant variable in the medium. The higher volume ratio of RH had deteriorated the packing in the matrix. This argument was further proven by PLA6DW20RH0 (7) where a drastic increment in compressive strength was observed with the well-graded distribution of sand in the matrix compared to the 100% RH replaced PLA6DW20RH100 (6) sample therefore the volume ratio of RH influenced the uniform distribution of particles over the surface area resulting porous medium leading to a reduction in the overall strength of the specimen.
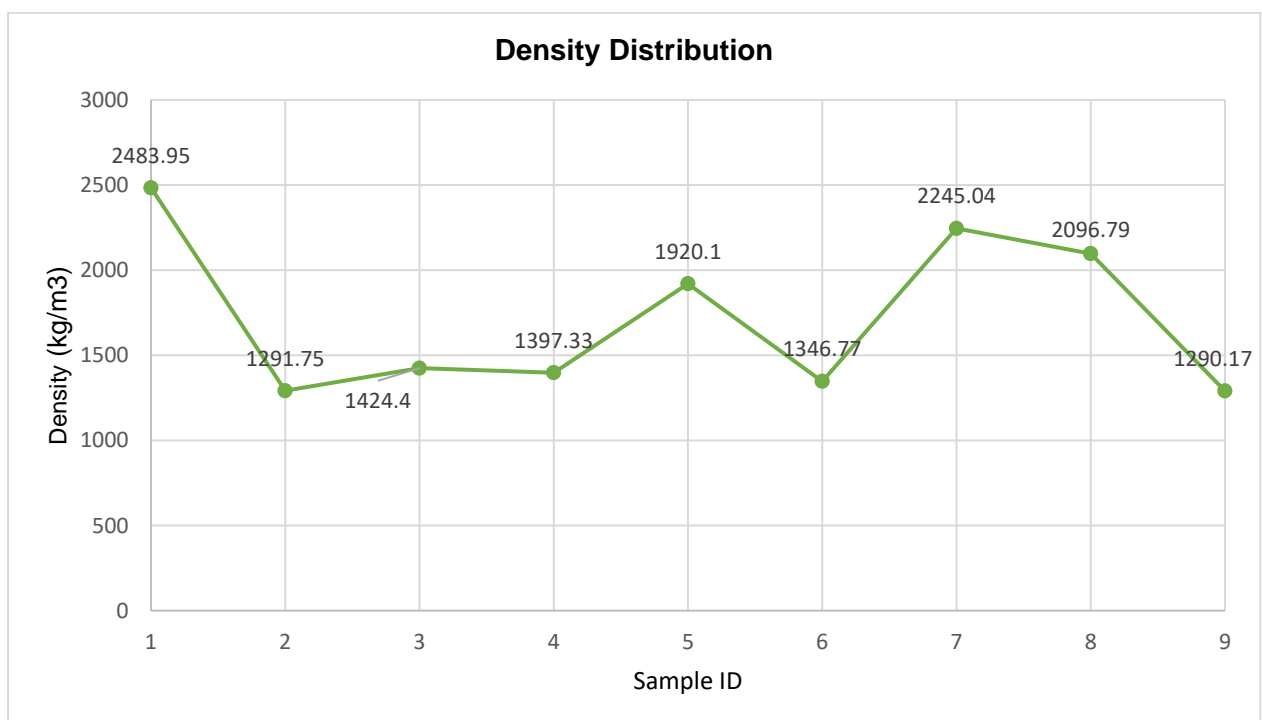


*Figure 6: Density Distribution*

Figure 6 represents the density variation of concrete samples. The average density of the control was obtained as 2483.95 $kgm^3$ for 28 days aged specimens.

According to Figure 7, average water absorption rates of 0.92% and 1.73 % were observed in control (1) after 7 and 28 days of curing. PLA0DW20RH50 (2), PLA2DW20RH50 (3), PLA2DW20RH100 (4), PLA4DW20RH100 (6), and PLA6DW20RH100 (9) had indicated higher water absorption rates. PLA4DW20RH50 (5), PLA6DW20RH0 (7), and PLA6DW20RH50 (8) respectively indicated low water absorption rates. The porous structure created by uniform-sized particle distribution of RH in the medium had caused an increment in water absorption rate in concrete with the increment of RH.
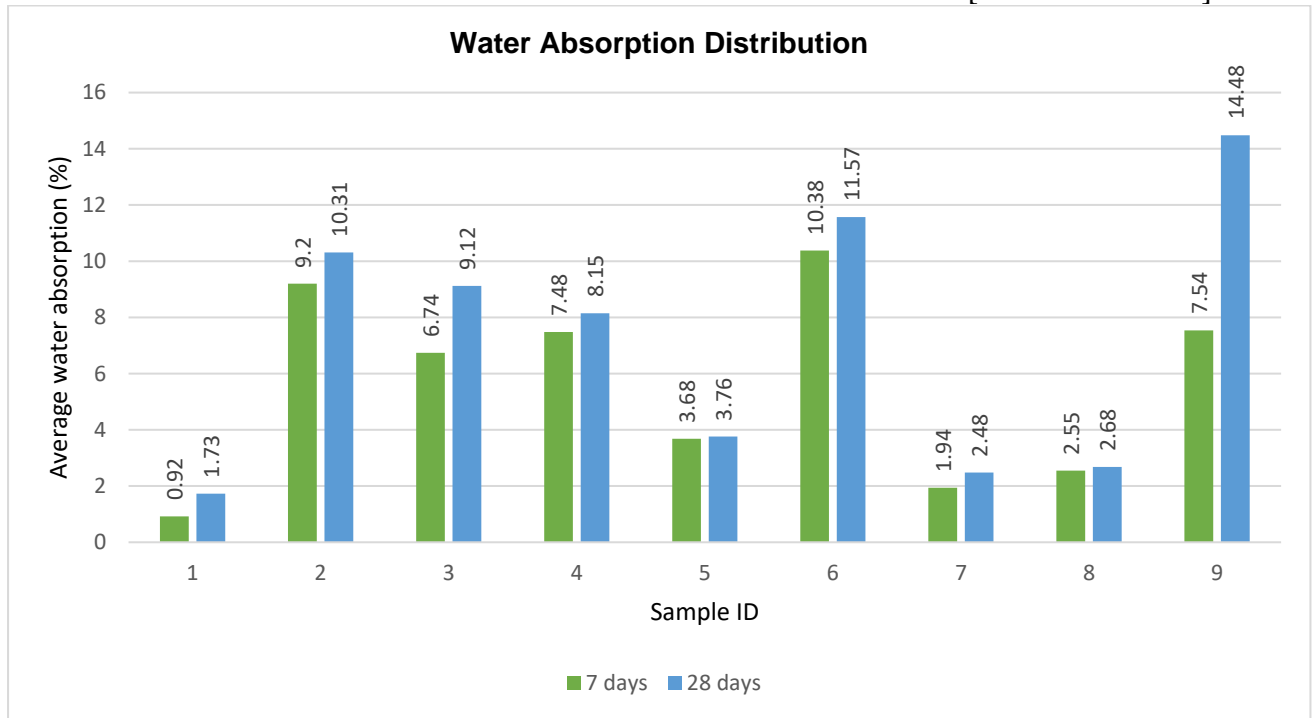
**Water Absorption Distribution**



*Figure 7: Water absorption distribution*

Figure 8 exhibits the relationship between compressive strength, density and water absorption. A linear relationship was observed between compressive strength and density where the density of a concrete specimen increased with their corresponding compressive strength value. It's evident from the $R^2$ values ($\approx 1$) that there's an existence of a strong correlation between these two parameters. Compressive strength had reduced with the increment in water absorption hence the graphical behavior indicates a linear inverse relationship between the parameters. Although a clear relationship cannot be determined due to the wide distribution of data, $R^2$ values lie between $\approx 0.5 - 1.0$ hence there is a definite correlation existing between these parameters. As the density of the concrete specimen increased, the water absorption rate of the specimen decreased hence linear inverse relationship is present between water absorption and density parameters. It is evident from the $R^2$ values ($\approx 1$) that there's a good correlation existing between these two parameters.
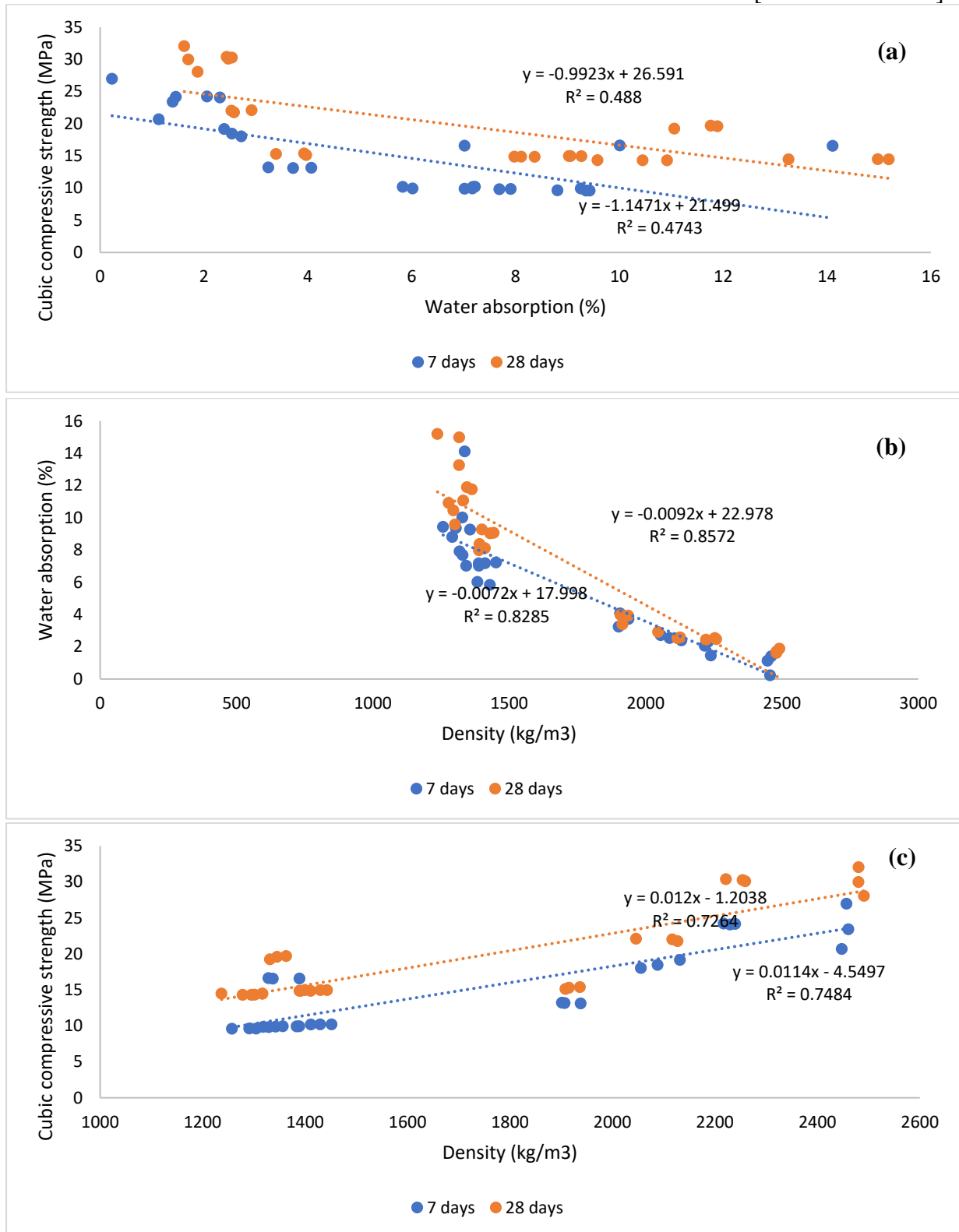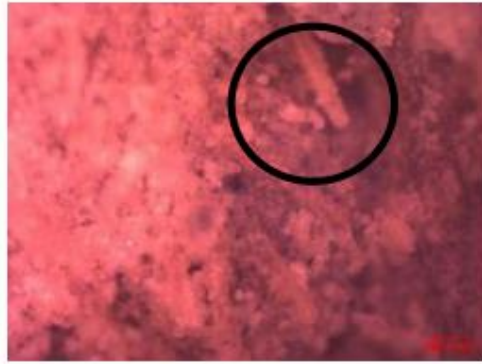
*Figure 8: Correlations between parameters (a) CS vs WA, (b) WA vs D, (c) CS vs D*

Optical microscopy images of control specimen had exhibited smooth surface texture. However, PLA0DW20RH50 (a) test specimen had shown the signs of large voids on the surface. This phenomenon was closely inspected under magnitude of x50.

(a)

Compared with (a), PLA2DW20RH50 (b) had smaller voids on the surface hence it's evident that other than improving the binding quality, PLA acted as a filling agent in (b) thus large voids developed due to the poor graded particle distribution of DW and RH had significantly improved under PLA addition in (b).
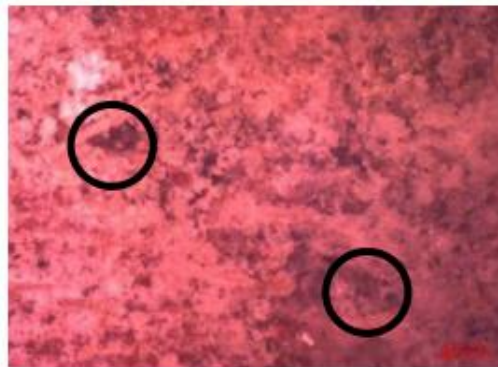


(b)

Considerably clear microstructural layout was observed in both PLA6DW20RH0 (c) and PLA6DW20RH50 (d). Neatly arranged DW aggregates were observed in uniformly smoothen surface of PLA6DW20RH0 in darkened form. it is evident that the well graded distribution of sand had reduced the void spaces in the medium thus hydration products were able to develop dense microstructure resulting uniform layout over the surface area. PLA6DW20RH50 had shown a similar surface arrangement. Although small voids were observed in the concrete medium, PLA6DW20RH50 had shown better microstructural development compared to other developed specimens and almost resembling surface characteristics of PLA6DW20RH0.

(c)



(d)
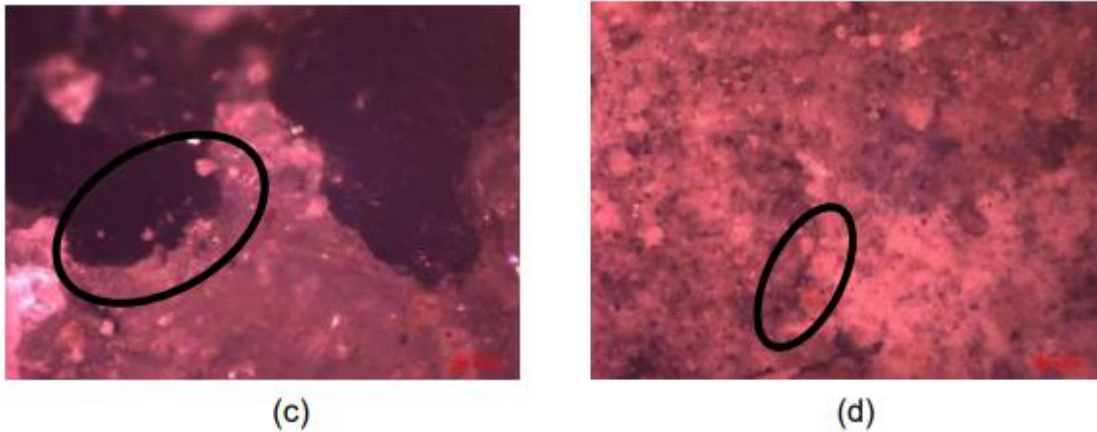
## Conclusions

Ever-increasing infrastructure demand with the growth of population had led to an expansion in annual concrete production causing major environmental, sustainable, and economic issues. This study took a step towards the development of the traditional concrete practice by investigating the optimum mechanical performance of grade 30 concrete by substituting suitable mix proportions of PLA, RH, and DW for the conventional materials used in the concrete matrix.

PLA acted as a both pozzolanic material in the cementitious binder and a filler in the concrete microstructure.

Although weak ITZs characteristics of DWA resulted in inferior properties, DWA had shown potential as a coarse aggregate alternative. However, it significantly raised the water demand for concrete.

Poor grain distribution in concrete matrix caused by RH-initiated porous microstructure.

The high presence of RH over the surface area had initiated the voids between hydrating cement particles leading to lesser dense C-S-H structure development resulting reduction in density and high permeability.

Reduction of density is favorable for thermal properties and construction cost since the dead load applied on the structure reduces concrete density.

Altogether, an increase of PLA, RH, and DW had reduced the mechanical performance of grade 30 concrete. compressive strength decreased drastically with a negative trend associated with the increment of each mix proportions.

Optimized triple mixing (OTM), Arabic gum biopolymer (AGB), Carbon fibre reinforced polymer (CFRP) and Dual Crystallization technology can be used to enhance the properties of concrete.

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# INTEGRATING PLASTICITY AND COMPRESSIBILITY CHARACTERISTICS FOR MATHEMATICAL MODELING OF SOIL CBR VALUES

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## Abstract

By anchoring the model to the plasticity index and compressive characteristics of soil samples, the research not only accelerates the assessment process but does so without compromising the precision and reliability integral to infrastructure design. However, in response to the inherent challenges associated with this conventional approach, this research undertakes a pioneering journey to present a novel mathematical model poised to revolutionize the prediction of CBR values. The overarching objective of this research is to probe into the intricate relationship between the CBR value and two key soil characteristics: the plasticity index (PI) and compressive characteristics. It is derived as $CBR = -0.7984 \times PI + 30.58$ and validated within the study. By delving into this association, the research aspires to pave the way for an expeditious and cost-effective alternative to the time-intensive and resource-draining laboratory testing typically employed for CBR determination. The envisaged mathematical model, once realized, holds the promise of ushering in a new era of efficiency and economy in the domain of pavement design and construction. As the test results emerge from the crucible of empirical analysis, the research pivots towards the development of a robust mathematical model.

**Keywords:** CBR value, Plasticity, Compressibility, Mathematical Modeling

## Introduction

The California Bearing Ratio (CBR) test, conducted by the California Department of Highways (Caltrans) in 1929, is still important in engineering and provides information on soil conditions that are critical to road construction (Caltrans, 1929). Through these activities, we aim to increase the accuracy of the prediction model and contribute to the advancement of geotechnical tools for the analysis and characterization of soils in various engineering applications. These investigations of bearing capacity and strength characteristics have stimulated extensive research to improve predictive models and expand the applicability of tests to a variety of geological conditions.

This study seeks to gain a deeper understanding of the complex relationship between CBR values and soil properties, overcoming the limitations found in previous models. Advanced computer techniques can improve the accuracy and efficiency of soil characterization, especially in road construction and other engineering applications. By participating in model improvements, it is aimed to promote more accurate and efficient soil analysis and characterization in civil engineering projects.

By contributing to model refinement, we aim to facilitate more accurate and efficient soil analysis and characterization in civil engineering projects. Soil samples from diverse regions underwent Atterberg limit tests and CBR tests, leading to proposed mathematical models, such

as 'CBR=0.7 Cu + 8.5' and 'CBR = -0.10L - 0.425 Pl + 1'. Concurrently, a Mexican research team focused on predicting CBR models for granular bases, incorporating physical and structural soil properties.

### Aim of the Study:

Create the mathematical relationship between CBR (California Bearing Ratio) and Plasticity index.

### Objectives:

1. To conduct a comprehensive literature review on the relationship between CBR values and plasticity index.
2. To collect a representative set of soil samples from various locations.
   Conduct laboratory tests to determine the plasticity index and other relevant soil properties, such as Atterberg limits, grain size distribution, and moisture content. Perform the CBR test on each soil sample to obtain their corresponding CBR values. Analyze the collected data to understand the variability and correlation between the plasticity index and CBR values.
3. To develop a mathematical model that establishes the relationship between CBR values and plasticity index
4. To validate the developed mathematical model using independent field data and series of secondary data
5. To provide recommendations and guidelines to geotechnical engineers on utilizing the mathematical model for predicting CBR values based on plasticity index.

### Unveiling the Complex Relationship between CBR and Plasticity Index in Geotechnical Engineering

It underscores the interconnected nature of soil properties and the need for a comprehensive understanding of plasticity in geotechnical analyses, emphasizing the indirect influences that plasticity may exert on broader soil characteristics.

In a case study conducted in Akwa Ibom State, Bassey et al. (2017) examined the correlation between CBR values and index properties of soils in the region, with a specific focus on plasticity index variations. The research underscored the importance of considering regional variations in plasticity when assessing CBR values, contributing to more accurate and applicable engineering solutions, especially in the context of the specific soil properties prevalent in the Kolkata region.

The study emphasized the importance of plasticity in determining the mechanical behavior of soils, offering insights into CBR values in specific soil types, especially those characterized by fine-grained materials. Amidst the multitude of soil properties, the plasticity index (PI) has emerged as a key parameter influencing CBR values, sparking extensive research endeavors to unravel the nuanced interplay between these two factors. The research aimed to create a practical tool for preliminary project assessments in geotechnical engineering, emphasizing the significance of readily available index properties, particularly plasticity, in predicting CBR values.

**Methodology**

*Data Collection*

Data collection forms the empirical backbone of our research, and as such, meticulous planning and execution are essential. This section provides a comprehensive overview of the steps involved in data collection:

*Collect soil samples from various locations:*

Soil samples are obtained from a variety of geographic locations, each representing distinct soil types and compositions. The selection of diverse sample sites ensures that the dataset is representative of a wide range of soil properties and characteristics. These soil samples were collected with attention to factors such as geological conditions, land use, and local variations.

*Perform laboratory tests for the plasticity index:*

To accurately determine the plasticity index, laboratory tests were conducted. The chosen method for assessing plasticity was the Atterberg limits test. This method is renowned for its precision in delivering reliable plasticity index values. The test comprises three critical components: the liquid limit, plastic limit, and plasticity index. These parameters are fundamental in characterizing soil plasticity. It is carried out after the sieve analysis (ASTM C136) testing.

Casagrande's method, outlined in "Research on the Atterberg Limits of Soils" (1932), is the global standard, detailed in codes like ASTM D4318-10e1. This test determines the moisture content at which soil shifts from plastic to liquid. Adherence to standardized methods ensures consistent and reliable assessments, contributing to soil mechanics understanding and applications.

*Conduct CBR tests on soil samples:*

Each soil sample undergoes California Bearing Ratio (CBR) testing to obtain the corresponding CBR values. This process adheres rigorously to standardized testing protocols to ensure the accuracy and reliability of the CBR results. The testing phase includes meticulous control of variables such as compaction, loading conditions, and sample size to guarantee the consistency of results.

*Record and document the data:*

The data obtained from the laboratory tests, encompassing plasticity index values, CBR values, and other relevant soil properties such as grain size distribution and moisture content, are meticulously recorded. This comprehensive data documentation is indispensable for subsequent analysis and model development.


*Data Analysis*

The data analysis phase is a pivotal aspect of our research, as it enables us to draw meaningful conclusions and derive insights from the collected data. This section outlines the detailed procedures of data analysis:

*Data examination:* The collected dataset is subjected to a thorough examination, involving both exploratory and descriptive analysis. This initial step allows us to identify any obvious trends or patterns in the relationship between the plasticity index and CBR values.

*Statistical techniques***:** Statistical techniques, including regression analysis, are applied to quantitatively describe the relationship between the plasticity index and CBR values.

Regression analysis, in particular, is a powerful tool for modeling the dependencies between variables and forms the basis for the mathematical model.

*Exploration of correlations and dependencies:* Correlations and dependencies between the variables are meticulously explored. This process helps us gain deeper insights into the strength and nature of the relationship between CBR and plasticity index. The resulting correlations provide valuable information that further supports the development of the mathematical model.

## Mathematical Model Development

The core objective of our research is to develop a robust mathematical model that can predict CBR values based on the plasticity index. This section delves into the details of the model development process:

*Model formulation:* Leveraging statistical methods and mathematical equations, we work to formulate the relationship between the plasticity index and CBR values. This formulation is the cornerstone for our predictive model. Various mathematical models are considered, with the ultimate choice being based on their accuracy and fit to the collected data.

*Calibration and validation:* The model goes through a crucial phase of calibration and validation using the collected dataset. During calibration, the model's parameters are meticulously adjusted to ensure precision and reliability in predicting CBR values. Validation is vital to assess how well the model performs with data it has not encountered during the calibration phase. This iterative process is pivotal in refining the model for enhanced predictive capabilities.

*Refinement and iteration:* This iterative approach makes the model that predicts CBR values based on the plasticity index robust and reliable. This model development stage also includes the application of a regression analysis approach to predict CBR values based on soil properties. To predict the CBR value, a multiple linear regression model is selected that considers the plasticity index (PI) and other relevant soil properties as predictor variables.

$$CBR = -0.7984 \times PI + 30.58$$

Where CBR represents the predicted CBR value, $\beta 0$ is the intercept, $\beta 1$ to $\beta n$ are the regression coefficients, and $X_2$ to $X_n$ are other soil properties. The model is trained using preprocessed data and optimized through feature selection techniques to identify the most significant variables contributing to CBR values. This method ensures that our predictive model is both accurate and efficient.

## Model Evaluation

The performance of the developed mathematical model (Figure: 1) is evaluated rigorously to ascertain its accuracy, precision, and reliability in predicting CBR values based on the plasticity index. This section outlines the steps involved in model evaluation:

*Comparison with field data:* The model's predictions are compared against actual field data and independent validation datasets. This direct comparison is crucial for assessing the accuracy and reliability of the model's predictions.

*Assessment of model performance:* The evaluation process includes a comprehensive assessment of the model's performance, taking into consideration metrics such as mean

absolute error (MAE), mean squared error (MSE), and R-squared values. These metrics provide a quantitative measure of how well the model aligns with the actual CBR values.

*Identification of limitations and improvements:* During model evaluation, we also identify any limitations or discrepancies. If necessary, we suggest modifications or improvements to enhance the model's performance and predictive capabilities. The developed model is given below. Upon inputting a Plasticity Index value within the range of 17 to 21, the corresponding CBR value is generated through the derived equation.
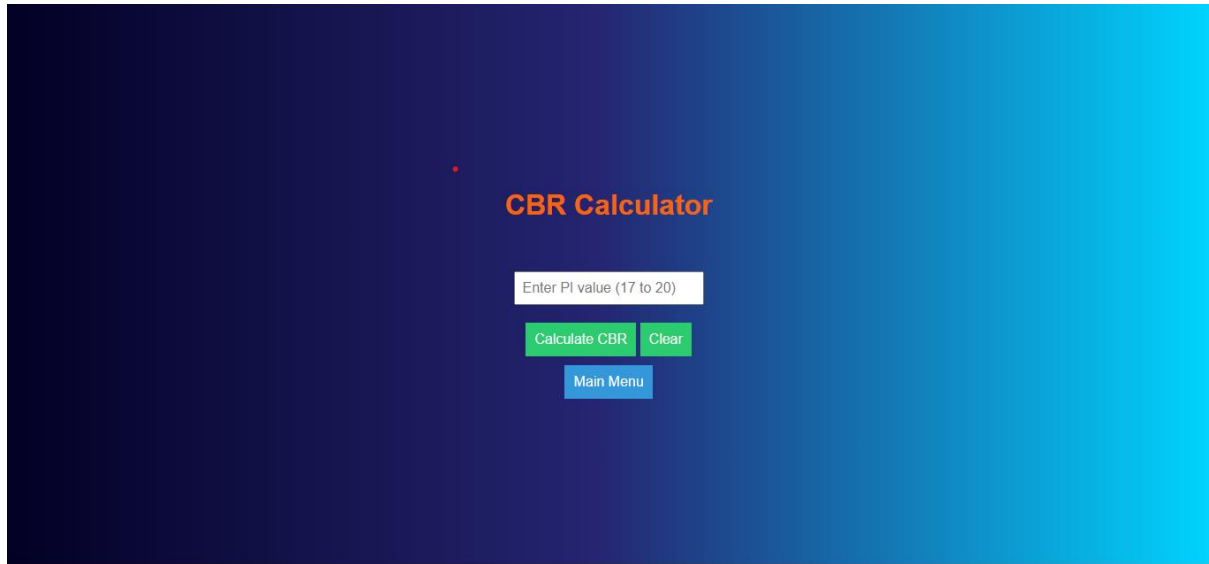


*Figure 1 - Software Model Interface*

As an example, when we enter the Plasticity index value as 18, it is automatically calculating the CBR value from the found equation and generates the relationship between CBR and plasticity index by a graph as it is shown below (Figure: 2).
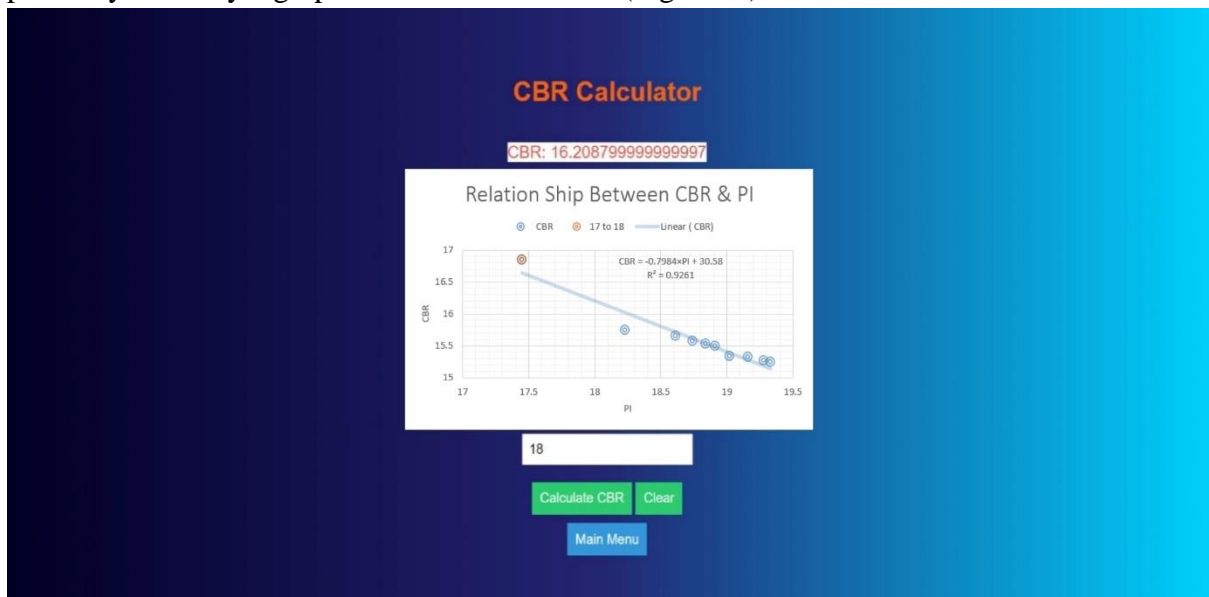


*Figure 2- Software Model Value Results Interpretation*

**Results and Discussion**

The developed mathematical model, expressed as CBR = -0.7984 × PI + 30.58, underwent thorough validation using a distinct dataset, revealing minimal discrepancies between predicted and founded CBR values, with error rates ranging from -0.01747 to 0.011993. The negative slope (-0.7984) indicated a downward trend, affirming the anticipated negative correlation between CBR and plasticity index in geotechnical engineering. The intercept (30.58) represented the starting point of the linear relationship, emphasizing its role in accurate predictions.

$$CBR = -0.7984 \times PI + 30.58$$

$$y \quad = \quad m \quad . \quad x \quad + \quad b$$

Validation analysis demonstrated the model's practical applicability, with relatively small error rates validating its performance on new data. Quantitative metrics such as MAE, MSE, and R-squared values provided a nuanced assessment, contributing to a comprehensive evaluation. While the model showed validity within the specific plasticity index range in the dataset, caution was advised for extrapolation beyond observed values. The research's implications for geotechnical engineering practices, particularly in highway construction, were underscored, as the model provided a valuable tool for predicting CBR values based on plasticity index, emphasizing the importance of considering plasticity characteristics in geotechnical analyses.

Table 1 - CBR & PI Values

| CBR | PI | As per Linear Equation | Error Rate |
|---|---|---|---|
| 16.85 | 17.45 | 16.64792 | 0.011993 |
| 15.75 | 18.23 | 16.025168 | -0.01747 |
| 15.65 | 18.61 | 15.721776 | -0.00459 |
| 15.58 | 18.74 | 15.617984 | -0.00244 |
| 15.53 | 18.84 | 15.538144 | -0.00052 |
| 15.49 | 18.91 | 15.482256 | 0.0005 |
| 15.34 | 19.02 | 15.394432 | -0.00355 |
| 15.33 | 19.16 | 15.282656 | 0.003088 |
| 15.27 | 19.28 | 15.186848 | 0.005445 |
| 15.25 | 19.33 | 15.146928 | 0.006759 |

A set of primary data is given in the table 1 above for the validation through the derived mathematical model. Soils with high plasticity indexes (high PI values) have a wide range between the plastic and liquidity limits (Figure 3). These soils can undergo significant

deformation and have higher water-holding capacities. Understanding the relationship between plastic limit and liquidity limit, as expressed by the Plasticity Index, is essential in soil classification systems and is valuable for assessing a soil's engineering properties.
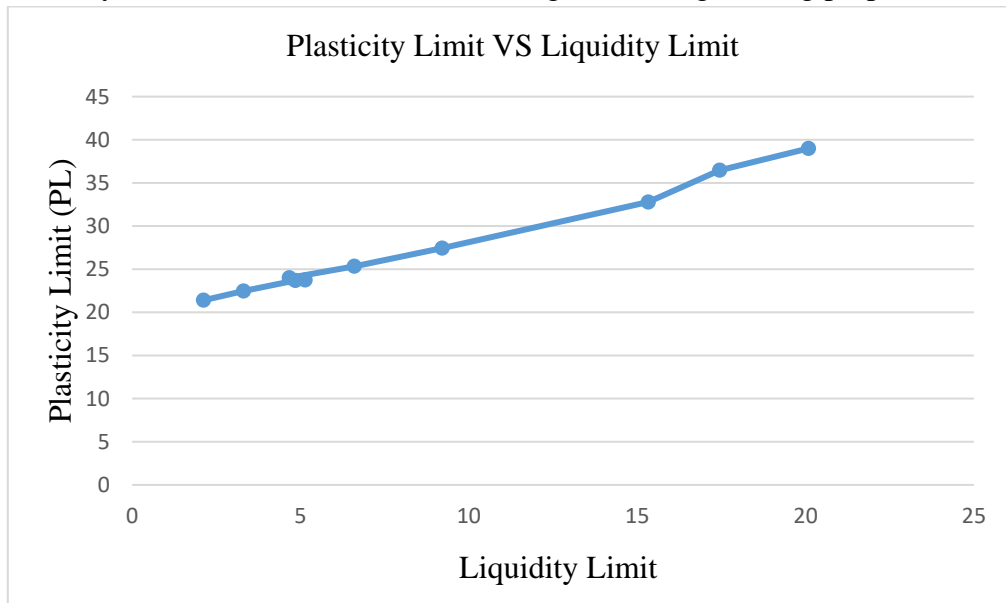


*Figure 3 - Plasticity Limit and Liquidity Limit Relationship for Validated Data Set*
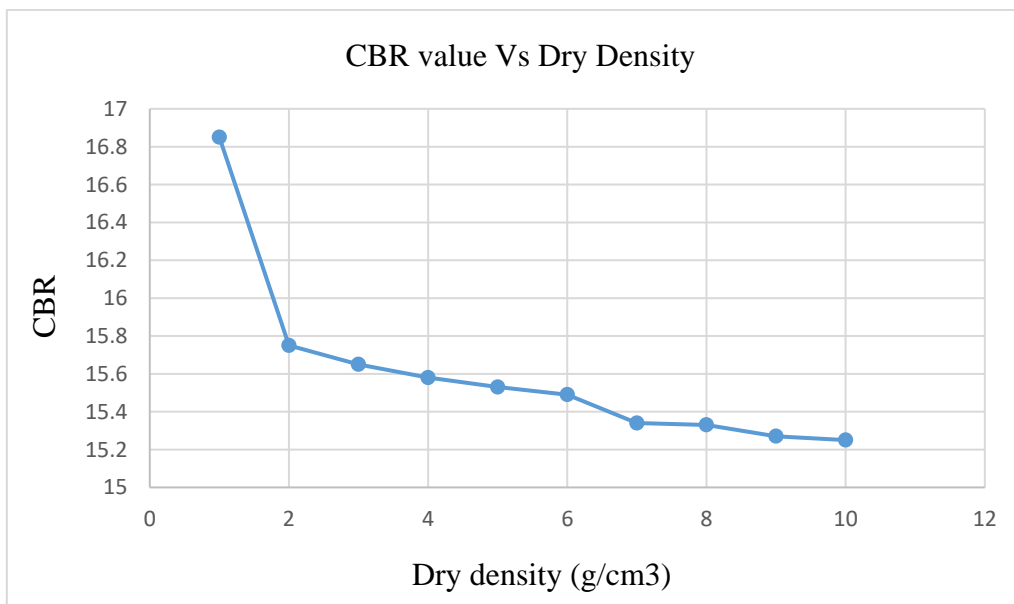


*Figure 4 - CBR Graph for the Validated Data Set*

In general, there is a correlation between CBR values and dry density (Figure 4), although the relationship can be influenced by various factors. Above Figure 4 has given the variation of CBR Vs Dry Density values for the primary data set to get a good understanding of the sample.

***Steps to Find Error Rates Referring to the Validated Data Set:***
1. Substitute each value of `PI` into the equation `CBR = -0.7984 × PI + 30.58` to calculate the predicted values of `CBR`.
2. Subtract the predicted values of `CBR` from the founded values of `CBR` to find the errors.

3. Divide each error by the corresponding value of `CBR` to calculate the error rates.

`CBR = 16.85` and `PI = 17.45`.

Substitute `PI = 17.45` into the equation:

CBR = -0.7984 × 17.45 + 30.58

Calculate the predicted value of `CBR`.

CBR = -0.7984 × 17.45 + 30.58 = 16.64792

Error = CBR - BR = 16.85 - 16.64792 = 0.20208

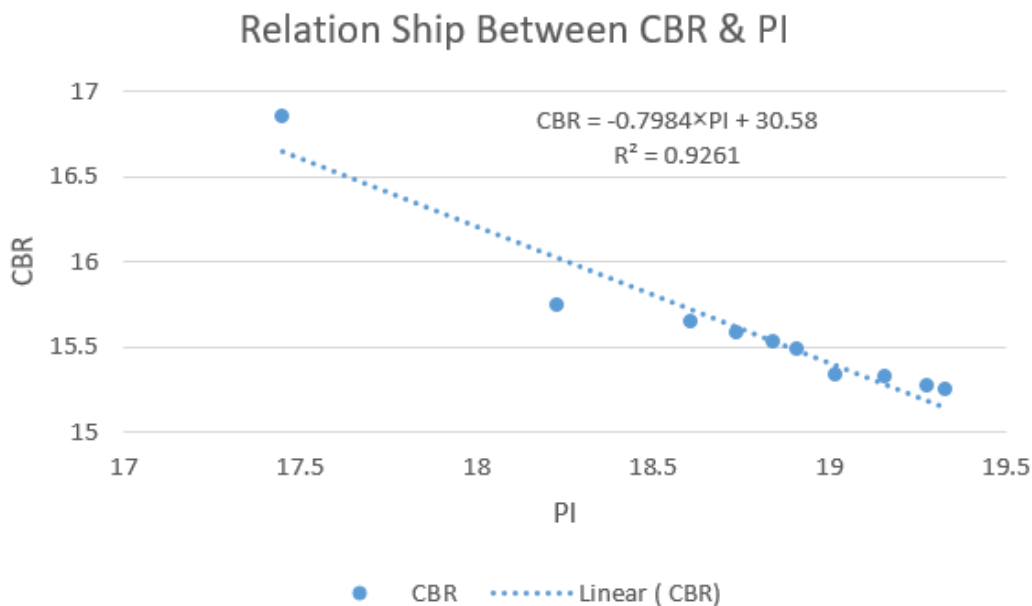$$Error\ rate\ = \frac{0.20208}{16.85} = 0.011993$$



*Figure 5 - Relationship between CBR and PL*

In the equation $CBR = -0.7984 \times PI + 30.58$, $"-0.7984"$ represents the slope of the line. The slope is a measure of how steep the line is. It indicates the rate at which the dependent variable of CBR changes with respect to a change in the independent variable of Plasticity Index. In other words: If the slope is positive, the line slopes upward from left to right, indicating a positive correlation between CBR and Plasticity Index. An increase in Plasticity Index corresponds to an increase in CBR.

If slope is negative, the line slopes downward from left to right, indicating a negative correlation between CBR and Plasticity Index. An increase in Plasticity Index corresponds to a decrease in CBR. If slope is zero, the line is horizontal, indicating no change in CBR as Plasticity Index changes. The variable 30.58 in the equation is the CBR-intercept, which is the value of CBR when Plasticity Index is zero.

***Validation Analysis:***

The provided data presents a validation analysis for a linear equation expressing the relationship between California Bearing Ratio (CBR) and Plasticity Index (PI) referring to the equation: $\boldsymbol{CBR = -0.7984 \times PI + 30.58}$

*Model Accuracy:*

The linear model aims to predict CBR values based on the Plasticity Limit, with coefficients -0.7984 as the slope and 30.58 as the intercept. This equation is used to calculate predicted CBR values.

*Error Calculation:*

To validate the model, the errors are computed by subtracting the predicted CBR values from the founded CBR values. The error rates are then calculated by dividing each error by the corresponding founded CBR value.

*Evaluation of Error Rates:*

The error rates in the given data range from -0.01747 to 0.011993, indicating relatively small discrepancies between the predicted and founded CBR values. This suggests that the linear model provides a reasonably good fit to the data.

*Slope Interpretation:*

The slope of -0.7984 signifies the rate of change in CBR concerning a change in Plasticity Index. With a negative slope, the line slopes downward from left to right, suggesting a negative correlation between CBR and Plasticity Index. This implies that as the Plasticity Index increases, the CBR tends to decrease.

*CBR-Intercept:*

The intercept of 30.58 in the equation represents the CBR value when the Plasticity Index is zero. This may not have a direct physical interpretation since the Plasticity Index is typically a positive value, but it is a characteristic of the linear model.

*Correlation and Causation:*

While the correlation between CBR and Plasticity Index is captured by the model, it's important to note that correlation does not imply causation. The linear relationship may suggest an association, but causation should be established through further investigation.

*Range of Plasticity Index:*

The model's validity may be influenced by the range of Plasticity Index values in the dataset. Between 16 to 21 range of PI can be apply to this program. It is advisable to ensure that the model is applicable across the relevant range of Plasticity Index values encountered in practical scenarios.

**Conclusion**

In conclusion, this research delves into the intricate relationship between California Bearing Ratio (CBR) values and soil plasticity characteristics. Commencing with an extensive literature review, we navigated diverse studies, emphasizing the importance of mathematical modeling in comprehending geotechnical nuances. The empirical foundation involved meticulous soil sample collection from diverse locations, with laboratory tests revealing insights into plasticity index and grain size distribution. Data analysis unveiled nuances in the relationship between plasticity index and CBR values, guiding the formulation of a predictive mathematical model through multiple linear regression. The resulting equation demonstrated a negative correlation, aligning with geotechnical expectations. Model evaluation, marked by small error rates and quantitative metrics, validated its accuracy. The developed model emerges as a practical asset for geotechnical professionals, offering a quantitative tool for decision-making in soil

engineering. While acknowledging limitations, including dataset dependence and the need for ongoing refinement, this research paves the way for future considerations, suggesting expansion of datasets and exploration of additional influencing factors. Ultimately, this research serves as a catalyst for ongoing exploration and refinement, contributing to the dynamic landscape of geotechnical engineering.

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# IMPACT OF COAL BOTTOM ASH AND RECYCLED GLASS ON COMPRESSIVE STRENGTH IN LIGHTWEIGHT CONCRETE

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## Abstract

The depletion of natural aggregates in various regions necessitates exploring alternative materials for sustainable concrete production. This study investigates the feasibility of using coal bottom ash (CBA) as a substitute for fine aggregates and recycled glass as coarser aggregates in lightweight concrete, aiming to address environmental concerns while meeting construction demands. The research examines the impact of replacing CBA and recycled glass on the mechanical properties and workability of lightweight concrete, with a focus on controlling negative effects through water-cement ratio adjustments. The primary objective was to determine an optimal mix design for high-performance lightweight concrete incorporating CBA and recycled glass. Nine concrete mixes, including a control, are prepared, with four sets at a water-cement ratio of 0.45 and another four sets at a ratio of 0.375. The incremental increase of CBA and crushed glass replacement (up to 16%) was investigated for both sets of mixes. The overall concrete grade utilized for the study was M15 grade (1:2:4 ratio). This study demonstrates that the optimal compressive strength for lightweight concrete was achieved at an 8% substitution rate. Notably, the material's lightweight properties became evident following a 12% substitution, suggesting its potential for sustainable construction in the face of diminishing natural aggregates.

**Keywords:** Coal Bottom Ash, Recycled Glass, Light Weight Concrete, Water-Cement Ratio, Natural Aggregate Depletion.

## Introduction

In a world where concrete is the backbone of modern construction, an emerging challenge looms on the horizon - the depletion of natural aggregates, especially the river sand (Elavenil & Vijaya, 2013). As cities grow and projects multiply, the demand for these essential resources escalates, casting a shadow on the sustainability of our construction practices (Sanjith, et al., 2015) (Agrawal, et al., 2017).

Another concept that requires attention is the need for lightweight concrete, a crucial component in modern engineering, the call for structures that are both sturdy and light, capable of withstanding the test of time while minimizing environmental impact, becomes ever more urgent (Mousa, et al., 2018) (Bejan, et al., 2020). Thus, CBA and recycled glass hold the potential to transform lightweight concrete production and pave the way for a greener future. This research aims to explore the potential of these alternative materials in lightweight concrete, focusing on their impact on compressive strength. The research will also explore

adjustments in the water-to-cement ratio to control potential negative effects and achieve the desired compressive strength.

In a world driven by the need for electricity, coal combustion stands as a prominent choice to generate power globally (Heidrich, et al., 2013). However, this process generates significant waste in the form of fly ash and coal bottom ash, demanding proper handling to mitigate environmental consequences. In Sri Lanka's Norochcholai coal-fired thermal power plant, a staggering amount of bottom ash is produced daily, leading to an environmental burden as it remains largely unused and discarded (Gimhan, et al., 2018) (Jayaranjan, et al., 2014). This waste material, rich in silica, possesses the potential to be a game-changer in the construction industry if harnessed effectively (Savitha, 2015). By replacing river sand in lightweight concrete production, coal bottom ash can provide a sustainable solution, not only addressing environmental challenges but also reducing the demand for natural resources (Ali, et al., 2022). Another critical aspect of sustainable concrete production involves the inadequate recycling of waste glass. Large volumes of post-consumer glass bottles are disposed of daily worldwide, with minimal recycling rates (Ling & Poon, 2011) (Dyer, 2015) (Ramzi, et al., 2016). Thus, unlocking the potential of recycled glass as a coarser aggregate in concrete promises a captivating journey in sustainable construction. With its remarkable strength and unique angular shape, this eco-friendly alternative can boost concrete's mechanical properties and resist compressive forces. Beyond its performance, the use of recycled glass diverts waste from landfills, reduces construction weight, and bestows a dazzling aesthetic to architectural designs (Petrella, et al., 2007) (Shi & Zheng., 2007).

Despite the progress in exploring alternative materials, the specific impact of incorporating CBA and recycled glass in lightweight concrete's compressive strength requires further investigation. This research aims to bridge this gap by developing an optimal mix design that combines CBA as a substitute for fine aggregates and recycled glass as a replacement for coarser aggregate. The findings of the research will be beneficial for researchers and practitioners to further enhance the strength of lightweight concrete for targeted industrial applications.

## Materials and Methods

This research was applied research based on an experimental approach which allows us to directly explore and analyze the effects of CBA and recycled glass on the compressive strength of lightweight concrete by conducting investigations and experiments.

### Constituent materials

The Constituent materials employed in the experimental study for lightweight concrete production are listed in Table 1.

Table 1: Constituent Materials

| Materials | Description |
|---|---|
| Cement | OPC Grade 42.5R<br>Specific Gravity = 3.15 |
| Bottom Ash | Specific Gravity = 1.7<br>Finer than 2.36mm |
| Recycled Glass | Size 4.75mm – 9.5mm |

## *Mix Design*

Concrete of M15 Grade was formulated with a mix proportion of 1:2:4, denoting one part cement to two parts fine aggregate to four parts coarse aggregate. The mix design was designed using a water-cement ratio of 0.57 in accordance with the chosen grade.

## *Mix Proportions*

A total of nine concrete mixtures were prepared for this study. Among them, one mixture was designated as the control, while the remaining eight mixtures were formulated by systematically varying the percentages of CBA and recycled glass, ranging from 4% to 16%. For each percentage variation, two batches of concrete were created featuring different water-cement ratios of 0.45 and 0.375. Details of the mix proportions are included in Table 2 and Table 3.

*Table 2: Summery of mix proportions*

| Specimen Number | W/C Ratio | Bottom Ash (%) | Recycled Glass (%) |
|---|---|---|---|
| Control | 0.57 | 0 | 0 |
| S-1-1 | 0.45 | 4 | 4 |
| S-1-2 | 0.45 | 8 | 8 |
| S-1-3 | 0.45 | 12 | 12 |
| S-1-4 | 0.45 | 16 | 16 |
| S-2-1 | 0.375 | 4 | 4 |
| S-2-2 | 0.375 | 8 | 8 |
| S-2-3 | 0.375 | 12 | 12 |
| S-2-4 | 0.375 | 16 | 16 |

*Table 3: Detailed Mix Proportions*

| Specimen | Cement (Kg) | Water (Kg) | Aggregates | | Coal Bottom Ash (Kg) | Recycle Glass (Kg) |
| --- | --- | --- | --- | --- | --- | --- |
| | | | Fine (Kg) | Coarser (Kg) | | |
| Control | 3.86 | 2.20 | 8.59 | 19.32 | 0.00 | 0.00 |
| S-1-1 | 3.86 | 1.70 | 8.25 | 18.55 | 0.34 | 0.77 |
| S-1-2 | 3.86 | 1.70 | 7.90 | 17.78 | 0.69 | 1.55 |
| S-1-3 | 3.86 | 1.70 | 7.56 | 17.01 | 1.03 | 2.32 |
| S-1-4 | 3.86 | 1.70 | 7.21 | 16.23 | 1.37 | 3.09 |
| S-2-1 | 3.86 | 1.40 | 8.25 | 18.55 | 0.34 | 0.77 |
| S-2-2 | 3.86 | 1.40 | 7.90 | 17.78 | 0.69 | 1.55 |
| S-2-3 | 3.86 | 1.40 | 7.56 | 17.01 | 1.03 | 2.32 |
| S-2-4 | 3.86 | 1.40 | 7.21 | 16.23 | 1.37 | 3.09 |

The cement, water, fine and coarse aggregates, coal bottom ash, and recycled glass were precisely weighed using an electronic balance with a minimum count of 0.1 mg, based on specific W/C ratios. The mixing process, illustrated in Figure 1, took approximately 14 minutes to achieve a uniform mixture.
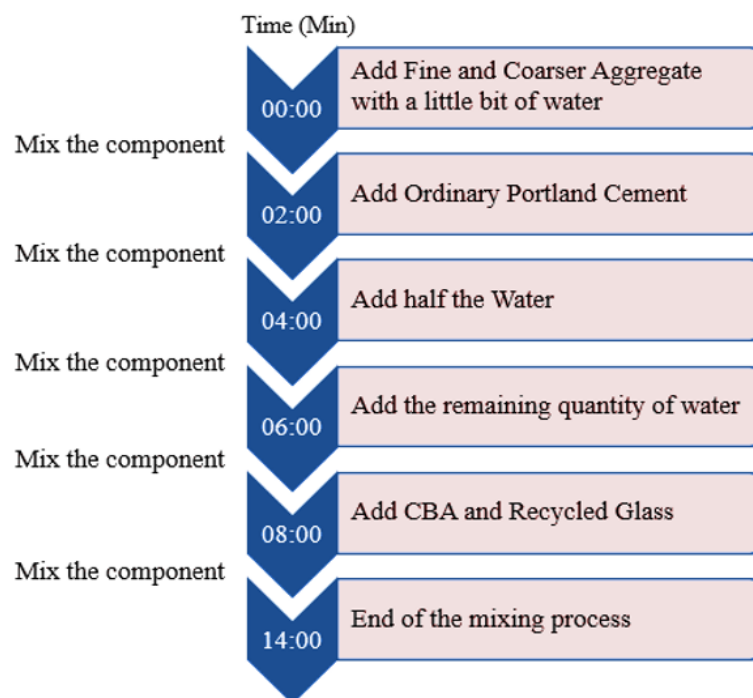


*Figure 1: Specimen preparation procedure:*

***Test Procedures***

*Workability Test*

The water-absorbing nature of coal bottom ash and the influence of adjusting the water-cement ratio on each specimen were evaluated through the slump cone test, adhering to ASTM C143/C143M guidelines. Each specimen underwent one test to assess its workability, where a mould with 8 in. base diameter, 4 inches. top diameter, and height of 12 inches was utilized.

*Compressive Strength*

The primary objective of this research was to identify the optimal mix design with the highest compressive strength; thus, this test was conducted using 150mm x 150mm x 150mm cubes following ASTM C39/C39M guidelines. After one day of casting, the cubes were de-moulded and water-cured until the 28<sup>th</sup> day when testing occurred. This assessment was facilitated using a state-of-the-art Universal Compressive Strength Machine (UTM), which facilitated precise and controlled loading at a maximum rate of 5 mm per minute under displacement control. Three cubes per specimen were cast and the average result was used to determine the concrete's strength.



*Figure 2: Test cube casting and testing process*

*Wet and Dry Unit Density*

The research experiment was to create a lightweight concrete mix. To achieve this, the unit weight of each specimen needs to be evaluated. The dry and fresh weights were precisely weighed using an electronic balance with a minimum count of 0.1 mg. Dry and wet unit

densities were determined by dividing the weights of the fresh and dry concrete cubes by their respective volumes, following ASTM C138 guidelines.

**Data Analysis and Discussion**

The results of the conducted research on the influence of CBA and recycled glass on the compressive strength of lightweight concrete provide critical insights into the performance and properties of the developed concrete mixtures. Through a comprehensive analysis of the experimental data, key trends and correlations emerge, shedding light on the intricate interactions between varying percentages of replacements and different W/C ratios. These findings contribute to a deeper understanding of the potential implications for sustainable and high-performance concrete formulations in the construction industry.

***Wet and Dry Unit Density***

The research investigation, documented in Figure 3 and Figure 4, examined the intricate interplay between different W/C ratios with varying percentages of CBA, recycled glass as substitutes for aggregate, and the resulting dry and wet density of concrete. Notably, the observed decline in overall dry density with increasing replacement percentages aligns with expectations derived from the current literature background (Singh & Siddique, 2015) (Mangi, et al., 2019) (Du & Tan, 2014). Furthermore, the observed increase in dry density values with decreasing W/C ratios aligns with established theories in the field. These complex findings, backed by detailed analysis and interpretation, are thoroughly discussed in the subsequent discussion section of the research report.
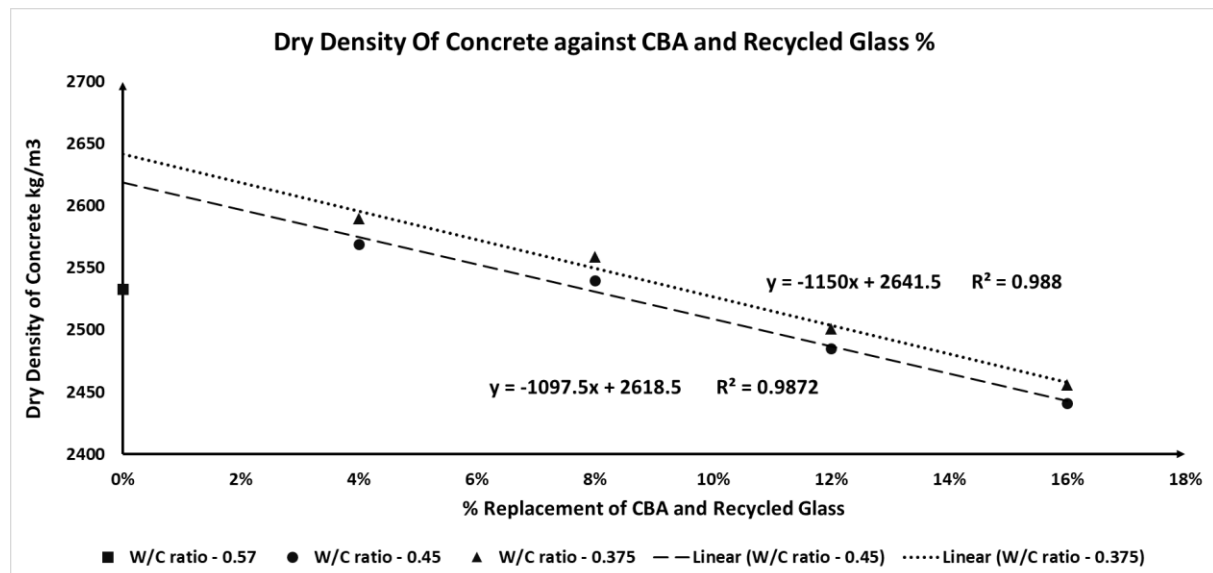


*Figure 3:Concrete dry density: aggregate replacement & w/c ratio impact*

The inclusion of Coal Bottom Ash (CBA) and recycled glass distinctly impacts the dry unit density of the concrete, as demonstrated in Figure 3. The graph exhibits a pronounced decrease in the dry unit density as the proportion of these lightweight materials increases, indicating their efficacy in reducing the overall density of the concrete mixture. Notably, the high R-square values of 0.988 for the 0.375 W/C ratio line and 0.9872 for the 0.45 W/C ratio line

signify a robust correlation between the variables, affirming the reliability of the data analysis. Analysis of the graphical representation of Figure 5, reveals that the 0.45 and 0.375 W/C ratio lines initially were higher than the control specimen's dry density with up to 8% substitution of CBA and recycled glass. However, beyond 8% substitution, a noticeable decline below the control indicates the attainment of lightweight properties. This underscores the role of CBA and recycled glass in reducing the dry density, owing to their porous and lightweight characteristics identified by previous literature (Choo & Newman, 2003) which enables more efficient packing within the concrete mixture. These findings align with existing research on lightweight additives, affirming their significance in developing sustainable and structurally sound lightweight concrete predicted to be achieved based on previous literature (Choo & Newman, 2003) (Nazri, et al., 2019) (Al-Sibahy & Edwards, 2012).

Nevertheless, it is crucial to note that the decrease in the water-cement (W/C) ratio to enhance the concrete's strength properties leads to an elevation in the dry density compared to that of conventional concrete. This underscores the delicate balance required between achieving lightweight properties and preserving the necessary structural strength. Consequently, a meticulous equilibrium must be achieved between the incorporation of lightweight materials and the optimization of the W/C ratio to attain the desired mechanical performance while minimizing the overall density of the concrete.
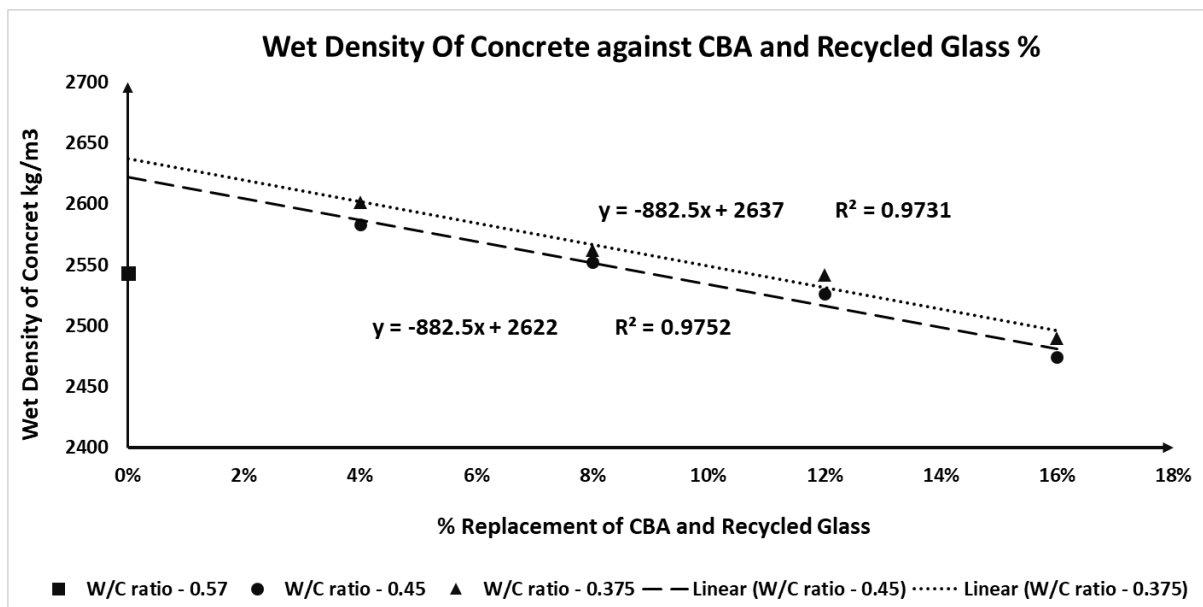


*Figure 3:Concrete wet density: aggregate replacement & w/c ratio impact*

The wet unit density demonstrated a similar trend to dry density, with slightly different R-square values of 0.975 for the 0.45 W/C ratio and 0.973 for the 0.375 ratio, as depicted in Figure 4. In contrast, to dry concrete, the behavior of wet concrete is influenced by factors like workability, consistency, and the amount of entrapped air. The reduction in wet unit density with the increased addition of CBA and recycled glass could be attributed to their lightweight nature, which facilitates a more dispersed and less densely packed concrete matrix.

As a result, the wet concrete experiences lower unit density due to the presence of air voids and the overall distribution of lightweight materials within the mixture. Conversely, the

increase in wet unit density with the decrease in the water-cement (W/C) ratio is linked to the concrete's improved workability and decreased water content (Varma, 2015) (Felekoğlu, et al., 2007). A lower W/C ratio promotes better particle packing and a denser cementitious matrix, thereby reducing the presence of air voids in the wet concrete. This leads to an increase in the wet unit density as a result of the more compact and closely packed structure.

Understanding these intricacies is crucial in ensuring the optimal design and performance of fresh concrete, as the balance between workability, density, and structural integrity plays a vital role in determining the overall quality and durability of the concrete structure.
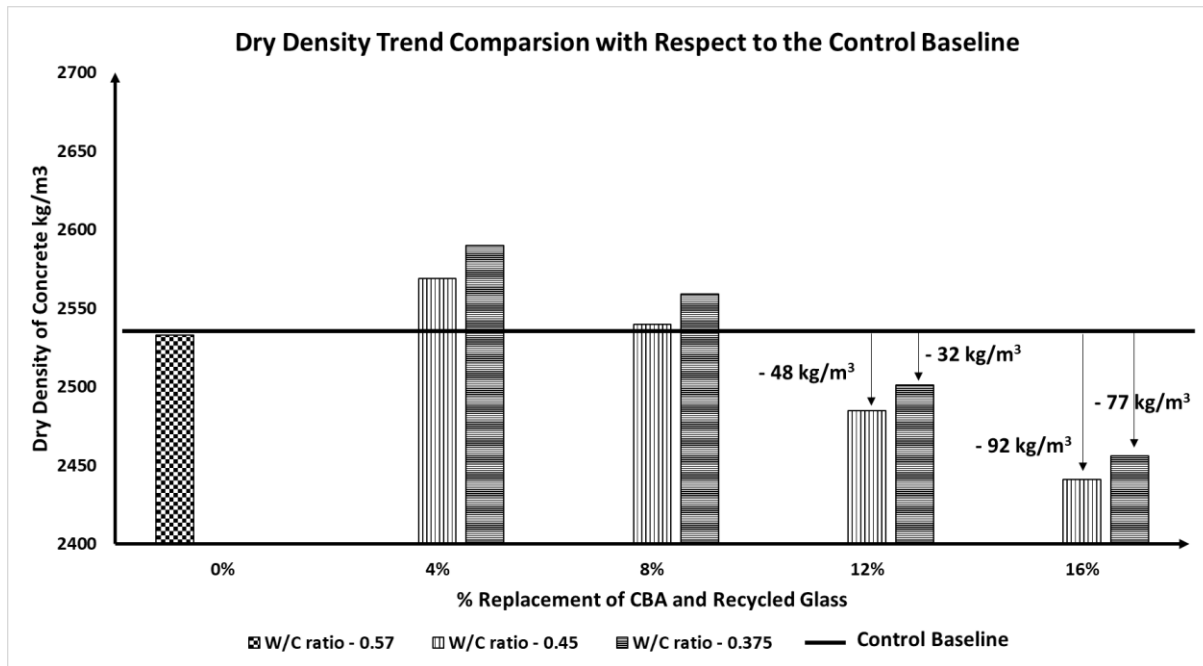


*Figure 4: Concrete dry density trends: aggregate replacement & w/c ratio impact*

### *Compressive Strength*

As shown in Figure 6, the 8% aggregate replacement level, a novel composition, yielded unexpectedly higher compressive strength, deviating from established literature. The results demonstrated a gradual increase in compressive strength as the aggregate replacement percentage increased, with the peak value achieved at 8%. Subsequently, a decline in compressive strength was observed for the subsequent replacement percentages, representing a critical shift from the initially ascending trend. These intriguing findings are comprehensively discussed in the discussion section, shedding light on the unique dynamics governing compressive strength in this innovative concrete mixture.
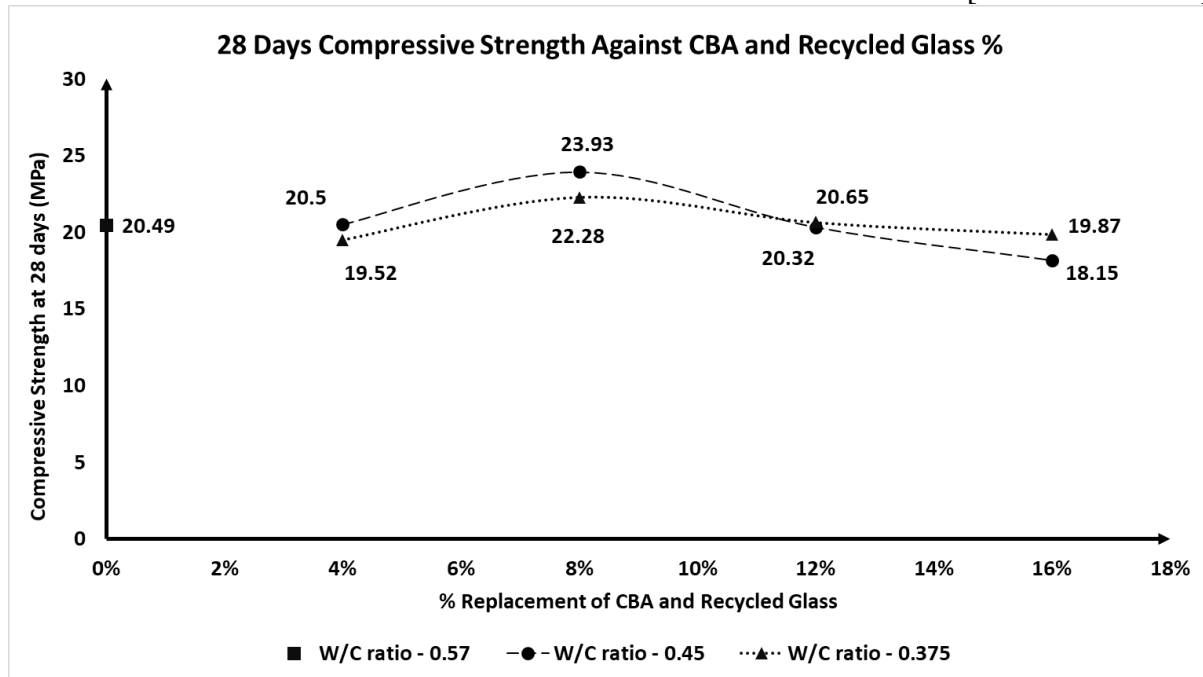
*Figure 5:Compressive strength at 28 days: aggregate replacement & w/c ratio variation*

The compression test results, as depicted in Figure 6, demonstrate an initial rise in the compressive strength at 28 days from 4% to 8% CBA and recycled glass substitution, peaking notably at the 8% mark which was higher than the control benchmark. Subsequently, a decline in strength is observed from 8% to 16% substitution, with the decrease at 16% noticeably less than the control benchmark. This is clearly highlighted in Figure 7. The initial increase in compressive strength is due to the reinforcing effects of recycled glass and Coal Bottom Ash (CBA), known for their pozzolanic properties, leading to improved particle packing and enhanced interfacial bonding within the concrete matrix. Additionally, the lower water-cement (W/C) ratio promotes more efficient hydration and denser cementitious matrix, contributing to the observed surge in compressive strength.

Surprisingly, specimens with a W/C ratio of 0.375 exhibited lower compressive strength compared to those with a W/C ratio of 0.45. This unexpected trend was attributed to the significantly reduced workability at the lower W/C ratio, resulting in challenges during compaction. These findings underscore the critical balance required between achieving optimal strength and ensuring suitable workability, highlighting the pivotal role of the W/C ratio in determining both the mechanical performance and handling characteristics of the concrete

### Workability Test

The workability test results revealed uniformly low workability across all specimens, evidenced by a zero-slump height except for the control sample, which exhibited a slump of 5.7 cm. The limited workability is indicative of the challenging nature of the concrete mixture, suggesting potential difficulties in its handling, placement, and finishing. Further elaboration on the factors influencing this restricted workability is discussed comprehensively in the subsequent sections.

The low workability observed in the specimens can be attributed to multiple factors, including

the absorptive nature of Coal Bottom Ash (CBA) (Andrade, et al., 2009) and the particular properties of the recycled glass, both of which can significantly affect the rheological properties of the concrete mixture. CBA, being a porous material, tends to absorb moisture from the mix, leading to a reduction in the effective water content available for hydration, thus contributing to the stiffening of the concrete. Similarly, the irregular particle shapes of recycled glass may hinder the efficient lubrication between the particles, resulting in increased internal friction and reduced workability (Singh, et al., 2015).

Moreover, the elevated ambient temperature during the mixing process can accelerate the setting time of the mixed concrete, leading to premature stiffening and further complicating the handling and placement of the concrete. This can be particularly challenging for the M15 grade concrete, which typically has a lower water-cement ratio, rendering it less flowable compared to higher-grade counterparts. The inherent design of the 1:2:4 mix proportion further exacerbates the issue, as the relatively lower water content in the mix results in a stiffer concrete paste that is difficult to manipulate and compact.

### *Compressive Load to Dry Unit Density Ratio Analysis*
The analysis of the data highlighted in Figure 7, depicts a crucial aspect of the research, emphasizing the delicate balance between achieving optimal compressive strength and minimizing the dry density in lightweight concrete. The findings underscore the significance of identifying the most suitable combination of CBA and Recycled glass replaced and water-cement (W/C) ratio to achieve the desired lightweight properties without compromising the concrete's structural integrity.

Notably, the optimal design is achieved at 8% CBA, and Recycled glass is replaced with a W/C ratio of 0.45, striking a balance between reduced density and enhanced compressive strength. Further examination reveals that the 12% CBA and Recycled glass replaced option is also preferred, offering a significantly lighter composition while still surpassing the benchmark. These trends shed light on the critical role played by the selection of materials and W/C ratio in achieving lightweight concrete with robust mechanical performance. Such insights hold the potential to inform future advancements in lightweight concrete design, fostering innovation and sustainability in the construction industry.
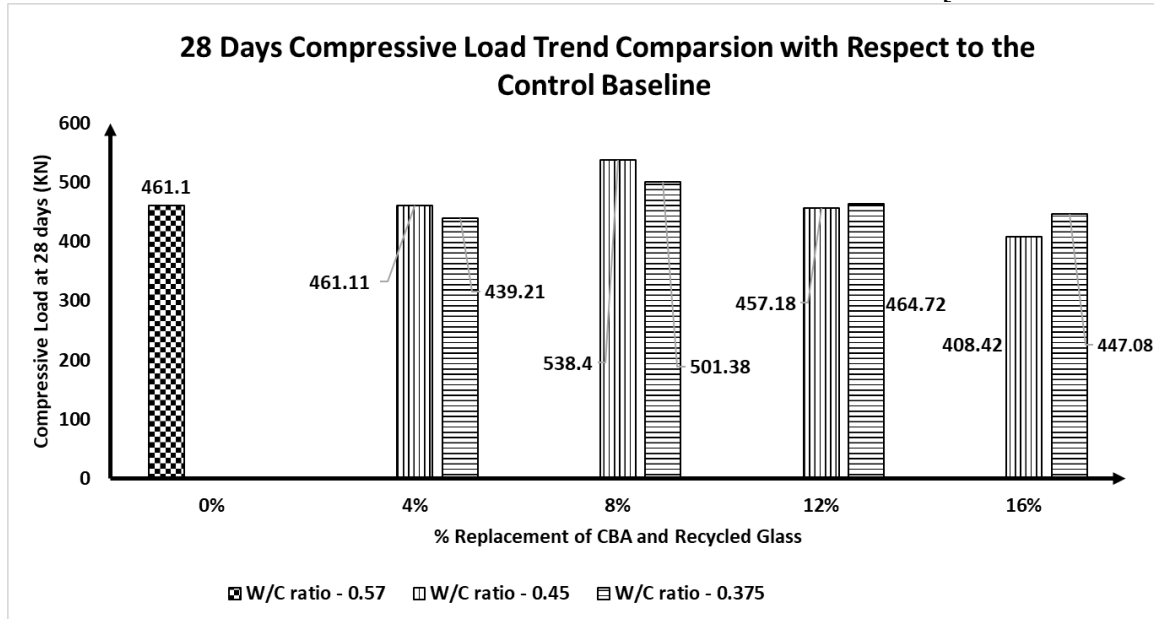
**28 Days Compressive Load Trend Comparsion with Respect to the Control Baseline**

Figure 6: Compressive load trend at 28 days: aggregate replacement & W/C ratio variation
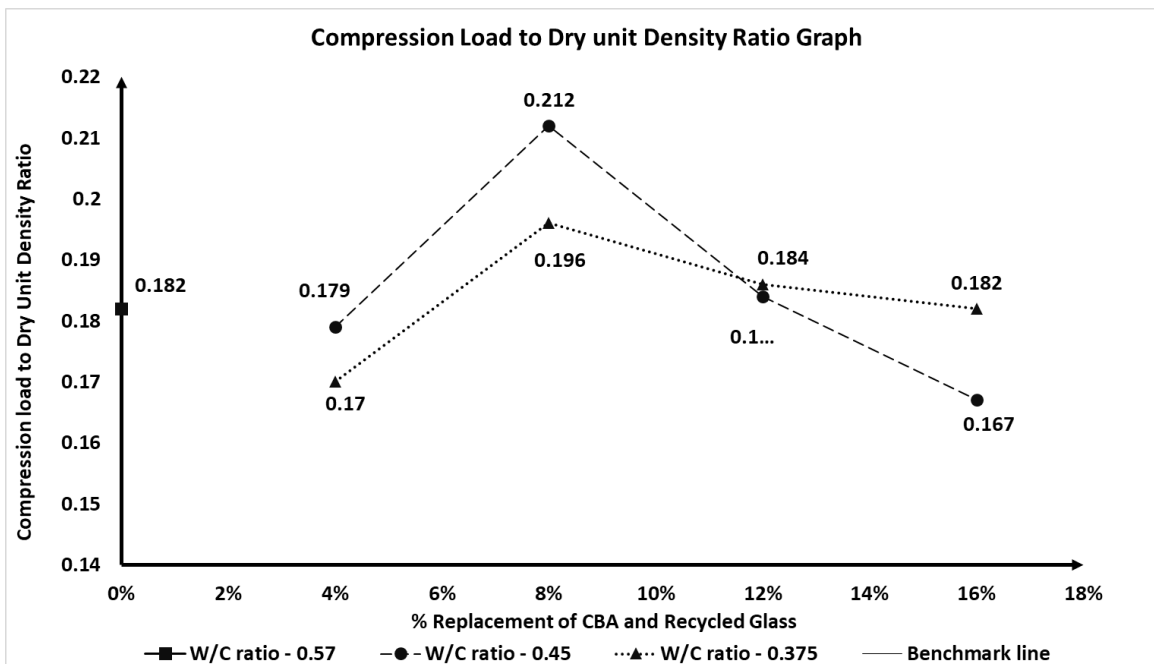
**Compression Load to Dry unit Density Ratio Graph**

Figure 7: Compressive load at 28 days to dry unit density ratio variation

**Conclusions**

This research aimed to determine the most effective mix design for high-performance lightweight concrete, utilizing coal bottom ash (CBA) as a substitute for fine aggregate and recycled glass for coarser aggregate. The study encompassed a comprehensive review of existing literature on CBA and recycled glass in concrete, examining the impact of various substitutions on compressive strength at different water-cement ratios.

An extensive analysis was conducted, comparing the properties of the modified concrete with those of conventional concrete. The findings revealed that the most substantial reduction in density while maintaining comparable strength occurred within the 12% to 16% substitution

range. In contrast, the 8% and 4% substitution levels, despite exhibiting higher compressive strength, did not effectively showcase the desired lightweight properties.

The elevated dry density at these levels, resulting from the lower water-cement ratio, contributed to this limitation. It was determined that the critical threshold for achieving genuine lightweight characteristics was within the 12% to 16% substitution range.

However, the study encountered limitations concerning Grade 15 concrete, which exhibited lower workability, leading to improper compaction and subsequently lower compressive strength. Nonetheless, upon thorough analysis and discussion, it became evident that higher substitutions were viable without significantly impacting the compressive strength. This observation highlights the potential for exploring higher substitution levels to achieve enhanced lightweight properties without compromising structural integrity.

**Recommendations**

The below recommendation can be derived based on the findings and observations of the present research.

Suggested Proportions for Grade 15 Concrete: Based on the study's findings, it is recommended to consider a substitution range of 12% to 16% along with a water-cement (W/C) ratio of 0.45. This strategic combination enables the achievement of lightweight properties without compromising the compressive strength, ensuring an efficient and effective construction process.

Priority Research on Grade 30 Concrete: Emphasize the need for in-depth research specifically focused on Grade 30 concrete to address the identified workability challenges encountered in Grade 15. This dedicated investigation will significantly enhance the overall performance of lightweight concrete applications, bolstering the durability and adaptability of construction materials.

Exploration of Higher Substitution Ranges and W/C Ratios: Investigate the implications of higher percentage substitution ranges in conjunction with both 0.45 and 0.375 (lowered) water-cement ratios. This critical analysis aims to optimize the concrete mix design, reducing the water-cement ratio while maintaining the structural integrity and functional excellence of lightweight concrete.

Implementation of Advanced Methodologies: Implement advanced and innovative methodologies to overcome the limitations associated with lower water-cement ratios, thereby enhancing the workability and compaction of lightweight concrete. Prioritizing the deployment of these sophisticated techniques will streamline construction processes and ensure the seamless integration of lightweight concrete across diverse building projects.

By focusing on the above recommendations, the construction industry can effectively leverage the findings of this study to advance the use of high-performance lightweight concrete, fostering sustainable and efficient construction practices

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# INNOVATIVE APPROACHES TO TRANSFORMING EXISTING RESIDENTIAL BUILDINGS INTO HIGH-PERFORMANCE GREEN BUILDINGS THROUGH ENHANCING ENERGY EFFICIENCY

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**Abstract**

In the construction industry, buildings directly contribute to all major environmental issues. Therefore, the industry introduced the concept of "Green Building", aiming to utilize fewer resources than conventional buildings, and hence can be part of the solution for environmental issues. This research paper investigates the importance of the "Green Building" concept and mainly focuses on energy efficiency strategies as a pivotal principle within the sustainable green building concept. The paper aims to identify and propose viable energy efficiency strategies tailored to the context of the Sri Lankan existing residential structures. Furthermore, the study investigates the economic benefits associated with implementing such strategies, emphasizing their potential impact on the overall sustainability of buildings. Archival research has been conducted for this study. Moreover, the paper explores the advantages of applying energy efficiency strategies as an innovative approach during the economic crisis in Sri Lanka.

**Keywords**: Construction, Energy efficiency, Green Building, Sustainability

## Introduction

The construction industry is significant in a country that serves as the bedrock for societal progress and development. Industry contributes greatly to economic growth by generating employment opportunities and contributing substantially to a nation's GDP (Gross Domestic Product). Residential building projects play a significant role in the industry, with varying sizes ranging from small-scale to large-scale developments. The execution of construction projects involves numerous activities and processes that have the potential to affect the economy, environment, and society adversely. Therefore, sustainability became popular in the industry to reduce the economic, environmental, and social negative impacts of construction projects along with their nature. (Zabihi, H. ,Habib, F. and Mirsaeedie, L., 2012). The "Green Building" concept was created when developing residential buildings to achieve sustainability by addressing energy efficiency concerns in construction, maximizing resources, and reducing the impact of emissions on the environment. (Mousavi et al, 2023). Energy efficiency is one of the key aspects of sustainability in green buildings (Ann, C.M. and Abualrejal, H.M., 2015). Furthermore, the authors explained that energy efficiency brings several benefits to society such as managing increasing energy costs, reducing environmental impacts, reducing the emission of greenhouse gases, and adding value to enhance the competitiveness of green buildings. The study used previous research studies, conference proceedings, and journal articles. This research is based on three main objectives. (1) Identify the principles and significance of the green building concept when developing residential buildings. (2) Study existing energy efficiency methods and techniques with a focus on their applicability to existing

residential buildings and identify access strategies that enhance the sustainability and performance of the building. (3) Investigate and propose innovative solutions for addressing Sri Lanka's economic downturn by adopting energy efficiency methods and techniques in existing residential buildings. Adopting energy-efficient strategies in the residential consumption context of Sri Lanka can serve as a potential solution to address the energy crisis and reduce the elevated costs associated with energy consumption.

**Methodology**

Data for this study was gathered from diverse sources, including Emerald Insight, Google Scholar, and ScienceDirect, through searches using the terms "Green buildings" and "Sustainable buildings." Subsequently, from the initially retrieved hundred papers, a refined selection process was employed to identify the top fifty most relevant past research papers. These carefully curated papers were then utilized to conduct an archival research study.

*Literature Review*
*The Concept of Green Building & and Its Importance*

Green building is one of the approaches to sustainable construction development. Constructing a healthy built environment focusing on energy efficiency resources is the main objective of the green building concept. (Ann, C.M. and Abualrejal, H.M., 2015). The green building concept concerns specific key areas such as efficient resource distribution, reduction of energy consumption, reduction of embodied energy, promoting reuse, recycling activities, and many more to achieve sustainability. Green buildings can be known as sustainable or "high-performance buildings".

Ibrahim (2017) found that green buildings need to incorporate several key features.

Energy efficiency is often viewed as a fundamental aspect and some organizations consider it a cornerstone. In addition, other features such as recycled materials, recycled water, and sustainable equipment contribute to the overall sustainability of green buildings. When developing a green building, construction activities and processes should be carried out, taking into consideration these key factors.

1. Minimal disturbance to landscapes and site conditions
2. Use of non-toxic and recycled materials
3. Efficient use of water and water recycling
4. Use of energy-efficient and eco-friendly equipment
5. Use of renewable materials
6. Quality of indoor air quality for human safety and comfort
7. Effective controls and building management systems.

Green buildings provide diverse benefits in environmental conservation, including biodiversity enhancement, ecosystem protection, and improved air and water quality. Economically, they reduce operating costs, enhance asset value, and optimize life-cycle performance. Societal advantages encompass improved health, indoor air quality, and overall quality of life, emphasizing the comprehensive benefits of green building practices.

### Design principles of green buildings

The green building design process commences by deeply understanding the site's intricacies, embracing an ecological approach that integrates introduced systems with existing on-site ecological functions. These functions include providing habitat, responding to sun movements, air purification, and water catchment. This is crucial in urbanized areas to bolster biodiversity and a robust ecosystem. The approach emphasizes creating new habitats on structures to support diverse species and maintain a healthy environment (Radwan et al, 2015).
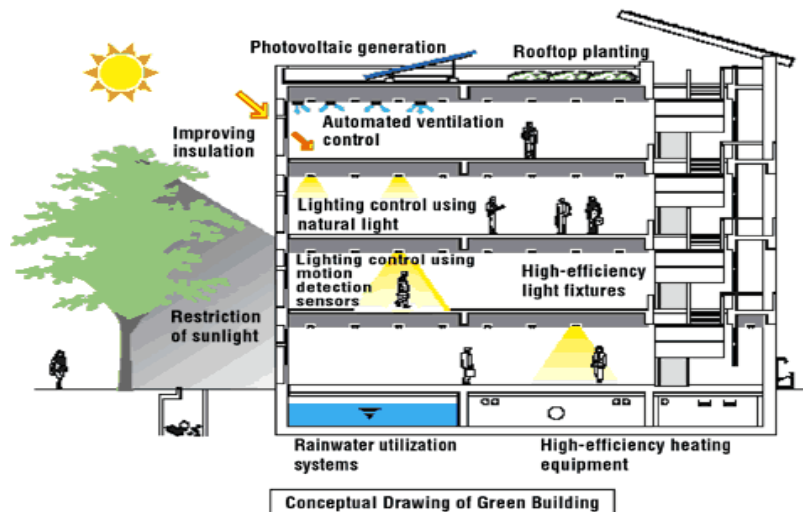


*Figure 1 : Conceptual Drawing of Green Building*

### Green Building Rating Systems

Utilizing tools that can assess the sustainability of buildings throughout their life cycle is crucial in enabling the transition towards a sustainable built environment, considering environmental, social, and economic aspects. Therefore, various Green Building Rating Systems (GBRS) have arisen in the last few decades, and they have been reviewed from different perspectives. (Braulio-Gonzalo, M., Jorge-Ortiz,A. and Bovea,M.D., 2022)

Furthermore, the authors stated in their paper that the initial advancement of Green Building Rating Systems (GBRS) came with the creating of the Building Research Establishment Environment Method (BREEAM) in 1990. Subsequently, various international organizations including the World Green Building Council (WGBC) established in 1990, the International Initiative for Sustainable Building Environment, and the Sustainable Building Alliance, have contributed to the development of new tools, applicable worldwide. However, some of the Green Building Rating Systems (GBRS) have been progressively adjusted to specific regions/countries to meet their contextual requirements.

The Green Building Council of Sri Lanka (GBCSL) was established to apply greener practices in building construction to achieve sustainability (Waidyasekara,K.G.A.S. and Fernando,W.N.J.K., n.d.).

*Figure 2 : Various Green Building Rating Systems*

***Energy Efficiency in Green Buildings***

Energy efficiency is the key to achieving sustainability in green building. (Ann, C.M. and Abualrejal, H.M., 2015). Zero-energy building is not a realistic solution, but low-energy building design would be the most possible target to achieve in sustainable building design, as evidenced by the research conducted by (Zin, M.H.M. and Ibrahim, N.L.N., 2012).

In addition, the authors stated in their paper that every building requires energy to operate, and efficient energy management is the most effective approach to reducing adverse environmental effects.

***Innovative Approaches to enhance energy efficiency in existing residential buildings.***

If a residential building has not been initially constructed with green building principles, it can be converted into a green building without causing detriment to the existing structure through the adoption of energy efficiency approaches. According to (Ann, C.M. and Abualrejal, H.M., 2015), energy efficiency can enhance productivity and trim down inflation problems. Sri Lanka has been going through a massive economic crisis and the economy has been suffering from a severe crisis. Simultaneously Sri Lanka has been facing a tremendous fuel shortage due to the economic crisis. (Nandy, D., Al-Mumun,A. and Akon, S., 2023). Amidst the ongoing economic and energy challenges, the Sri Lankan government has consistently raised electricity tariffs, causing significant hardship for the general population. In response to this, addressing the residential energy crisis through the implementation of energy practices and management has emerged as a potential solution. (Caldera et al, 2023), determined that Sri Lanka has scarce indigenous fossil fuel reserves but plentiful solar, wind, hydro, and sustainable biomass resources distributed throughout the island and the current crisis in Sri Lanka presents an opportunity to reinvent the energy system to one that is based on abundant indigenous renewable energy (RE) resources and able to meet the country's energy demand. Numerous approaches and strategies exist for improving the energy efficiency of existing buildings. A few of the methods and techniques are outlined below. Solar thermal panels use energy from the sun to heat water or air for space heating, providing a renewable and sustainable alternative to conventional heating systems. Infrared heating panels utilize radiation to warm objects in the room, offering a more precise and efficient heating method that requires minimal maintenance. It is necessary for guidance from professionals to identify the most suitable green heating method based on location, climate, size of the home, and availability of renewable energy sources. (Farghali et al, 2023). (Zin, M.H.M. and Ibrahim, N.L.N., 2012), stated that

"Photovoltaic (PV) cells can be used to convert the energy of the sun directly into electricity, without noise or pollution, and with little visual impact and they can be integrated with building elements such as roof and walls to be more economical. Natural daylight represents a valuable strategy to decrease electricity expenses in residential buildings. By strategically incorporating sufficient well-designed windows, skylights, and other architectural features, residents can minimize their reliance on artificial lighting during daylight hours. This contributes to cost saving while enhancing the overall energy efficiency of the building, aligning with suitable and eco-friendly practices. According to (Ann, C.M. and Abualrejal, H.M., 2015), LED light bulbs, currently experiencing rapid growth which can save energy and less energy consumption which can achieve energy efficiency effectively in the building. In certain regions of Sri Lanka blessed with wind resources, harnessing wind energy emerges as a promising solution to address the nation's energy challenges by generating electricity through wind power. However, the successful implementation of this approach relies heavily on the proactive involvement of the government and other professionals. It is their responsibility to spearhead initiatives that encourage public engagement, provide financial resources, and comprehensive knowledge, and equip the population with the necessary technology and tools. Above mentioned strategies and techniques can be implemented within existing residential buildings without changing the structures. It is necessary to provide knowledge and awareness about energy efficiency strategies when implementing these methods and techniques. Adopting these methods and techniques can gain economic benefits while simultaneously improving the eco-friendliness and longevity of buildings.

**Conclusion**

In summary, this research paper highlights the vital role of green building concepts and energy efficiency strategies in advancing sustainable residential construction. The construction industry's impact on economic and societal growth, particularly through residential projects, is emphasized. The adoption of green building principles, aiming to alleviate environmental and social impacts, is crucial. Key considerations in green building design encompass landscape preservation, resource efficiency, and indoor air quality. The integration of green building rating systems and a focus on energy efficiency contribute to sustainable construction. The study's emphasis on innovative approaches for energy efficiency aligns with Sri Lanka's economic challenges, offering solutions for energy crises and sustainability. Identified strategies, including solar thermal panels, infrared heating, photovoltaic cells, daylight utilization, and wind energy, provide practical solutions for energy efficiency without structural changes. The research advocates the widespread adoption of energy-efficient methods for economic benefits, environmental sustainability, and building longevity.

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# ADOPTING GREEN LEASING AS A COMMERCIAL OPTION FOR GREEN BUILDING CONCEPT IMPLEMENTATION IN THE SRI LANKAN BUILDING CONSTRUCTION INDUSTRY

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**Abstract**

In delving into the intricacies of implementing green building concepts in Sri Lanka's construction sector, this research takes a comprehensive mixed-methods approach. The study rigorously examines the significance of green leasing, meticulously identifying both the obstacles impeding its adoption and the factors that facilitate its integration into the industry. The findings underscore a paramount need for heightened awareness and knowledge within the sector to overcome the challenges observed. A crucial revelation is made through the analysis, emphasizing that for sustainable adoption, stakeholders must be well-informed and conscious of the benefits and practices associated with green leasing. While the research successfully sheds light on these aspects, it candidly acknowledges the inherent methodological limitations encountered along the way. This acknowledgment underscores the importance of adopting a balanced research approach in future endeavors, ensuring a more nuanced understanding of the complexities involved in fostering green practices within the Sri Lankan construction landscape. Striking this balance becomes imperative for the robustness and relevance of future research in advancing sustainable building practices in the region.

**Keywords:** Construction, Green Leasing, Green Building, Commercial Options, Sustainability.

**Introduction**

Within the ever-changing context of Sri Lanka's building construction sector, including sustainable practices has become essential, calling for a closer look at new strategies like green leasing (Hettige, *et al*., 2017). The notion of green leasing presents itself as a viable means of promoting a more environmentally conscious built environment, particularly as the construction industry struggles with issues related to resource usage and environmental effect. Like many other industries worldwide, the building and construction sector in Sri Lanka is at a crossroads where environmental responsibility and economic prosperity must align. The industry's standard procedures frequently fail to meet the growing issues of resource depletion, energy use, and environmental sustainability in general. The study centers on green leasing, which is a deliberate partnership between renters and landlords with the goal of overseeing sustainable building operations, in response to this urgent demand building (Abdelfattah, 2020).

However, despite the growing recognition of the importance of sustainable construction practices, there is a significant research gap in understanding and implementing commercial options in the green leasing sector in the Sri Lankan context. This study aims to explore

unexplored avenues and highlight how commercial options can play a key role in advancing green building concepts (Hettige, *et al*., 2017). To emphasize the originality of our study, it is important to highlight a unique research gap in the existing literature. Although the global conversation on green leasing has gained momentum, the specific challenges and opportunities in Sri Lanka's construction sector have been less explored. Our research seeks to fill this void by focusing on the unique case of Sri Lanka, focusing on aspects that are often neglected in broader discussions of green building practices (Abdelfattah,2020). By addressing this research gap, our study not only contributes to the academic discourse but also provides practical insights to industry stakeholders, policymakers, and practitioners who wish to navigate the intersection of economic interests and environmental sustainability in the Sri Lankan context. This research aims to investigate the adoption of the green lease concept as a commercial option to implement green building concepts in the Sri Lankan construction sector.

*Research Objectives*

To study the concept of green lease and understand its importance to the Sri Lankan building construction industry.

To identify impediments and adoptions of the green leasing concept

To research the factors that can implement the green lease concept in the Sri Lankan building construction industry and recommend solutions to reduce the obstacles in implementation.

To develop a framework for the adoption of the Green Lease concept in Sri Lankan building construction industry.

The significance of this research lies in its potential to catalyze a paradigm shift within the Sri Lankan construction industry. By unraveling the complexities surrounding green leasing, the study aspires to provide stakeholders, policymakers, and industry players with valuable insights. These insights, in turn, can inform strategic decisions, reshape industry practices, and contribute to the overarching goal of creating a more sustainable built environment in Sri Lanka. As the nation strives for economic progress, the integration of green leasing practices not only aligns with global sustainability trends but also positions Sri Lanka at the forefront of environmentally responsible construction practices. The outcomes of this research can thus serve as a guiding beacon for transformative change within the industry, fostering a balance between economic growth and environmental ownership.

**Methodology**

To comprehensively investigate the adoption of commercial options for green building concepts in the Sri Lankan construction industry, a mixed-methods approach was employed. This methodological framework integrates both qualitative and quantitative analyses, allowing for a nuanced understanding of the multifaceted factors influencing the implementation of green leasing concepts. Digitalized questionnaire will be conducted with industry experts to gather primary data. The questions will be semi-structured, allowing for flexibility and in-depth exploration of the research objectives. The research's qualitative component entailed a thorough investigation of the individualized elements associated with green leasing. We made use of academic journals, business briefs, and in-depth interviews with significant figures in

the Sri Lankan construction industry. The goal of this qualitative technique was to capture the complex viewpoints, opportunities, and difficulties related to green leasing. Using content and theme analysis, significant insights were drawn from the collected qualitative data. Quantitative data collection involved a structured survey distributed among a representative sample of stakeholders within the Sri Lankan building construction industry. The survey instrument was designed to capture quantitative information on awareness levels, challenges faced, and factors influencing the adoption of green leasing practices. The statistical analyses included correlation analysis to identify relationships between variables and regression analysis to model the impact of key factors on the adoption landscape.

Snowball Sampling Strategy, in this approach, industry experts who possess in-depth knowledge and experience in green building practices will be identified as the initial participants. These experts will be selected based on their involvement in sustainable construction projects, relevant publications, and recommendations from industry professionals. Additional participants will be identified through referrals from the initial experts, forming a network of knowledgeable individuals. This sampling strategy allows for the inclusion of experts who may not be easily accessible through traditional sampling methods.

In-depth interviews and a methodical evaluation of pertinent literature were used to gather qualitative data. A digitally distributed structured survey was used to gather quantitative data, and a secure platform was used to collect replies. Both open-ended and closed-ended questions were used in the survey to elicit further information and to quantify important variables.

**Results**

The validity analysis encompassed the Kaiser-Meyer-Olkin (KMO) measure and Bartlett's Test. The KMO measure recorded a value of 0.814, signifying a highly satisfactory level of adequacy for the dataset. This suggests that the data is suitable for factor analysis, a crucial aspect of validating the underlying structure of the research constructs. Bartlett's Test of Sphericity, with an approximate chi-square value of 107.484 and a significance level of 0.001, further supports the suitability of the data for factor analysis. These results affirm the dataset's adequacy for exploring underlying patterns and relationships between variables. The reliability analysis, as measured by Cronbach's alpha, returned a value of 0.837. This high alpha value indicates a strong level of internal consistency among the items in the survey instrument. In the context of hypothesis testing, a reliable survey instrument ensures that the data collected consistently measures the intended constructs. Researchers can have confidence in the dependability of the results, reinforcing the robustness of the study's findings.

Table 1: Reliability Statistics

| Reliability Statistics | |
| --- | --- |
| Cronbach's Alpha | N of Items |
| .837 | 12 |

Table 2: Validity Analysis

| KMO and Bartlett's Test | | |
|---|---|---|
| Kaiser-Meyer-Olkin Measure of Sampling Adequacy. | | .814 |
| Bartlett's Test of Sphericity | Approx. Chi-Square | 107.484 |
| | df | 66 |
| | Sig. | .001 |

The analysis provides robust support for Hypothesis 1, affirming a positive relationship between the range and accessibility of commercial options (IV1) and the adoption of green lease concepts. Both qualitative and quantitative evidence, including a comprehensive literature synthesis, correlation analysis, and regression model, align with the hypothesis, emphasizing the pivotal role of diverse and accessible commercial options in shaping the adoption landscape.

Hypothesis 2 is strongly validated by the findings, indicating that barriers and challenges (IV2) exert a negative influence on the adoption of green lease concepts. Through a combination of qualitative insights and quantitative measures such as regression analysis and ANOVA, the study underscores the significant adverse impact of barriers like low awareness, budget constraints, and emerging regulations on the adoption landscape.

The analysis convincingly supports Hypothesis 3, highlighting a positive impact of cost-effectiveness and affordability (IV3) on the adoption of green lease concepts. The results from the regression model and ANOVA underscore the statistical significance of this relationship, providing valuable insights for stakeholders seeking to promote the adoption of green leasing practices in the Sri Lankan building construction industry.

Hypothesis 4 is strongly affirmed by the analysis, indicating a positive correlation between awareness and knowledge (IV4) and the adoption of green lease concepts. Both qualitative synthesis of the literature and empirical evidence from the regression model and correlation analysis emphasize the crucial role of awareness and knowledge in overcoming barriers and fostering the adoption of green lease concepts in the Sri Lankan context.

Table 3: Model Summary

| Model Summary | | | | |
|---|---|---|---|---|
| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate |
| 1 | .657[a] | .431 | .420 | .65963 |

Table 4: ANOVA

**ANOVAᵃ**

| Model | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| 1 | Regression | 62.467 | 2 | 31.233 | 36.886 | .000ᵇ |
| | Residual | .000 | 117 | .000 | | |
| | Total | 62.467 | 119 | | | |
| a. Dependent Variable: Green Lease | | | | | | |
| b. Predictors: (Constant), Challenges, Awareness and Knowledge | | | | | | |

Table 5: Coefficients

**Coefficients**

| Model | | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. |
|---|---|---|---|---|---|---|
| | | B | Std. Error | Beta | | |
| 1 | (Constant) | 2.059 | .066 | | 1.730 | .000 |
| | Awareness And Knowledge | .081 | .080 | -.556 | -4.459 | .000 |
| | Challenges | 1.500 | .000 | 10.825 | .000 | .000 |
| a. Dependent Variable: Green Lease | | | | | | |

**Discussion**

This study delves into the dynamics of green leasing adoption within the Sri Lankan construction industry and explains unique challenges and opportunities. The findings underscore a pivotal role for awareness initiatives, mirroring global trends. However, the contrast between the global discourse on green leasing and its nascent stage in Sri Lanka highlights a distinctive context. Comparative analyses with international practices offer insights into potential strategies for overcoming barriers, emphasizing the need for context-specific interventions. Bridging this knowledge gap not only contributes to the global dialogue on sustainable construction but also provides a roadmap for tailored advancements in Sri Lanka's evolving real estate landscape.

**Conclusions and Recommendations**

This study sheds light on the Sri Lankan construction industry's adoption of green buildings and the use of green lease principles. The results, which are backed up by a thorough methodology, point to a positive future with a strong uptake of green buildings. Most importantly, the study draws attention to the obstacles most notably, poor awareness and limited resources that call for focused solutions. The significance of educational programs is highlighted by the favorable association observed between awareness, knowledge levels, and acceptance of green leases.

Recommendations based on the study's findings are meant to accelerate Sri Lanka's implementation of green lease ideas. The suggested activities constitute a strategic roadmap and range from thorough workshops and regulatory studies to cooperative platforms and established rules. Stakeholders may actively contribute to a sustainable built environment and

ensure a healthy balance between economic development and environmental stewardship by raising awareness, removing barriers, and promoting collaboration.

Table 6: Recommendations

| Recommendations | | |
|---|---|---|
| Conduct comprehensive workshops to enhance awareness among industry stakeholders regarding the benefits and implementation of green leasing. These workshops should cover the principles, advantages, and practical applications of green leases, fostering a deeper understanding within the construction community. | Create collaborative platforms that bring together key players in the construction industry, including developers, occupiers and regulators. These platforms can serve as forums for sharing best practices, discussing issues and working collectively towards the common goal of sustainable construction. | Develop clear and well-defined rules and guidelines for the implementation of green leasing in the construction industry in Sri Lanka. These should include green building certification standards, tenancy provisions and dispute resolution mechanisms, providing a structured framework for industry stakeholders to follow. |

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# IMPACT OF THE FLYASH ON COMPRESSIVE STRENGTH PERFORMANCE OF LIGHTWEIGHT CONCRETE BY SUBSTITUTING PLASTER SAND

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## Abstract

In modern days, most structural engineering industries face a lot of failures such as compressive and tensile failures, bending failures, shear failures, and buckling failures. Compressive strength failure also generally affects Sri Lankan buildings during construction or after that. Because it is the main indicator of how effectively concrete can resist loads that impact its size, taking this aspect of concrete into consideration is vital. Therefore, concrete has great compressive loading resistance. In recent years, a technique for improving the strength of concrete by utilizing self-curing ingredients for internal curing has been developed. Fly ash can be added to cement to improve concrete strength as a solution to strength failure. The strength qualities of the concrete are tested by keeping it in ambient curing in the laboratory at a temperature of 27`C, and the experimental results on the concrete of up to 30% replacement of fly ash with cement have been revealed. Furthermore, this research is being undertaken to add different percentages of fly ash (>30%) and to analyze the strength of lightweight concrete up to the typical M25 grade of concrete.

**Keywords:** Lightweight concrete, Compressive strength, Workability, Mix proportion, Fly ash percentages, Cast and curing, expanded clay

## Introduction

Construction activity has been quickly expanding for the development of infrastructure, and concrete as an essential material has seen a surge in its use for structure construction. (Feng, et al., 2023) Because of the numerous areas of utilization, concrete is the second most consumed material on the planet, solely after water, with a worldwide creation of around 4.1 billion tons of concrete in 2021 (Monteiro,, et al., 2017) (Nilimaa, 2023). Modern infrastructure development and construction engineering need excellent material performance, which translates to great energy absorption capacity, hardness, and strength. Novel materials that can achieve an ultimate compressive strength of 120–240 include High-Performance Concrete (HPC) and Ultra High-Performance Concrete (UHPC). The use of additional cementitious materials, including fly ash (FA), enables the development of mechanical qualities, such as strength, workability, and durability (Cucuzza, et al., 2023).

(Bejan G. , Bărbuță, Robert, Vizitiu, & Burlacu, 2020) Since light buildings reduce their weight, the frequency of natural disasters like earthquakes throughout the world has raised the demand for lightweight structural solutions. For concrete, a density of less than 2200 kg/m3 qualifies it as lightweight. ( Wibowo & Saidani, 2023) By this concept, BS EN 206–1 describes lightweight concrete as having an oven-dry density of at least 800 kg/m3 and not more than

2000 kg/m3, which corresponds to the substitution of lightweight aggregates for natural aggregates. Lightweight concrete may lower concrete volume, rebar branching, and beam size in building projects, despite its high cost per cubic meter drawback. Additionally, by lowering the superstructure loads, the building that made use of the LWC decks was able to save money, build more quickly, and have little impact on traffic (Mousa, et al., 2018) . As a result, by lessening the strain on the building structure, it would also be possible to lower overall construction costs by improving time and cost efficiency. Depending on the use, lightweight concrete might be autoclaved aerated concrete (AAC), foamed concrete, or lightweight aggregate concrete. Rather than employing structural concrete, lightweight concrete blocks are frequently used in the construction of homes. (Chaipanich & Chindaprasirt, 2015) ( Wibowo & Saidani, 2023)

Natural, synthetic, and recycled materials are the primary sources of lightweight aggregate (LWA), a type of aggregate utilized in the creation of concretes and cementitious composites. Various forms of low-weight asphalt (LWA) have been examined and applied, such as waste rubber, pumice, expanded clay, sintered fly ash, oil palm shells, brick chips, and so on ( Saha, et al., 2021), ( Huda, et al., 2018), (Ravindrarajah & Tuck, 1994) ( Akçaözoğlu, et al., 2013) (Mohammed, Azmi, & Abdullahi, 2011) and (Zhang & Aslani, 2021) According to (Prasad, 2017), Fly ash is a fine powder that is a byproduct of burning pulverized coal in electric generation power plants. The use of fly ash in concrete enhances both the strength and durability of hardened concrete as well as the workability of concrete. Fly ash (FA) is a tiny particulate substance that is mostly composed of silica, alumina, and calcium compounds that give it pozzolanic properties. It is precipitated from the stack gases of coal-burning power plants. Fly ash has gained widespread acceptance as a supplemental cementitious ingredient for use in the creation of ecologically friendly concrete mixes because of its advantageous chemistry for use in cementitious mixtures. (Yang, et al., 2019) (Park & l Choi, 2021) Fly ash is generated in enormous quantities across the world, but its recycling rate is far lower than its production rate (Bhatt, et al., 2019) . Just 14% of the approximately 27 million tons of fly ash produced in the US alone in 2019 was recycled (Nassar & Room, 2023). Conversely, around 9 billion tons of concrete are produced annually worldwide. Hence, a significant measure of the fly ash can be utilized as SCM for substantial creation. Concrete created with fly ash has huge energy, natural, and money-saving advantages as it is a waste material and doesn't need the utilization of energy in its creation. Contingent upon the level of fly ash utilized as PC substitution, the subsequent cement can be named high-volume fly ash (HVFA) or low-volume fly ash (LVFA) concrete. (Nassar & Room, 2023)

(Gellert & München, 2010) Say expanded clay, when used as a thermal insulation material, is primarily utilized to fill voids and, for example, helps to improve the sound insulation of suspended floor constructions. Expanded clay is also used as a lightweight aggregate in the production of masonry units and precast concrete elements, as well as to improve the insulating qualities of mortar, render, and plaster in small grain sizes. According to (Boudaghpour, 2008) it is used in structural backfill against foundations, retaining walls, bridge abutments, and other similar structures, LECA can lower earth pressure by 75% when compared to conventional materials, while simultaneously increasing stability and minimizing settlement land deformation.

The present study is to determine a suitable mix design proportion of concrete with fly ash percentage to achieve an optimum compressive strength of lightweight concrete by substituting plaster sand. That this concrete will hold all the components/parameters together and perform the intended function.

## Methodology

### Materials and Methods.

The following materials are employed in these experiments. Ordinary Portland cement of SLS 1697: 2021 grade 42.5N/R with a specific gravity of 3.14. As a fine aggregate, locally available fly ash obtained from the thermal power station is used, and locally available plaster sand with a Specific gravity of 2.6 is used. As a coarse aggregate, crushed granite stone with a specific gravity of 2.75 is employed. The expanded clay with extremely fine pores is lightweight. Weight, size, and strength can all be precisely regulated. Pellets with diameters ranging from 4 to 8 mm are available. Lightweight expanded clay aggregates have a dry density of 300 to 500 kg/m$^3$. This research takes 25% of clay balls instead of coarse aggregates.

In addition, 150mm ×150mm×150mm cube molds, Compressive Test machines (BS 1881-108: 1983), Slump cones, and tamping rods are used.

### Mix Proportions

The quantities of materials, cement, and fine aggregate used in normal concrete are employed in the first trial mixes according to IS 10262: 2019 criteria without the replacement of fly ash. The proportions of materials for M25 grade concrete are 1: 1: 2 (IS 10262) with a W/C ratio of 0.45.

The Second trail mixes according to IS 10262: 2019 criteria within fly ash and expanded clay. The concrete materials are batch-measured according to the mix design for the required grade of concrete. Hand mixing is used to make the concrete.

Table 1: Mix Proportions

| Mix Proportion (1:1:2) | | | | | |
|---|---|---|---|---|---|
| | W/C | Fly Ash % | Expanded Clay (kg) | 12 mm Corse Agg. (Kg) | Plaster Sand (kg) |
| Control | 0.45 | - | - | 22.8 | 11.4 |
| Test 1 | 0.69 | 35 | 5.7 | 17.1 | 11.4 |
| Test 2 | 0.75 | 40 | 5.7 | 17.1 | 11.4 |
| Test 3 | 0.82 | 45 | 5.7 | 17.1 | 11.4 |

One method that helps to minimize concrete potential strength is the cure. Concrete continues to hydrate after curing, which results in ongoing strong growth. The concrete must be kept at a suitable temperature and moisture content for a long enough time to continue to hydrate.

*Figure 1: Test cube casting and testing*

## Data Analysis and Discussion

### Compressive Strength

The concrete cube specimens ($150 \times 150 \times 150$mm) are tested according to IS 516 at the ages of 7 and 28 days. For each control proportion and each percentage of cementitious material (Fly ash) substitution, three specimens are tested, and the average of the three is used to determine the concrete's strength. Compressive strength test results for M25 concrete are shown in Figure 2.
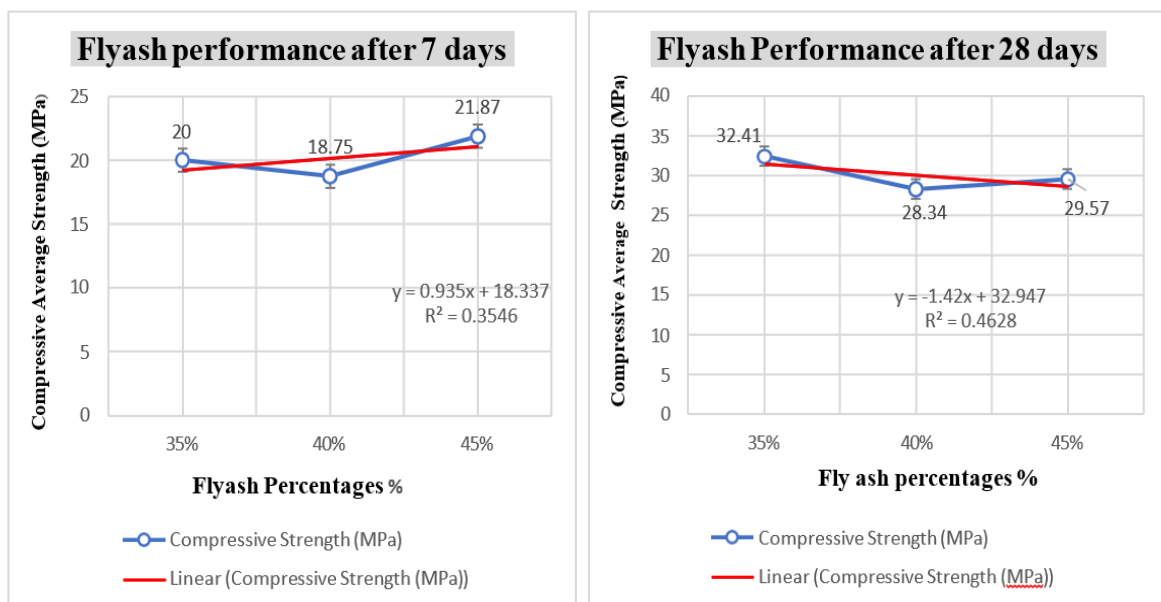


*Figure 2 : Compressive strength distribution*

After 7 days, this (Figure 2) shows some variation. At the beginning, it shows 20MPa at adding 35% of fly ash and gradually decreases that compressive strength value to 18.75 MPa. At the same time, it shows a value of 21.87 MPa at 45%. It is shown as the maximum value in the graph. The graph (Figure 2) shows that R2 = 0.3546. It appears to not correlate. Normal M25 concrete shows a strength of 66% of full strength after 7 days and fly ash concrete also obtains

the lowest percentage of strength among the above-average values. (>16.5%) Thus, the R-value provides more confirmation. When analyzed after 28 days, the graph shows a maximum value at the beginning, and gradually it falls to a minimum value of 29.57 MPa. Accordingly, it can be assumed that no matter how much the fly ash is increased in 28 days, the overall strength does not increase. Further, after 28 days, $R^2 = 0.4628$. It also seems to still not correlate. After 28 days, the strength of normal M25 concrete is 99% of its full strength (24.75%), while fly ash concrete has attained a higher percentage of normal strength than 99% (>24.75%).
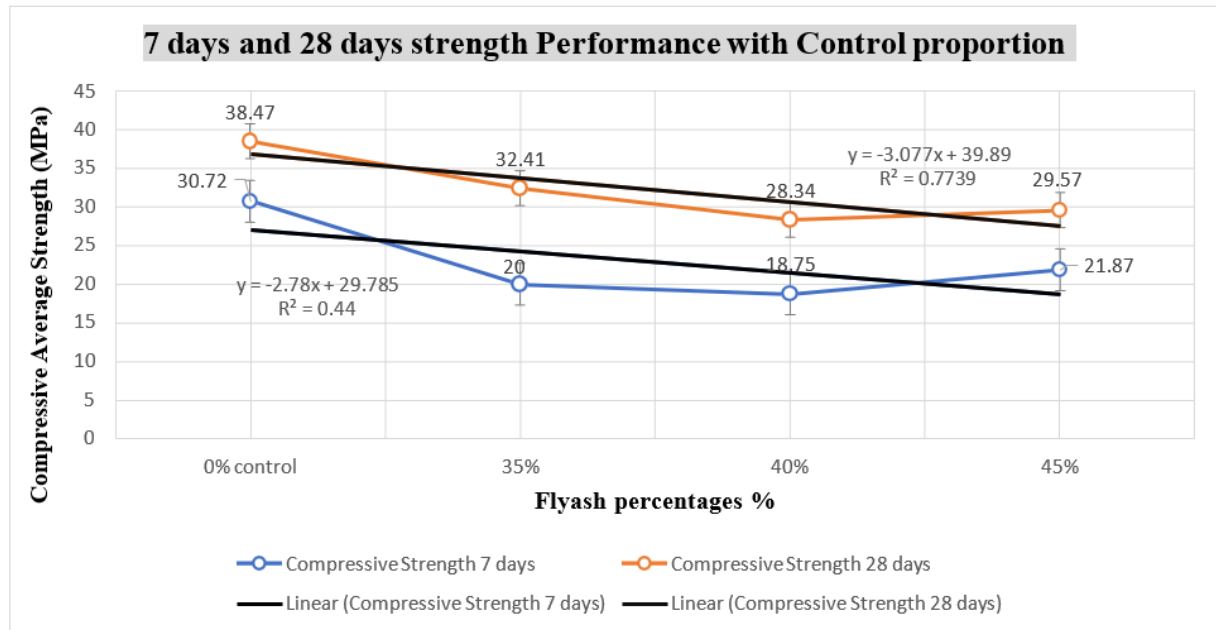


*Figure 3 : Total compressive strength performance*

Figure 3, shows how the strengths of the fly ash percentages used in the test vary with the control proportion. Considering the above $R^2$ values in Figure 2 and the $R^2$ values there is some difference between 7 and 28 days. This was mainly due to the change in the control mix and not having fly ash percentages exceed it. Overall, fly ash concrete was capable of withstanding the strength of M25 within 28 days, giving it an advantage over M25. But here, in 28 days, the strength required for M25 has been exceeded. This is an anomaly found during the experiment and the reason for this can be assumed to be the effect of the plaster sand used.

*Lightweight variety of fly ash concrete.*

At the end of 28 days, another objective of the research has been fulfilled. That is to reduce the overall weight of fly ash concrete than normal concrete. The special point here is the contribution made by expanded clay. This proves that lightweight aggregate like expanded clay reduces the weight of the entire concrete system. In addition, wood and plastic particles, expanded vermiculite, pumice, and pelletized expanded slag can be used as substitutes. Figure 4, shows the average test cube wight of each test after 28 days.
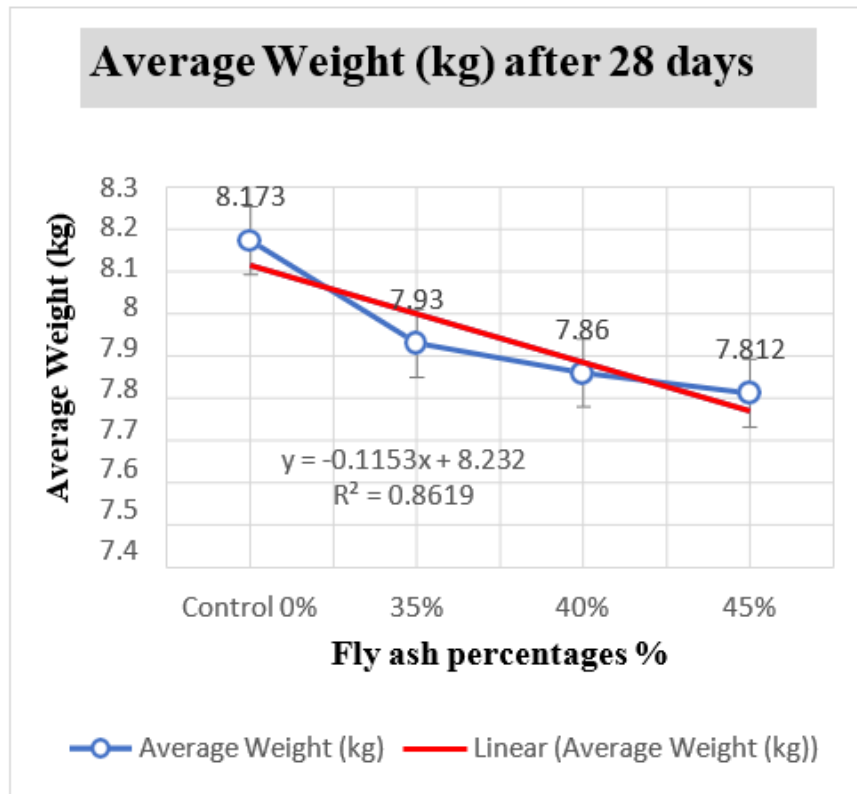
*Figure 4 : Test cube weight variation*

### Workability

To overcome the limitations of conventional empirical tests like the slump test, fresh concrete workability should be assessed using its rheological characteristics (Nagaraj & Shamanna, 2015).
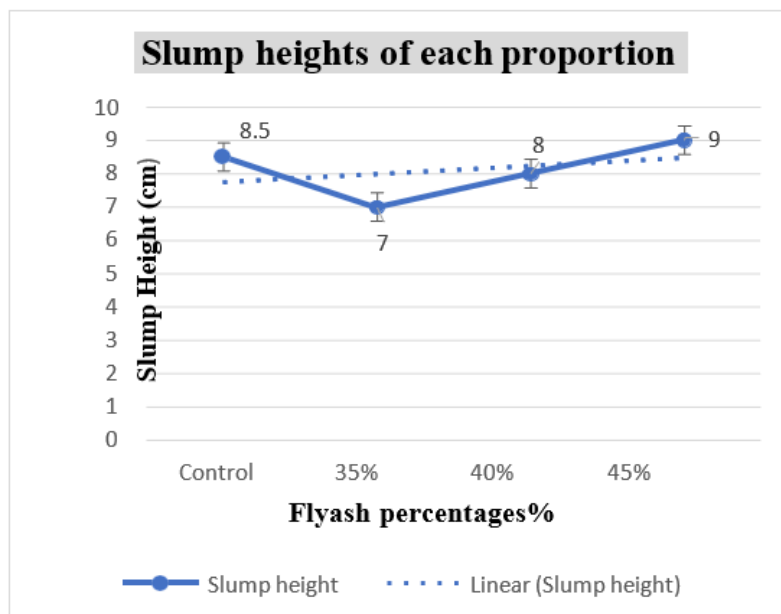


*Figure 5 : Slump heights*

As shown here, the slump height of the initial control mixture is higher than the others. Slump height has decreased at 35% and gradually increased in the remaining percentages. However,

all these heights belong to the true slump type. True slump - The majority of the concrete's ability to retain its cone shape is a sign that the mixture is cohesive and is not particularly workable. However, the advantages of this form of a slump are greatest for slabs, columns, and beams. (20 - 80mm) (Joseph & K, 2009).

All the same, based on the aforementioned experiment, it is inferred that adding plaster sand to cement increases the strength and workability of concrete.

**Conclusions**

In this experiment, 3 percentages of fly ash including the control experiment were carried out. Overall, the test was completed with all objectives achieved.

In the first control test, 6 samples were made and tested for 7 and 28 days by mixing cement, sand, and coarse aggregates appropriately for M25. Similarly, the above process was followed for fly ash lightweight concrete, and by replacing fly ash 35, 40, and 45 % with cement, expanded clay was added as a substitute for crushed stones, and 18 samples were made and tested.

According to the first objective, the strength of the fly ash aggregates mostly determines the compressive strength of concrete. Despite the low strength of the aggregate, the strength of concrete is determined by the strength of the aggregate's influence on the concrete. Comparing these concretes (LWAC) to normal aggregate concrete (M25), earlier research found that they had higher compressive strengths. Also, it was observed that the strength of the aggregate plays a considerable part in regulating the strength of LWAC and doesn't only affect the compressive strength of the concrete produced.

After 28 days, the replacement of 45% fly ash can be suggested as the most suitable partial replacement of fly ash percentage to achieve an optimal compressive strength of concrete. This is because according to Figure 3, it has fulfilled M25 compressive strength. When it comes to weight, it has reduced total weight and is well-suited for lightweight concrete.

Creating samples for the workability of fly ash aggregate concrete as a function of mixed proportion variables including cement content, water content, and volume fraction of fly ash was another goal that was accomplished. The volume proportion of aggregate in the composition, which is the principal interaction effect, has a significant impact on the workability of concrete in addition to the water content.

**Recommendations**

The below recommendation can be derived based on the findings and observations of the present research.

Due to its many benefits, such as its light weight, strength, good seismic performance, good durability, and outstanding heat insulation performance, lightweight aggregate concrete (LWAC) can be utilized in high-rise buildings, large-span bridges, and offshore platforms.

When considering material cost, lightweight concrete saves 8% of the cost compared to normal-weight concrete.

As a result, lightweight concrete is a more economical option than normal concrete.

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# RELATIONSHIP BETWEEN TOP MANAGEMENT STRATEGIESAND EXTERNAL CRISIS MANAGEMENT STRATEGIES IN SRI LANKAN CONSTRUCTION INDUSTRY

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**Abstract**

The Sri Lankan Construction Industry (SLCI) is suffering from crises that are generated from external factors. Crisis Management (CRM) success or failure depends on top management decisions. The lack of studies regarding external CRM (ECRM) in SLCI, generates knowledge gaps and risks to SLCI. Hence, determining the relationship between Top Management Strategies (TMS) and ECRM Strategies (ECRMS) in SLCI is necessitated to survive construction organizations during external crisis periods. Online questionnaire survey was used to collect quantitative data relevant to ECRMS and TMS. 101 SLCI industry participants joined for quantitative data gathering. Pearson correlations test is used to identify linear relationships between TMS and ECRMS. It revealed that ECRMS has moderate positive linear relationships with TMS. Hence, organizations can apply those TMS strategies for increasing effectiveness of ECRM. The final outcomes of the study will be facilitated to smooth operations during external crises in large scale main contractors' organizations registered under the Construction Contractors Grading Schema of the Construction Development Authority of Sri Lanka.

**Key Words:** External Crises, External Crisis Management Strategies (ECRMS), Top Management Strategies (TMS) and Sri Lankan Construction Industry (SLCI)

**Introduction**

A crisis can be defined as an unpredictable event that can potentially generate negative outcomes (Park, 2017) for an individual, a group or an organization. Construction organizations are easily affected by crises due to high initial investments that increase huge financial losses (Sahin, Ulubeyli and Kazaza, 2015). Crisis creates sudden changes to organizations which encourages the necessity of forming new systems to manage crises. Several environmental and organizational factors influence creation crises. Economic, political, technological, legal, and natural factors are key reasons for external crises (Nassar and Erzaij, 2023). Sri Lankan Construction Industry (SLCI) is one of the most innovative, dynamic, and technologically advanced industries among other industries (De Silva, Darmicka and Fernando, 2014). Although, SLCI is suffering from several external crises such as terrorism, natural disasters, economic and financial crises, political instability, and competitions generating from foreign contractors' involvement etc.

CRM can be defined as the dynamic and continuous process used to identifying, planning and resolving of crisis by application of both reactive and proactive actions (Nassar and Erzaij,

2023). CRM success or failure depends on top management decisions. Top management should consider several factors to effective crisis management such as; focusing on financial aspects of crisis, maintaining information flow, tackling information flow bottlenecks, developing flexibility of managerial strategies, monitoring and managing interpersonal relationships (Sahin, Ulubeyli and Kazaza, 2015).

SLCI is suffering from external crises. And identification of effective CRM strategies and processes necessary to smooth running of construction organizations. Lack of studies regarding external CRM (ECRM) in SLCI, generate knowledge gaps and risks to SLCI. Hence, determining relationship between Top Management Strategies (TMS) and External Crisis Management Strategies (ECRMS) in SLCI is necessitated to surviving during the external crisis periods.

Research findings were focused only on external crises situations in SLCI. The findings can be only applied to large scale main contractors' organizations in SLCI which are registered under C3, C2, C1, CS1 and CS2 as per the Construction Contractors Grading Schema of Construction Development Authority of Sri Lanka. This study only focused on TMS and ECRMS.

**Methodology**

The quantitative Research Methodology approach was applied to determine the linear relationship between TMS and ECRMS in SLCI. Several three ECRMS and four TMS applied during external crisis periods were identified through the literature sources. As per the operationalization Table 1, the online survey developed by using Google Forms. All these strategies were measured by using five point Likert scale; 1-Strongly Disagree, 2-Disagree, 3-Neutral, 4-Agree and 5-Strongly Agree.

Table 1 – Operationalization Table for Online Questionnaire Development

| Concept | Measures | Question Number in Questionnaire |
|---------|----------|----------------------------------|
| **ECRMS** | M1. Crisis management plan preparation | 2.1 |
| | M2. Decision making framework | 2.2 |
| | M3. Organization's resource management | 2.3 |
| **TMS** | M1. Maintain behavioral change | 3.1 |
| | M2. Monitoring and supervision | 3.2 |
| | M3. Organization overhead controlling | 3.3 |
| | M4. Motivation | 3.4 |

A Linear relationship between identified TMS and ECRMS was investigated for fulfilment of research objective. ECRMS is considered as a Dependent variable. TMS is considered as Independent variables. The Person Correlation was conducted by developing below null and alternative hypotheses as Table 2.

Table 2 - Hypothesis for Identification of Linear Relationship between TMS and ECRMS in SLCI

| Purpose | Hypotheses |
|---|---|
| **Identify linear relationship between ECRMS and TMS** | H$_0$ – there is no any significant linear relationship between top management strategies and external crisis management strategies. |
| | H$_1$ – there is a significant linear relationship between top management strategies and external crisis management strategies |

Present study focused on SLCI employees which are currently working in Sri Lanka. The below criteria used to define the population.

1. Employee should be worked in SLCI as a representative of client, contractor, consultant or subcontractor.
2. Employee should not be minor staff, skilled labour or unskilled labour in construction firm.

Simple random sampling technique used to identify sample of the online questionnaire survey (Osiyevskyy, Shirokova and Ritala, 2020).
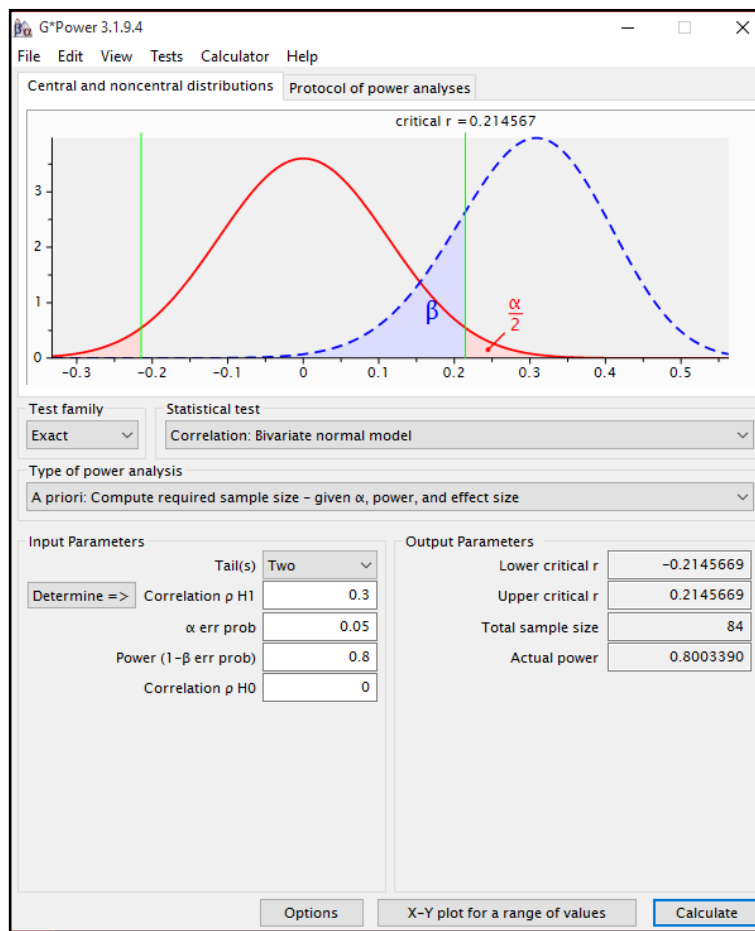


*Figure 1 - Minimum Sample Size Calculation for Online Questionnaire Survey by Using G*Power Software*

G*Power software is recommended for sample size calculation (Kang, 2021). Minimum sample size requirement for questionnaire survey was determined through for G*Power (version 3.1.9.4) software as Figure 01. The minimum sample size for online questionnaire survey should be 84. The power of rejecting hypothesis is 80%.

**Results and Discussion**

*Sample Description*

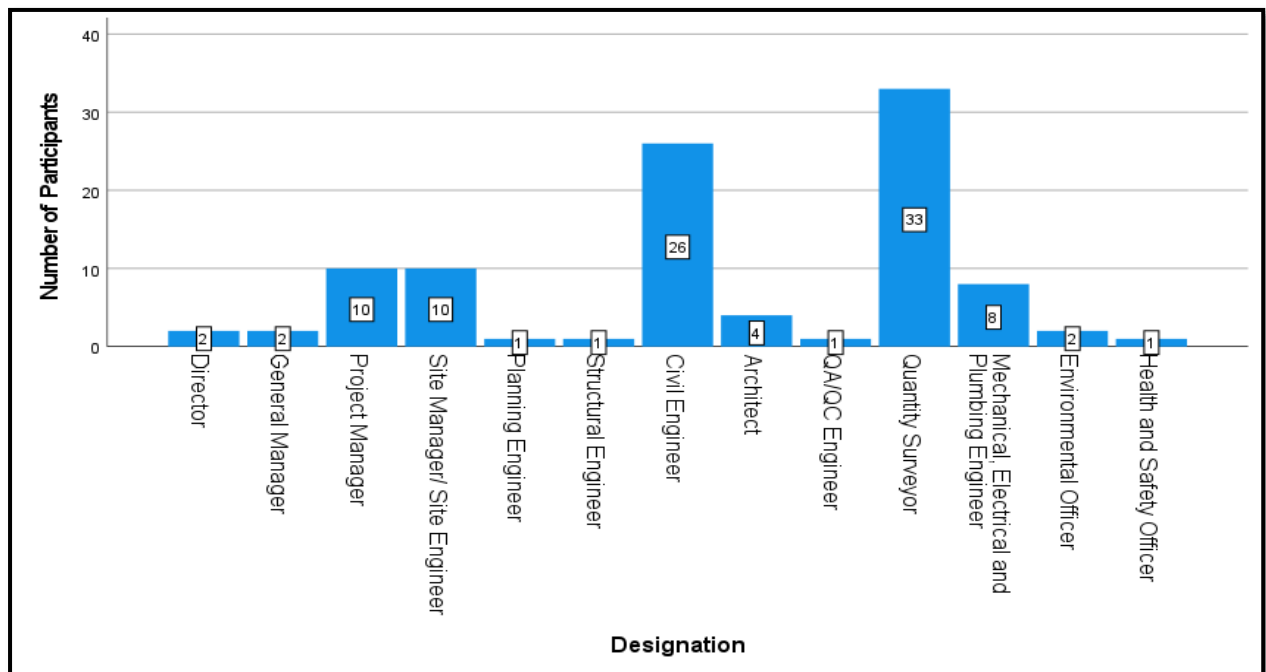101 SLCI experts were participated in online questionnaire data collection process. The details of designations are shown in Figure 2.



*Figure 2 – Graphical Presentation of Participants' Designation in Online Questionnaire Survey*
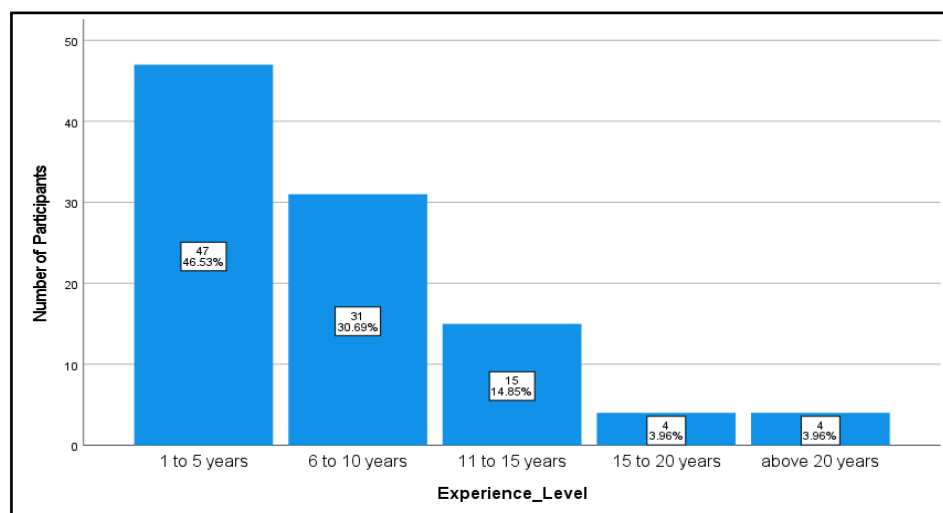


*Figure 3 - Graphical Preseantation of Online Questionnaire Survey Participants' Construction Industry Experience Level*

As the figure 4, Majority of respondents (75.25% of respondents) were working in large scale construction organizations which mentioned in research limitations.
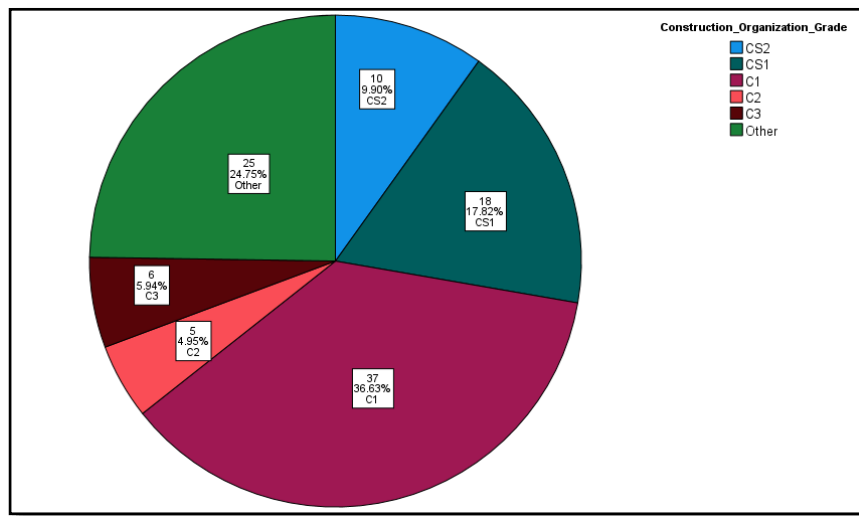


*Figure 4 - Graphical Presentation of Online Questionnaire Survey Participants' Organizations Categories*

### *Identification of the linear relationship between ECRMS and TMS*

The main intention of this analysis is to identify the linear relationship between TMS and ECRMS. Pearson correlation test is widely used to measure the strength of the linear relationship between two variables. Several Correlation coefficient values indicate the strength of the linear relationship between variables. Those values are listed in Figure 5.

| Correlation coefficient value (r) | Strength of linear relationship |
|---|---|
| $r = +1$ | Perfect positive linear relationship |
| $0.7 < r < 1$ | Strong positive linear relationship |
| $0.3 < r < 0.7$ | Moderate positive linear relationship |
| $0 < r < 0.3$ | Weak positive linear relationship |
| $r = 0$ | Zero linear relationship |
| $0 < r < -0.3$ | Weak negative linear relationship |
| $-0.3 < r < -0.7$ | Moderate negative linear relationship |
| $-0.7 < r < -1$ | Strong negative linear relationship |
| $r = -1$ | Perfect negative linear relationship |

*Figure 5 - Correlation Coefficient Values' Indications (Akoglu, 2018)*

Significance level (α) in Pearson correlation result use to test hypothesis. If α < 0.05, there is enough evidence to reject null hypothesis (H0) (Supena, Darmuki and Hariyadi, 2021). Hypotheses analyses for this study are shown below.

Pearson correlation test results for ECRMS and TMS are shown in Figure 6.

|  |  | ECRMS |
|---|---|---|
| TMS | Pearson Correlation coefficient (r) | 0.365 |
|  | Significance level (α) (2-tailed) | <0.001 |
|  | Numbers | 101 |

*Figure 6 -Pearson correlation test results for ECRMS and TMS*

The α value = < 0.001 which was less than 0.05 was less than 0.05. Hence, there was enough evidence to reject H0. Due to that, there is a significant linear relationship between ECRMS and TMS. The r value = 0.365 which was in between r range of 0.3 to 0.7. Hence, there is a moderate positive linear relationship between ECRMS and TMS.

Effect of crisis increases natural tension in organizations and decrease ability to cope with changes. Continuous monitoring is necessary to maintain these kinds of behavioural (Sahin, Ulubeyli and Kazaza, 2015). Top management decisions can be made for managing complex situations by monitoring the relationship between organizational complexity and employees' behaviours (Daniel and Daniel, 2018). Continuous monitoring is necessary to identify external facilities that are required in CRM. Team distraction can occur due to close supervision. Hence, senior management should consider the organization's managerial size for effective monitoring and supervision (Choi, Sung and Kim, 2010). Evidence of previous studies revealed that monitoring and supervision key strategies in CRM. Organizations can achieve benefits during crises through employees' motivation (Sahin, Ulubeyli and Kazaza, 2015). Any actions which are decrease morale of employees should not be taken in crises situations (Taneja, 2014). Closing organization departments, employees' salaries reduction, given unpaid vacations, restrictions in extra services and employees dismissal are some overhead management strategies that top management implied to CRM as a reactive approach. Those strategies are only suitable for short-term and small-scale CRM. Those strategies caused to loss of experienced employees to organization (Sahin, Ulubeyli and Kazaza, 2015) and the reduction of employees moral. Evidence of previous studies revealed that monitoring, supervision and motivation are key strategies in CRM.  Overhead management is not acted in a key role in ECRM.  But, the TMS is necessity to effective ECRM. It revealed that the positive moderate linear relationship between ECRMS and TMS.

**Conclusion and Recommendation**

SLCI is now experiencing multiple external crises. Hence, it is imperative to determine the relationship between TMS (Top Management Strategies) and ECRMS (External Crisis Management Strategies) in order to ensure the resilience of SLCI in times of external crises. The study obtained quantitative data from 101 participants of the SLCI by utilizing Google Forms. The primary objective of quantitative data collection was to ascertain the linear relationship between TMS and ECRMS.

The Pearson correlation test was employed to identify of linear associations between TMS and ECRMS. The analysis demonstrated that there is a moderate positive linear relationship between ECRMS and TMS. Hence, it is advisable to implement such TMS tactics to enhance the efficiency of ECRM. Furthermore. Implementing efficient TMS will enhance the construction organizations' resilience during external crises.

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# WASTEWATER PURIFICATION USING MICROBIAL FUEL CELLS

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## Abstract

Wastewater should be treated before releasing to the environment to remove harmful materials from water bodies. This experiment has been conducted in order to build up a renewable wastewater treatment technology which generates electricity as a product. Here, constructed wetland microbial fuel cell has been developed to treat wastewater and to improve its power output. Graphite plates have been used as both anode and cathode and gravel, alum sludge and glass wool have been used as separators. pH test, COD test, DO test and turbidity tests were conducted before treating collected wastewater and after the treatment to identify the amount of pollutants in the sample and to demonstrate the efficiency of the microbial fuel cell. The system was able to perform an average COD removal of 58.88% and generate a peak power density of 7.778 mW/m$^2$.

**Keywords:** COD - Chemical oxygen demand, DO - Dissolved oxygen, MFC - Microbial fuel cell

## Introduction

A significant amount of wastewater is released to the environment during construction projects and it is a critical issue for all the living beings. Untreated wastewater can contaminate surface and groundwater resources. They can also carry pollutants, pathogens, and nutrients that can harm aquatic life, impacting biodiversity and ecosystems. Inadequate wastewater management can further exacerbate these issues (Edokpayi, 2017). Inadequate management can lead to waterborne diseases, affecting human health and quality of life. Also, this can lead to negative economic impacts on industries like fishing and tourism. Proper wastewater treatment and responsible disposal are essential to mitigate these risks and protect the environment and public health (Silva, 2023). Treating wastewater is essential and it is a challenge due to energy consumption, skills of people and availability of facilities. Here, plant microbial fuel cell is used as wastewater treatment method. Plant Microbial Fuel Cell (PMFC) is one of the alternative energy developments that is able to produce electric current from the microbial oxidation of organic matter (Logan, 2006). Microorganisms around the roots of the plant convert unabsorbed organic materials from photosynthesis into electrons and protons. These charges are then harnessed to generate electric current through microbial fuel cells, offering potential for sustainable energy production (Helder, 2013).

In this experiment, Graphite will be used as both anode and cathode. Alum sludge, glass wool and gravel will be used as separators (Asefi, 2019). Common water hyacinth has been tested to study the effect of root excreted oxygen on microbial fuel cells. Therefore, MFC can be designed that incorporated water hyacinth plants growing in the cathode chamber (Pamintuan, 2018). pH, turbidity test COD test and DO test can be conducted to identify the amount

pollutants in wastewater. After treating the wastewater, the relevant tests should be conducted in order to determine the treatment efficiency and voltage drop would be measured to identify the electrical performance and according to the results obtained, the efficiency of MFC can be analyzed.

According to previous studies, the removal of organic matters by MFC is about 74% - 86% (Zhang, 2009). MFC is an eco-friendly method used to purify wastewater. Although MFC is a sustainable method, it still requires some technical advancements (Chen, 2020). The aim is to develop an effective wastewater purification technology (Microbial Fuel Cell) with the use of microorganisms which generates electricity as a product. There are four specific objectives to achieve the main aim of the research. The objectives of the study are to determine the properties of wastewater sample, to develop a suitable microbial fuel cell for wastewater purification, to determine the applicability of MFC in wastewater purification and energy production and finally, to analyze the treatment efficiency of developed microbial fuel cell and determine its environmental impact. To achieve above objectives, chemical and physical characteristics of the water sample, such as pH, DO, COD, nutrient content, and presence of pollutants should be analyzed. Then appropriate materials and optimize conditions for the MFC to operate efficiently should be selected by conducting systematic literature review. The applicability & efficiency can be determined by measuring removal rates of pollutants, evaluating water quality improvements, and investigating byproduct generation.

**Methodology**

This section explains the specific procedures that were used to identify and analyze the information in this research.

The system was developed using a PVC column of 500mm height and 145 mm of internal diameter. A black PVC column is used to avoid and control algae growth (Yadaw, 2013). Graphite plates were used as electrodes for both anode and cathode. They were connected to each other using copper wires (Srikanth, 2011). Dewatered alum sludge was used as separator as it is able to increase the removal efficiency of COD and phosphates from the wastewater according to previous suggestions (Zhao, 2013). Gravel (average size 20-25 mm) was used as the wetland substrate. Wastewater sample was collected from industrial construction site which contained sediment, suspended solids, oil, grease, chemicals, and construction-related materials.

Common water hyacinth, Pontederia crassipes, was planted in the cathode section of MFC due to its rapid growth, high biomass, high-density of root and ability to survive in the contaminated land (Zhao, 2013). To determine the properties of initial wastewater sample COD test, pH test, DO test and Turbidity test was conducted in laboratory (Auriga Research, 2022).

*Configuration and Setup*

The system was setup by putting alum sludge (dewatered) at the bottom of the PVC column to a height of 210 mm, with the anode placed. As a physical barrier, a glass wool layer of 10 mm was placed. In the cathode compartment, and above the separator (glass wool) 60 mm layer of gravel was placed. At that moment air diffusion heads were positioned in the cathode compartment above where an additional 130 mm of gravel was placed and then the cathode

was placed on the top. Then, another gravel layer    of 90 mm was placed. Then, the water hyacinth was planted there in order to complete the microbial fuel cell. The electrodes were connected externally using an electrical resistor of 100Ω (Zhao, 2013).
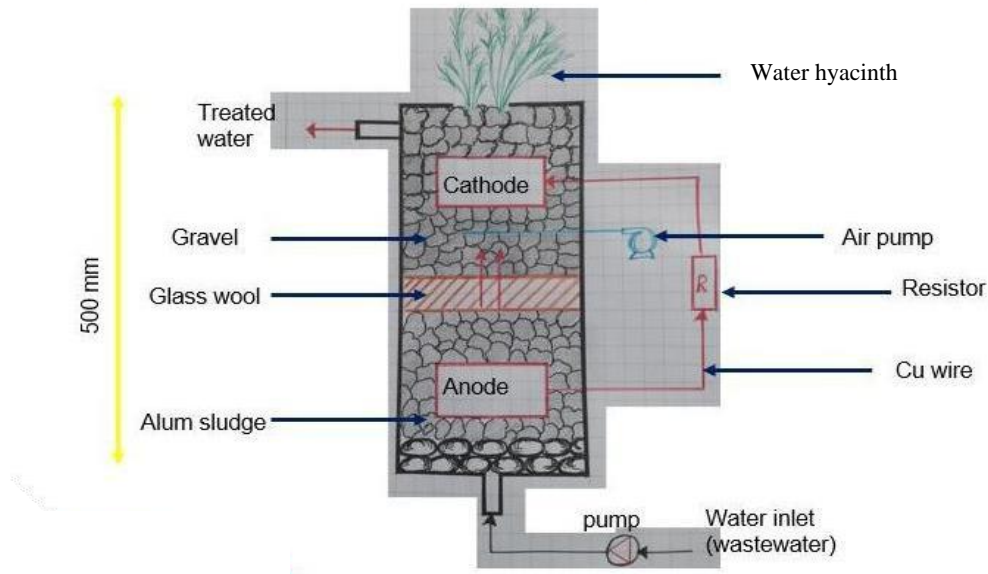


*Figure 1 : Setup of plant microbial fuel cell*

An inlet pipe would be supplied at the bottom of MFC and it can be linked to a pump and on the top of the column another two connection ports would be added in order to allow continuous flow mode.
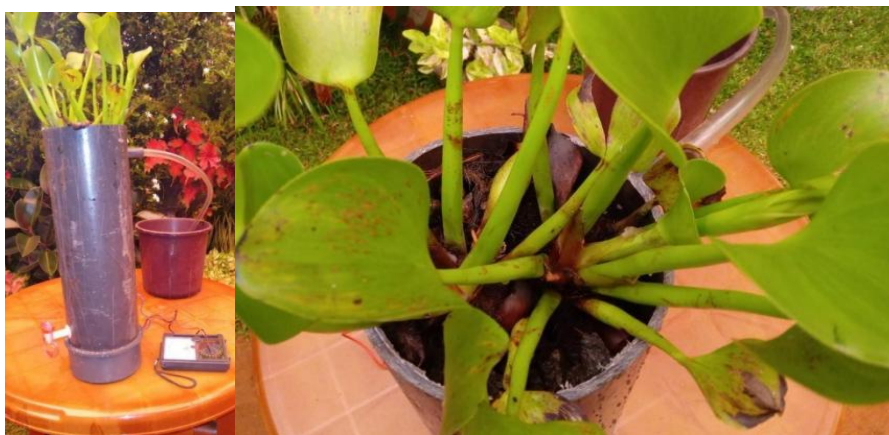


*Figure 2 : Constructed plant microbial fuel cell*

System was operated under a continuous vertical upper flow. During the experiment process, the flow rate was diverse between 1.9 - 3.2 L/day. Air diffusion heads were positioned in the section of cathode supplied air using an air pump at a rate of 100-120 mL/s. The ability of microbial fuel cell to purify wastewater was determined by the removal efficiency of COD and DO content. The voltage drop (V) was measured daily in order to determine electrical performance.

**Results and Discussion**

This section explains the process of applying statistical /logical techniques to evaluate and describe data.

To analyze the treatment efficiency, COD test, pH test, DO test and Turbidity tests were conducted after treating initial water samples and the efficiency of the system was determined by analyzing the obtained results. COD of the water sample was tested for every 3 days for a 9 days' time period while DO was tested for every 2 days within 10 days' time period. Turbidity and pH readings were taken before treating wastewater. The pH value of the wastewater sample was 7.06. It was considered as neutral while the obtained turbidity value was 2.6 NTU. Guidelines have recommended turbidity levels below 5 NTU for recreational water (USGS, 2018). The constructed MFC was able to produce electricity consistently throughout the experiment. The energy production were determined through basic calculations and it was able to generate maximum current of 2.65mA and maximum power density of 7.778 mW/m$^2$.

All the tests were conducted under room temperature (27°C).

Table 1: Obtained results of COD/ DO/ turbidity and pH

| Physio-chemical Parameter | Mean concentration | |
|---|---|---|
| | Initial Sample (mg/L) | Final Sample (mg/L) |
| COD | 798.93 | 55.02 |
| DO | 4.11 | 7.01 |
| Turbidity | 2.6 NTU | |
| pH | 7.06 | |

*COD Removal Efficiency with Time*

COD removal efficiency in a pant microbial fuel cell over time can be influenced by various factors, such as the type of plant, environmental conditions, nutrient availability, variations in temperature and the design of the PMFC system. To determine COD removal efficiency, wastewater was treated for 9 days and COD of the effluent was tested for every 3 days (Table 2).

Table 2: COD removal efficiency with time

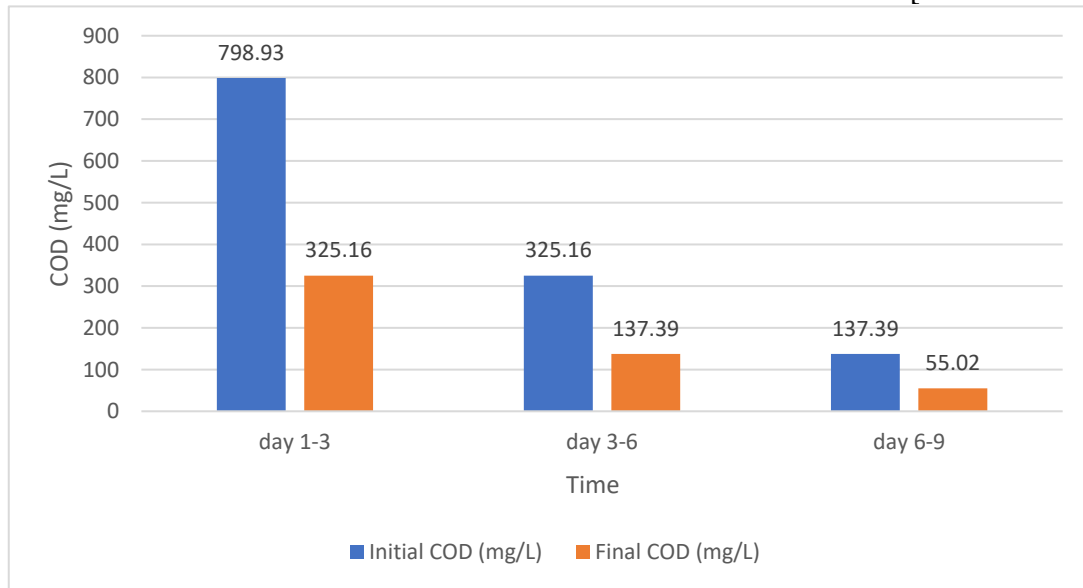| Initial COD (mg/L) | Final COD (mg/L) | Time duration (Days) | COD removal efficiency (%) |
|---|---|---|---|
| 798.93 | 325.16 | 1-3 | 59.30 |
| 325.16 | 137.39 | 3-6 | 57.74 |
| 137.39 | 55.02 | 6-9 | 59.95 |

*Figure 3 : Initial COD and final COD vs time (days) graph*

During days 1-3, Initial COD concentration was measured as 798.93 mg/L (starting concentration) and after some processing, it was reduced to 325.16 mg/L. On the 3rd day, Initial COD concentration was obtained as 325.16 mg/L and during days 3-6, final COD content was acquired as 137.39 mg/L. Wastewater was treated for 3 more days from days 6-9 with the Initial COD concentration of 137.39 mg/L on the 6th day. Finally, after refinement COD content was reduced to 55.02 mg/L on the 9th day.
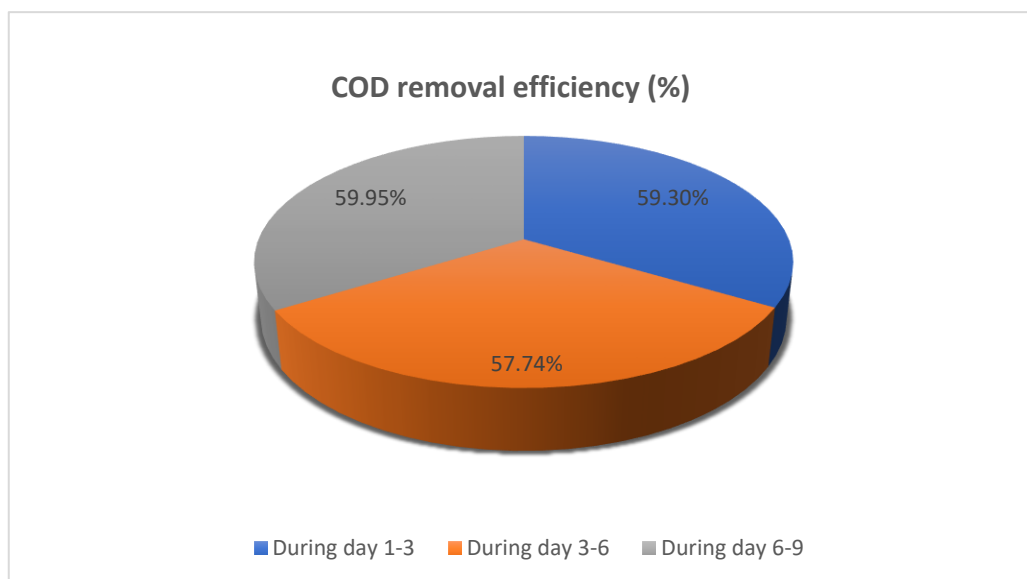


*Figure 4 : COD removal efficiency vs time*

During first three days, COD removal efficiency was obtained as 59.30%. On the sixth and ninth days it was obtained as 57.74% and 59.95% respectively. From these results, the average COD removal efficiency was calculated as 58.88% and the removal efficiency was not as good as expected since the obtained COD removal efficiency was lesser than the efficiencies reported

in previous studies (In previous studies, an average of 74% of COD has been removed) (Research Gate, 2012).

### *Dissolved Oxygen Concentration with Time*

DO concentration of the constructed MFC was monitored for every two days during 10 days' time period (Table 3). From day 2-8 DO content has increased from 4.11 - 7.12 mg/L. Within the next two days, it is reduced to 7.01 mg/L. Healthy Range of DO content in water sources is 6 - 12 mg/L and optimal Range for most aquatic life is 8 - 9 mg/L (USGS, 2018). The obtained results indicated that the DO content of MFC varied within acceptable ranges.

Table 3: DO variation during 10 days' time period

| DO (mg/L) | Time (Days) |
|-----------|-------------|
| 4.11 | 2 |
| 5.73 | 4 |
| 6.70 | 6 |
| 7.12 | 8 |
| 7.01 | 10 |
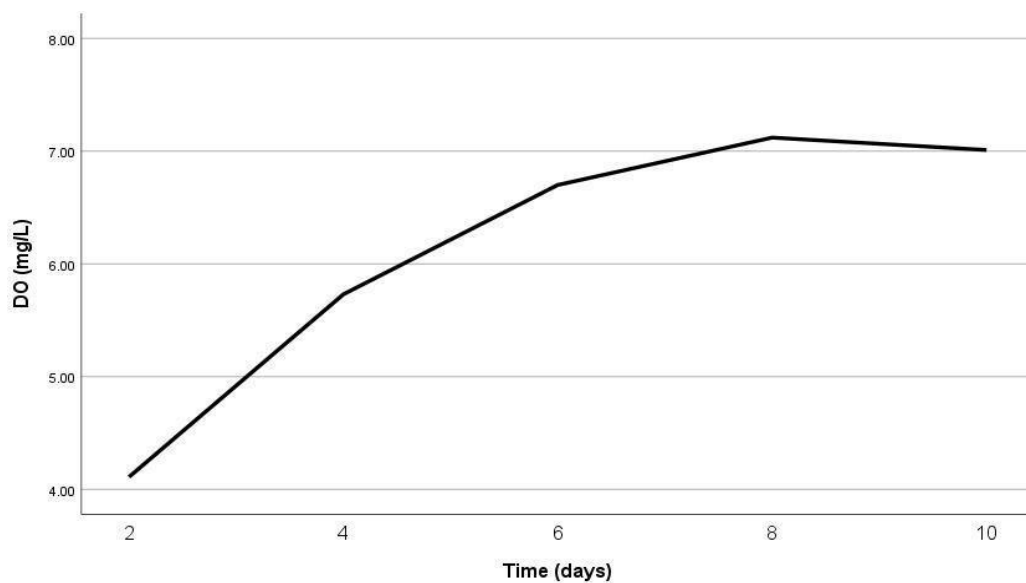


*Figure 5 : Dissolved oxygen vs time graph*

Table 4: Variation of Dissolved Oxygen with voltage

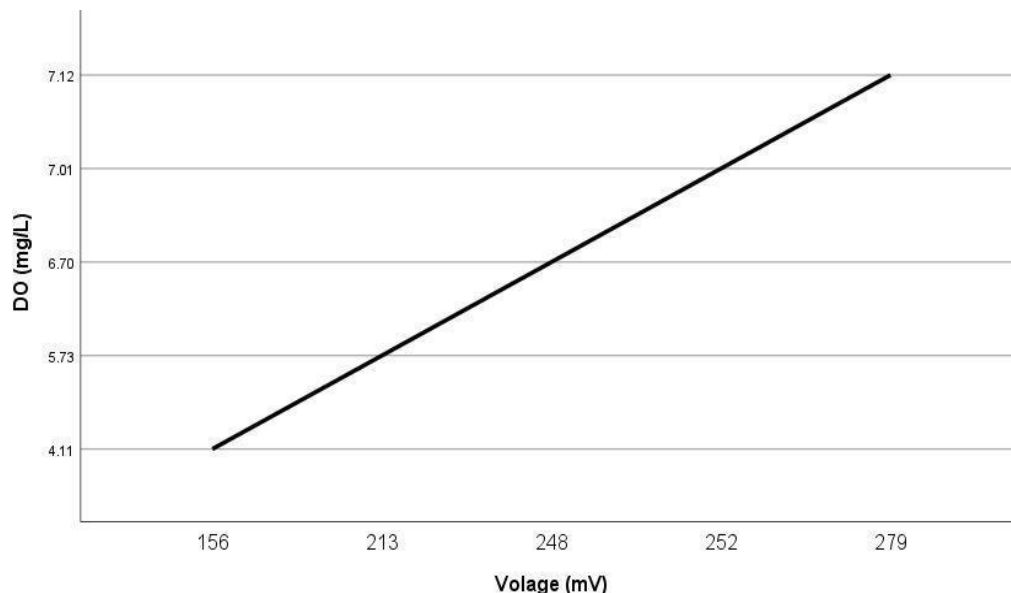| DO (mg/L) | Voltage (mV) | Time (Days) |
|---|---|---|
| 4.11 | 156 | 2 |
| 5.73 | 213 | 4 |
| 6.70 | 248 | 6 |
| 7.12 | 279 | 8 |
| 7.01 | 252 | 10 |



*Figure 6 : Dissolved oxygen vs voltage graph*

Initial DO concentration of the water sample was determined as 4.11mg/L. The system is subjected to a continuous flow with aeration in the cathode chamber via a pump in order to supply oxygen. DO variation is between 4.11 mg/L minimum and 7.12 mg/L of maximum value. During this period, it was met with voltage from 156mV to 252mV. This small increment of voltage indicated that the system was not much restricted by the limited DO availability due to aeration. Changes in environmental factors and Cathode Reactions can impact microbial activity, electrochemical reactions, plant species, and oxygen solubility. These changes might have resulted in variations in both dissolved oxygen concentration and voltage output.

### *Variation of Voltage with Time*

Voltage drop (V) was measured daily over a 10 days' time period across the external resistor of 100Ω using a multimeter. According to the obtained results, the average daily voltage was calculated as 209.17 mV. The current production (I = V/R) and power generation (P = VI) were determined as 2.091 mA and 0.437 mW respectively. The power density was obtained as 4.846

mW/m$^2$ by dividing the power with the surface area of the anode (90250 $\times 10^{-6}$ m$^2$). The peak voltage drop of 265mV was observed on the ninth day which resulted maximum current and power of 2.65mA and 0.702 mW respectively. The obtained maximum power density was 7.778 mW/m$^2$

Table 5: Voltage variation with time

| Voltage (mV) | Time (Days) |
|--------------|-------------|
| 156 | 1 |
| 168.52 | 2 |
| 189.10 | 3 |
| 173 | 4 |
| 196.7 | 5 |
| 213.5 | 6 |
| 231 | 7 |
| 247.9 | 8 |
| 265 | 9 |
| 251 | 10 |
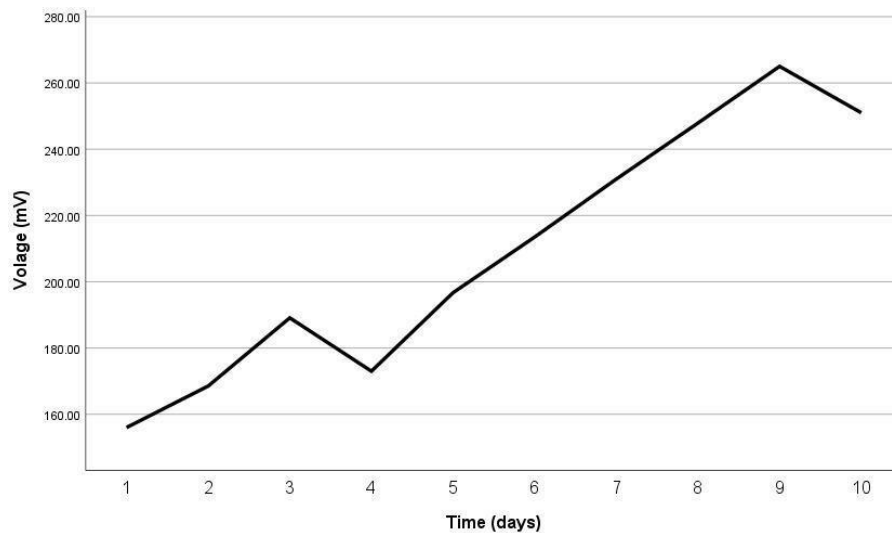


*Figure  7 :  Variation of voltage with time (days)*

***Organic Loading Rate (OLR)***

OLR is a measure of the amount of organic material applied to a treatment system per unit of reactor volume per day. Organic loading rate can be calculated using the equation, Organic loading rate = Total organic matter × Flow rate / Area, when the area of the reactor is constant (0.52185 m$^2$). According to Table 6, Organic loading rate is influenced by both the total organic matter in the influent and the flow rate. A higher flow rate with a higher COD concentration would result in a higher OLR.

Table 6: Organic loading rate results with total organic matter and flow rate

| Total organic matter/ COD content (mg/L) | Flow rate (L/day) | Organic loading rate (mg/m$^2$/day) |
|---|---|---|
| 798.93 | 2.1 | 3215.01 |
| 325.16 | 2 | 1246.18 |
| 137.39 | 1.9 | 500.222 |

***Electricity Production***

For 10 days period, average voltage was 209.17mV peaking at 265 mV. Constructed plant microbial fuel cell was able to produce an average power density of 4.846 mW/m$^2$ and the maximum power density of 7.778 mW/m$^2$ (Zhao, 2013)

***Ph Value***

The initial pH value of the obtained wastewater sample was 7.08. Therefore, the pH was considered as neutral during the process.

***Turbidity***

Initial turbidity of the wastewater sample was 2.6 NTU.

***Factors affected for the Performance***

*Effect on Wetland Plant*

Power density: The organic carbon from wetland plants serves as an electron donor for microbial metabolism, facilitating the production of electricity through microbial redox reactions. This will help to increase the power density. The expected COD removal efficiency was 74% - 80% but the obtained efficiency was 58.88% and the average power density was 4.846 mW/m2 while the maximum power density was 7.778 mW/m2.

Organic removal: The roots of wetland plants are able to provide some extra organics due to the decay of their roots, tissues & leaves. In the section of cathode, the DO concentration was relatively higher without planting the water hyacinth. As it was planted, DO concentration was reduced.

*Electrode Material and Size*

For this experiment, 2 plates of uncoated graphite were used as electrodes. Electrical conductivity of graphite is lower than nickel, brass and stainless steel. The electricity generation can be increased by using electrodes with a higher conductivity.

Table 7: Conductivity of different electrodes

| Material | conductivity (S/m) |
|---|---|
| Nickel | $1.43 \times 10^7$ |
| brass | $1.59 \times 10^7$ |
| Stainless Steel | $1.45 \times 10^6$ |
| graphite | $3.3 \times 10^2$ |

By increasing the electrode size, the voltage and power generation can be increased (ACS Publications, 2020).

**Conclusion and Recommendation**

This experiment is conducted in order to integrate microbial fuel cell technology into constructed wetland to achieve two goals mainly, of wastewater purification and then power generation. A model of laboratory scale microbial fuel cell was built and tested in continuous flow mode. Compared with past publications of researches, the obtained results indicated that the performance was not up to the expected limit and organic removal efficiency was lower than expected percentage.

Low organic loading and using graphite as electrodes which has a low electrical conductivity resulted low performance and efficiency. Also due to electrochemical loses, such as kinetic losses (mass transfer loss), Ohmic losses (due to ion and electron transfer) and activation losses, the performance of microbial fuel cell was reduced. The performance of MFC can be enhanced by extending the surface area of the electrodes, using electrodes with high electrical conductivity and increasing the amount of organic loading.

Plant microbial fuel cells can be considered as one of novel technology to fulfill future demands for wastewater purification and power generation from organic contamination. From the literature it can be concluded that plant microbial fuel cells can produce effluent quality of water within environmental regulations for irrigation application and this can be considered as real time application with low carbon footprints.

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**INVESTIGATION ON IMPROVING SOIL STABILIZATION BY USING CACL2 IN SUBGRADE FOR ROAD CONSTRUCTION**

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**Abstract**

This research project focuses at the use of Calcium Chloride ($CaCl_2$) in subgrade soil stabilization for construction of roads, with the goal of addressing the recurring issue of road failure owing to insufficient soil compaction. The study emphasizes the importance of $CaCl_2$'s hygroscopic properties, emphasizing its ability to efficiently stabilize soil by drawing moisture and preventing evaporation, hence improving compaction and ensuring a long-lasting foundation. Chemical soil stabilization is recognized for its time and cost savings, waste reduction, and application to a wide range of soil types, making it a viable option in civil engineering projects. The goal is to enhance soil stabilization using $CaCl_2$, with objectives including $CaCl_2$ property research, the creation of soil samples with varying $CaCl_2$ amounts, laboratory testing, and result analysis. The procedures include executing Proctor compaction and CBR tests, as well as doing literature research and procuring industrial-grade $CaCl_2$. The results show that $CaCl_2$ treatment increases soil strength and stability. Despite its limits, the study suggests the prudent use of chemicals in construction for improved soil quality, providing useful insights to the worldwide engineering community.

**Key Words:** Calcium Chloride ($CaCl_2$), Road Construction, Soil, Stabilization, Subgrade

**Introduction**

The background of the research involves addressing a critical issue in road construction, specifically related to the failure of some projects due to inadequate soil compaction. The Colombo-Negombo main road, located in the Seeduwa area of the Western Province, serves as a pertinent example where subsidence has occurred, highlighting the importance of thorough soil compaction for the longevity and stability of highways. The failure of certain road construction projects is attributed to the lack of proper compaction of the Earth's soil at the construction site before the commencement of highway construction. Inadequate soil compaction can lead to structural instability, causing roads to collapse or subside over a relatively short period. The negative consequences of such failures include increased maintenance costs, disruptions in transportation, and potential safety hazards for commuters. The research aims to address this critical issue by investigating the use of Calcium Chloride ($CaCl_2$) as a soil stabilizer in subgrade preparation for road construction. Calcium Chloride is chosen for its hygroscopic qualities, which efficiently stabilize soils by attracting moisture and resisting subsequent evaporation. This property is expected to enhance compaction during construction, ensuring a robust and lasting foundation material for highways. The significance of this research lies in its potential to revolutionize soil compaction processes, offering a quick and efficient method for preparing the land on which highways are built. Successful implementation of Calcium Chloride in soil stabilization could lead to streamlined construction

procedures, saving both time and labour costs. Furthermore, it has the potential to reduce waste, increase the structural lifespan of roads, and provide a sustainable solution applicable to a wide range of soil types. The broader context emphasizes the environmental impact, versatility, and sustainability of chemical soil stabilization in civil engineering projects. By minimizing waste, limiting environmental disturbance, and ensuring durable structures across various geological conditions, this research contributes to the advancement of construction practices and aligns with the principles of sustainable infrastructure development. (Barman & Dash, 2022). The primary aim of this investigation is to enhance soil stabilization in subgrade for road construction through the application of Calcium Chloride. The focus of the research lies in improving both the stabilization and compaction of soil by leveraging the hygroscopic qualities of Calcium Chloride. By attracting moisture and resisting subsequent evaporation, Calcium Chloride is expected to facilitate efficient compaction during the construction process, thereby contributing to the creation of a robust and durable foundation material for highways. (Yu et al., 2021) To achieve the stated goal, the research plan includes the execution of two crucial laboratory tests: the Proctor compaction test and the California Bearing Ratio (CBR) test. These tests are instrumental in evaluating the compaction characteristics and strength parameters of the soil treated with Calcium Chloride. (Pooria Ghadir et al., 2021) The Proctor compaction test will provide insights into the optimum moisture content and maximum dry density achievable for the treated soil, while the CBR test will assess the soil's strength and load-bearing capacity (Karami et al., 2021). Furthermore, the research methodology involves a comprehensive review of existing literature, research reports, books, and documents relevant to soil stabilization using Calcium Chloride. This thorough examination of prior studies will provide a solid foundation for understanding the principles, methodologies, and outcomes associated with the use of Calcium Chloride in soil stabilization. By building upon existing knowledge, the research aims to contribute novel insights and advancements to the field. The anticipated outcome of this research is not only the verification of the hypothesis regarding the effectiveness of Calcium Chloride in improving soil stabilization but also the generation of accurate and reliable data through laboratory testing. The aim of this investigation is to investigate the improvement of soil stabilization using Calcium Chloride in subgrade. Through a systematic approach encompassing literature review, laboratory experimentation, and detailed reporting, this investigation seeks to make a meaningful contribution to the knowledge base and practices in soil stabilization for sustainable infrastructure development.

**Methodology**

This section acts as the approach of overall research project, defining the methodology that is going to be used. Quantitative research descriptive method was used for this research study by testing the samples using selected test methods. The research methodology outlines the processes that were done, from reviewing the literature and data gathering to testing in laboratories and result analysis, giving a road map for the study's execution and assuring a thorough and repeatable procedure for conducting research.

The use of $CaCl_2$ in the subgrade for road building may improve soil stability. The grant objective of this research is to improve the stabilization of the soil in the area where the construction work is carried out at the highest quality level during the construction of roads. It

is felt that this research will be successful. Some of the related facts were discovered in the literature review mentioned above. If we compare the progress and the facts contained in it with this research, it is felt that this research will be successful.

The Properties of Calcium Chloride ($CaCl_2$), The methodology followed here is Literature Reviews. It is hoped to get the necessary information from the RDA and using old records. This method is helpful for the research because of the existing results should be useful to obtain assumptions which needed to obtained while the research. Obtain the Industrial Grade Calcium Chloride Flakes 77% from the market.

The methodology followed here involves comprehensive literature reviews and the extraction of essential information from existing reports. Drawing upon insights from prior studies, calcium chloride will be added to the soil samples following methodologies outlined in previously documented reports. This approach ensures a consistent and informed application of calcium chloride. The goal is to produce four distinct soil samples, each containing varying percentages of calcium chloride (0%, 5%, 10%, 15%, 20%), allowing for a nuanced exploration of its impact on soil stabilization within the subgrade. This systematic and controlled variation in calcium chloride content contributes to a thorough understanding of its effectiveness in enhancing soil properties for road construction.

The methodology involves conducting two crucial laboratory tests, namely, the Proctor compaction test and the CBR test. This strategic selection of tests aims to validate the relevance and accuracy of the research topic. The tests will be meticulously carried out at the ICBT Geology lab, ensuring precision and reliability in the assessment of soil properties.

After conducting all the laboratory tests, the readings taken from them are used, and the correct results are obtained using Microsoft Excel. The test results obtained here are helpful to continue the research. All the test results obtained from the above-mentioned laboratory researches are evaluated in detail and finally the final results of the research are proved by using the most meaningful graphs. correct results are obtained using Microsoft Excel. The test results obtained here are helpful to continue the research. All the test results obtained from the above-mentioned laboratory researches are evaluated in detail and finally the final results of the research are proved by using the most meaningful graphs.

**Results and Discussion**

The section reveals the core of a research effort by summarizing the results of careful laboratory experiments. Here, unprocessed information converges to elucidate discoveries, laying the basis for conversations and furthering knowledge in the selected topic. Dive into this critical section, wherein scientific results influence the research's perspective.

*Proctor Compaction Test*

Five samples were used for these laboratory tests. Relative to their soil calcium chloride values, they are classified as 0%, 5%, 10%, 15%, and 20%. Also, each sample was divided into three or four cots, and the test was carried out in such a way as to increase or decrease the water ratio. The water-to soil ratio is 8%, 10%, 12%, and 14% added to each mixture. The table 1 below shows the results of Proctor Compaction Test.

Table 1 : Results of Proctor Compaction Test

| Sample Number | Water Ratio | Calcium Chloride Ratio (CaCl₂) | Moisture Content, $w$ (%) | Dry Unit Weight |
|---|---|---|---|---|
| 1 | 8% | 0% | 8.07 | 1852.55 |
|   | 10% | 0% | 10.26 | 1883.03 |
|   | 12% | 0% | 12.26 | 1943.82 |
|   | 14% | 0% | 14.02 | 1839.48 |
| 2 | 8% | 5% | 8.03 | 1946.40 |
|   | 10% | 5% | 10.04 | 1968.54 |
|   | 12% | 5% | 12.05 | 1881.30 |
| 3 | 8% | 10% | 8.08 | 1950.33 |
|   | 10% | 10% | 10.07 | 2054.70 |
|   | 12% | 10% | 11.90 | 1879.08 |
| 4 | 8% | 15% | 8.00 | 1981.23 |
|   | 10% | 15% | 10.37 | 2140.16 |
|   | 12% | 15% | 12.55 | 1966.35 |
| 5 | 8% | 20% | 8.20 | 2.26.51 |
|   | 10% | 20% | 10.07 | 2194.19 |
|   | 12% | 20% | 12.01 | 2033.34 |

From the first sample to the last, i.e., the fifth sample, a gradual increase in the obtained results can be seen.

Max. dry density of 1st sample < Max. dry density of 2nd sample < Max. dry density of 3rd sample < Max. dry density of 4th sample < Max. dry density of 5th sample

**1943.82 < 1968.54 < 2054.70 < 2140.16 < 2194.19**

Accordingly, the dry density value is higher in the last sample than in the first sample. Also, the range of these results has also increased atomically. Considering the facts of the previously analyzed reports, surveys, and sources, it can be interpreted that the results of this study are meaningful. Maximum dry density of four soil samples in a previously discussed survey was respectively 1587, 1310, 1560, and 1343. The optimum moisture contents of all 4 soil samples are 18, 34, 18, and 30 percent, respectively (Vitales et al., 2022). After analyzing all those references, it can be stated that the results obtained by this test are all very successful. Therefore, it can be concluded that this calcium chloride can increase the dry density of the soil and bring it to very good compaction. It can be mentioned that the mixing ratio of calcium chloride and soil used for this research is very suitable for road construction projects.
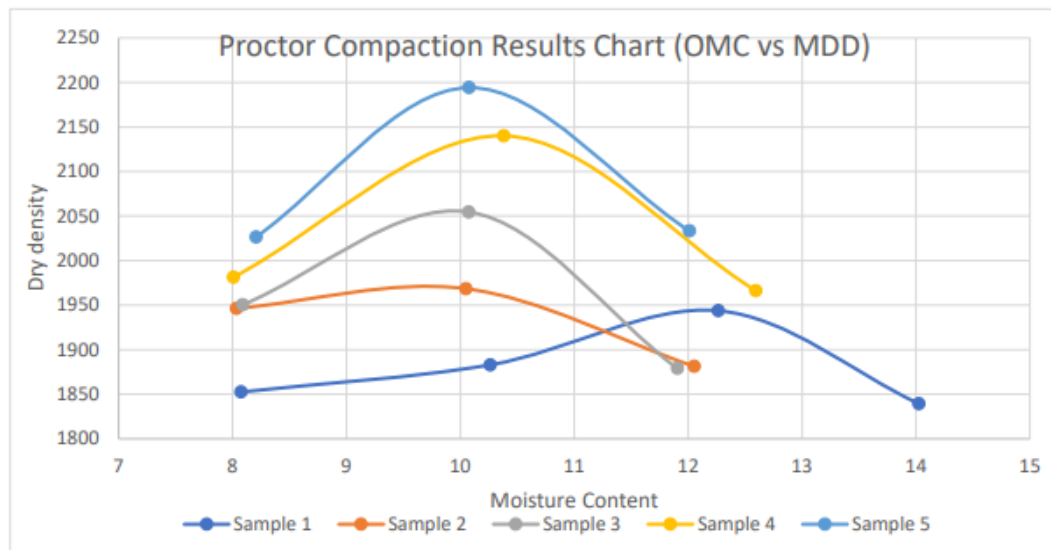
*Figure 1 : Max. Dry Density vs Optimum Moisture Content*

### California Bearing Ratio (CBR) Test

These scientific experiments used five samples. They are categorized as 0%, 5%, 10%, 15%, and 20% relative to soil calcium chloride levels. In this test, the ratio of water to soil was taken as 8%. Also, the automatic CBR apparatus was used for this experiment. The following table 2 provides a better understanding of the results obtained after conducting the survey.

Table 2 : Results of CBR Test

| Sample Number | Calcium Chloride Ratio | Penetration of plunger (mm) | Standard Load (kN) | CBR Value | Final CBR Value |
|---|---|---|---|---|---|
| 1 | 0% | 2.5 | 0.9921 | 7.5162 | 9.6907 |
| | | 5.0 | 1.9381 | 9.6907 | |
| 2 | 5% | 2.5 | 1.1305 | 8.5650 | 10.944 |
| | | 5.0 | 2.0188 | 10.0944 | |
| 3 | 10% | 2.5 | 1.3267 | 10.0507 | 11.8245 |
| | | 5.0 | 2.3649 | 11.8245 | |
| 4 | 15% | 2.5 | 1.7074 | 12.9349 | 13.7285 |
| | | 5.0 | 2.7457 | 13.7285 | |
| 5 | 20% | 2.5 | 1.9381 | 14.6828 | 16.6122 |
| | | 5.0 | 3.3225 | 16.6122 | |

A gradual rise in the acquired findings can be seen from the first sample to the last, i.e., the fifth sample.

CBR value of 1st sample < CBR value of 2nd sample < CBR value of 3rd sample < CBR value of 4th sample < CBR value of 5th sample

**9.6907 < 10.0944 < 11.8245 < 13.7285 < 16.6122**

As a result, the CBR value in the last sample is greater than the CBR value in the first sample. Furthermore, the range of these findings has expanded. Given the facts from the previously examined reports, surveys, and sources, the findings of this research can be taken as significant. The CBR test is intended to measure the strength of a material.

Accordingly, it can be said that this laboratory test done with samples made by mixing calcium chloride and soil is successful to some extent Based on the previous surveys and tests, their CBR value increases to some extent. But in the CBR test conducted for this research, the water molecule ratio was taken as 8% compared to soil. The results of previous tests may vary due to the proportion of water applied as well as the type of soil.

Note: The graph which proves all the facts mentioned above is given below.
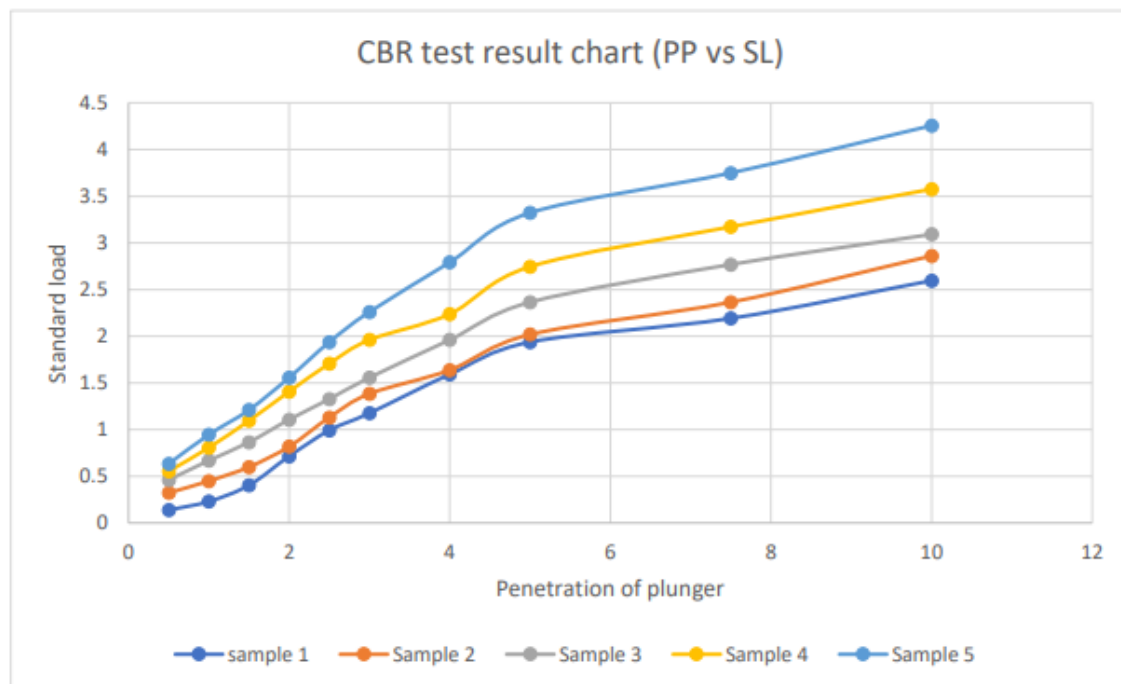


*Figure 2 : Results of CBR Test*

**Conclusion and Recommendation**

This research was conducted with the aim of making soil compaction more stable by using calcium chloride. Before conducting this research, four objectives were made, and all kinds of activities required to achieve those objectives were carried out. Conducting laboratory tests, reading and knowing the content of pre-printed books, and analyzing pre-released research reports were all done to achieve the objectives of this research. The results obtained by conducting laboratory research related to this research are all very accurate and successful. By analyzing the results of the Proctor compaction test and the CBR test with understanding, it can be concluded that the strength and stability of the soil can be increased more effectively by

applying calcium chloride. (Ge et al., 2021) Only two laboratory tests related to this research were conducted (Proctor compaction test and CBR test), but it is possible to conduct several other laboratory tests for this research. Permeability tests and direct shear tests are some of those tests. It is a research limitation that occurred while conducting this research. Also, the mixing ratios (0%, 5%, 10%, 15%, and 20%) taken during the laboratory research related to this research are as above. (Wang, Zhang and Li, 2022) But it is possible to carry out this research by increasing the mixing ratio. Thus, a very accurate understanding can be obtained about this research. It is also a research limitation that occurred while conducting this research. Chemical stabilization is typically more costly compared to biological techniques and raises concerns regarding the environment. Also, it was possible to carry out the laboratory research related to this research by using the laboratory equipment that was used for some time, which is also a limitation of the research.

"The problem that prompted the research is that while the majority of projects are effective, others fail spectacularly as the road collapses in a relatively short period of time. This is because the natural soil at the construction location was not properly compacted prior to the construction of the roadway." Increasing the stability of the soil by using chemical liquids is very suitable to solve the problem mentioned above. Chemicals are a very productive, efficient, after conducting this research, recommendations can be given to the construction industry that the use of chemicals can increase the quality and stability of the soil. Accordingly, these types of sources can be used to avoid various problems and technical omissions in the construction industry. By carrying out this kind of research, it is possible to get a very high-quality result in the field of engineering as well as in the field of construction. Also, when this research is well analyzed and the facts are known, every possible technical step must be taken to apply it. Thus, this research will be useful for Sri Lanka as well as the whole world.

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# A STUDY ON IMPROVING BEARING CAPACITY OF SEA SAND BY ADDING CaO AND FLY ASH FOR LAND RECLAMATION

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**Abstract**

The research investigates the enhancement of bearing capacity in dredged sea sand through the application of Class C fly ash and commercial rapid lime. The study involves varying mix proportions by 0.5% to assess their impact on permeability, compaction, and CBR. The objective is to determine the optimal mix percentage for improving soil conditions in land reclamation projects. Results indicate that specific fly ash and lime percentages lead to increased bearing capacity, permeability, and compatibility. Limitations include fixed 0.5% variations. The research extends beyond bearing capacity to address challenges in land reclamation, particularly in areas like Colombo International Financial City in Sri Lanka, where dredging is crucial for creating new land. The dredged sand, often slurry-like, has low permeability and high viscosity, requiring extensive time for consolidation. The study aims to improve the compatibility and permeability of such sea sand, crucial for achieving the desired quality in land reclamation. This research contributes valuable insights for engineering measures to enhance the construction industry, particularly in regions with significant land reclamation projects, potentially revolutionizing strategies in port cities, coastal areas, and along rivers.

**Key Words:** Land reclamation, fly ash, Lime, Bearing capacity, Sandy Soil (Sea bed soil)

**Introduction**

Land reclamation, a widely adopted method to alleviate land shortage issues, primarily employs hydraulic techniques that involve utilizing dredged sea sand from the seabed. However, the sea bed sand used in reclamation projects is often characterized by its smooth and soft nature, exhibiting low compatibility and high permeability. This inherent soil quality poses a challenge for construction activities, necessitating effective soil improvement methods before commencing any building projects on reclaimed lands. (Wenlong Zhu, 2018). Traditionally, chemical soil stabilization has proven to be a valuable approach for enhancing the ground properties in such scenarios. Previous research efforts in ground improvement have frequently employed materials such as fly ash, cement, and lime to address the challenges associated with sandy soils. The specific nature of sea bed sand, artificially created during land reclamation, makes it more critical to address soil improvement compared to naturally occurring sandy lands. (Gaafer, 2015). To adequately address this issue, it becomes imperative to comprehensively evaluate the current texture of the sea bed soil, considering its unique characteristics and properties. Previous research has established the need for significant improvement in sandy soils before initiating construction, and this is especially true for reclaimed lands, which require meticulous attention due to their artificial creation. Among the various soil improvement materials, fly ash and quicklime (CaO) have emerged as highly effective applications for enhancing soil properties such as compatibility and permeability.

Both fly ash and quicklime have been employed independently in previous studies to improve soil characteristics, including plastic limit and water content. (Biswal, 2018). This research aims to advance the existing knowledge by exploring the synergistic effects of combining fly ash and quicklime in different mix proportions. The focus is on improving the bearing capacity of dredged sea sand, commonly used for land reclamation purposes. By systematically studying the impact of varying mix proportions of fly ash and quicklime, the research endeavors to provide valuable insights into optimizing soil improvement strategies for reclaimed lands. The findings of this study are anticipated to contribute significantly to the understanding of effective ground improvement techniques in the context of land reclamation projects. *(Afrin, 2017)*.

In addressing the inherent challenges posed by the high permeability and low compact ability of dredged sea sand, this study focuses on modifying its physical, chemical, and biological characteristics through the incorporation of fly ash and lime (quicklime). The overarching aim is to enhance the bearing capacity of sea sand, particularly when utilized for land reclamation purposes. The utilization of dredged sea sand in land reclamation is a prevalent practice, yet the smooth and soft nature of this material presents significant obstacles to construction due to its suboptimal compaction and high permeability. To overcome these challenges, the study explores the synergistic effects of fly ash and lime as soil improvement agents. Both fly ash and lime have demonstrated effectiveness in modifying soil properties individually, and this research seeks to harness their combined potential to achieve superior results. The primary objective is to investigate the optimal mix proportions of fly ash and lime for enhancing the bearing capacity of dredged sea sand. By systematically examining the physical, chemical, and biological transformations induced by these additives, the study aims to provide insights into a comprehensive and efficient strategy for improving the overall stability and load-bearing capacity of sea sand. The findings from this research hold the potential to inform best practices for soil improvement in land reclamation projects, contributing to sustainable and resilient infrastructure development.

**Methodology**

The use of the fly ash and the quick lime helps to improve the bearing capacity of the dredged sandy soil which were taken from the sea bed. As mentioned in the introduction, fly ash and quicklime has been used separately in many existing researches to improve many properties in the soil itself. Data collection for the research mainly can be get from the literature reviews and conducted tests' results. The suitable data from the existing research papers has been analyzed and marked. The results obtained from the permeability test, proctor compaction test, CBR test, specific gravity test and sieve analysis test.

According to the first objective of the study, properties of CaO and fly ash could be obtained by the existing research papers. The researches about the biological, physical and chemical properties about both fly ash and CaO useful to obtain the required information to conduct the research. The chemical properties of fly ash should capable to increase the CBR value and to reduce the specific gravity as well. Lime (CaO) inspires the soil to bond with fly ash and to improve the ability of compaction and reduce the high permeability in dredged sea sand.

*Materials*

Fly ash & Lime: The previous reviews showed that the Class C fly ash (CaO) gives more positive results compared to other classes of fly ash. Therefore, commercially available fly ash class C was used for the research.

According to the previous researches Lime has two variations as Ca (OH)$_2$ & CaO which generally called as hydrated lime and quick lime. In this research the CaO (quick lime) has been used and commercially available lime (CaO) was used of this purpose.

Soil: The chemically untreated dredged sea soil samples were taken from the Port City Colombo. This soil was dredged by the method of floating pipes by the use of bottom opened barges.

Existing researches has been used to develop the samples with suitable mix proportions of Cao and fly ash. The selected suitable mix proportion percentages are changing in only 0.5% of percentage to study the soil improvement by the change of small about of additives. This research would be helpful to understand the workability of the fly ash and lime on dredged sea sand as well.

Table 1 : Percentages of Mix Proportions

| Sample No | Amount of Fly Ash % | Amount of Lime % | Amount of Soil % |
|-----------|---------------------|------------------|------------------|
| 1 | 6.5 | 2.5 | 91 |
| 2 | 7 | 2 | 91 |
| 3 | 7.5 | 1.5 | 91 |
| 4 | 8 | 1 | 91 |
| 5 | 8.5 | 0.5 | 91 |
| 6 | 0 | 0 | 100 |

The specialty of the research is to continue the soil percentage as 91% while changing the percentages of fly ash and lime mix proportion accordingly to study how fly ash and lime react to improve the permeability, compact ability and CBR of dredged sea sand.

The main objective of the research is to improve the dredged sea sand up to the required permeability level and compaction. Therefore, if dredged soil could be able to improve with small number of additives compared to the soil amount, that would be an added advantage of this research.

According to the third objective, bearing capacity of all developed soil mixtures were determined. Bearing capacity is the key component of the research. The compact ability and the permeability are also parameters of bearing capacity. Therefore, after chemically treating the soil sample with fly ash and CaO with proposed mix proportions, the soil sample should be test out whether the required parameters have been improved or not.

As this research ultimate goal is to develop the compatibility and permeability to improve the CBR of the dredged soil, the permeability test, proctor compaction test and CBR test should be conducted for the five different soil samples.

The sixth soil sample which is not containing any chemical (Chemically untreated dredged sea sand) also should be test out to have an idea about the selected soil sample and also to compare

the obtained results. Behalf of main three tests, to analyze the soil particle distribution and to determine the void ratio of the dredged sea sand, the sieve analysis test and the specific gravity tests were conducted. All the tests were conducted in room temperature and the standard apparatus and materials were used while the tests.

Data analyzing is one of the important things in the research. Appropriate tables, graphs and diagrams could be used to analyze the data which were obtained from the conduced tests. After analyzing the obtained results from the conducted tests to identify the bearing capacity of the developed soil mixtures for different mix proportions, the results could be used to decide the best and most suitable mix proportion of the dredged sea sand for the land reclamation.

**Results and Discussion**

The process of applying statistical methods to evaluate and describe data can be identified as data analysis. The fourth objective is to analyze the results to recommend the suitable mix proportion of sandy soil for the land reclamation.

***Effect of Fly Ash & CaO (Lime) on Soil Compaction***

Proctor Compaction Test was conducted to analyze the effect of Fly Ash & CaO (Lime) on soil compaction. Five different soil samples were used for the proctor compaction test under the percentages as mentioned in the below table 2.

Table 2 : Results of Proctor Compaction Test

| Sample | Water Ratio | Fly Ash (%) | Lime (CaO) (%) | Moisture Content (%) | Dry Unit Weight ($\gamma$) |
|--------|-------------|-------------|----------------|----------------------|----------------------------|
| 1 | 8 | 6.5 | 2.5 | 8.026 | 1920.04 |
|   | 10 |   |   | 10.99 | 1946.89 |
|   | 12 |   |   | 12.02 | 1948.04 |
|   | 14 |   |   | 13.91 | 1674.00 |
| 2 | 8 | 7.0 | 2.0 | 7.99 | 1926.43 |
|   | 10 |   |   | 10.07 | 1926.64 |
|   | 12 |   |   | 11.93 | 1958.97 |
|   | 14 |   |   | 13.83 | 1851.82 |
| 3 | 8 | 7.5 | 1.5 | 8.301 | 1897.56 |
|   | 10 |   |   | 10.3824 | 1904.01 |
|   | 12 |   |   | 12.006 | 1976.66 |
|   | 14 |   |   | 14.17 | 1734.97 |
| 4 | 8 | 8.0 | 1.0 | 8.05 | 1990.21 |
|   | 10 |   |   | 10.50 | 2015.1 |
|   | 12 |   |   | 12.33 | 2023.66 |
|   | 14 |   |   | 14.45 | 1906.54 |

| 5 | 8 | 8.5 | 0.5 | 8.1 | 2003.86 |
|---|---|---|---|---|---|
|   | 10 |   |   | 10.79 | 2017.39 |
|   | 12 |   |   | 11.3 | 2045.47 |
|   | 14 |   |   | 14.47 | 1897.04 |
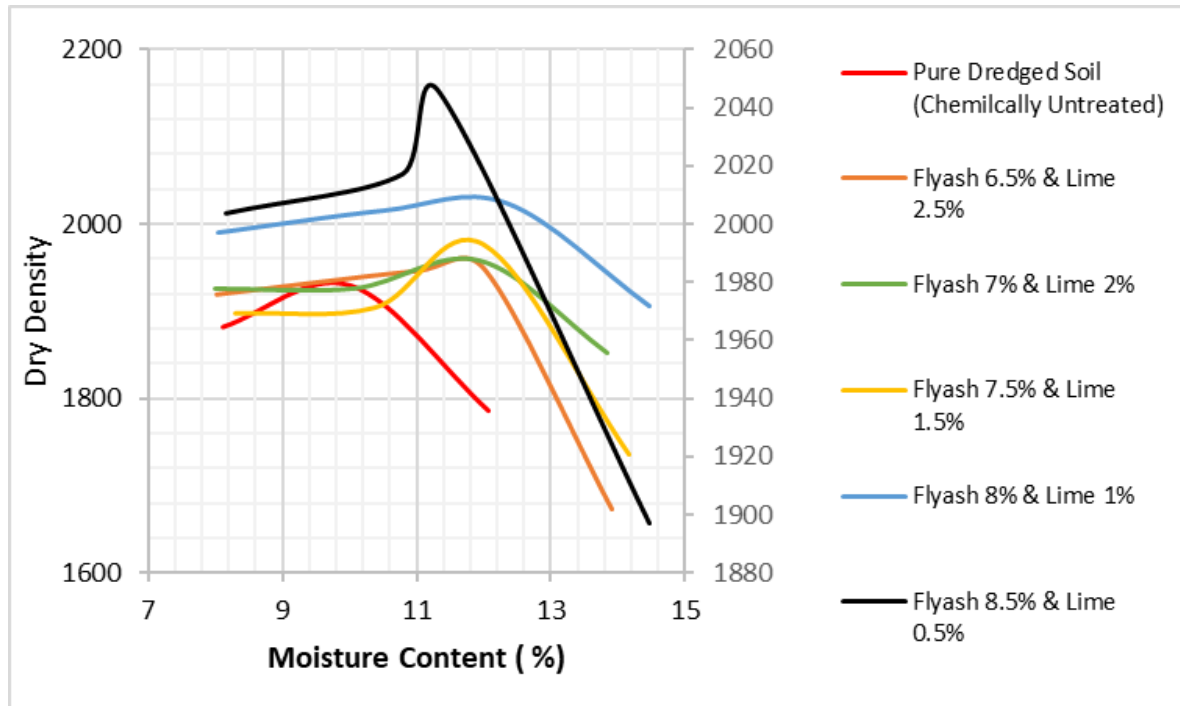


*Figure 1: Dry Density Vs. Moisture Content Graph*

Figure 1 shows the variation of the moisture content against the dry density. Dry density depends on the mass and the volume of the dry soil sample. Dry density should be high in a good soil sample. Generally, the dredged sea soil is a sandy type soil. Therefore, normally the dry density of the dredged soil is very low. As in the graph 1 it indicates that the dry density of the chemically untreated soil sample carries a lower dry density value compared to the other chemically treated soil samples. Figure 1 clearly indicates that the dry density has been increased when the fly ash percentage is increasing and lime percentage is decreasing.
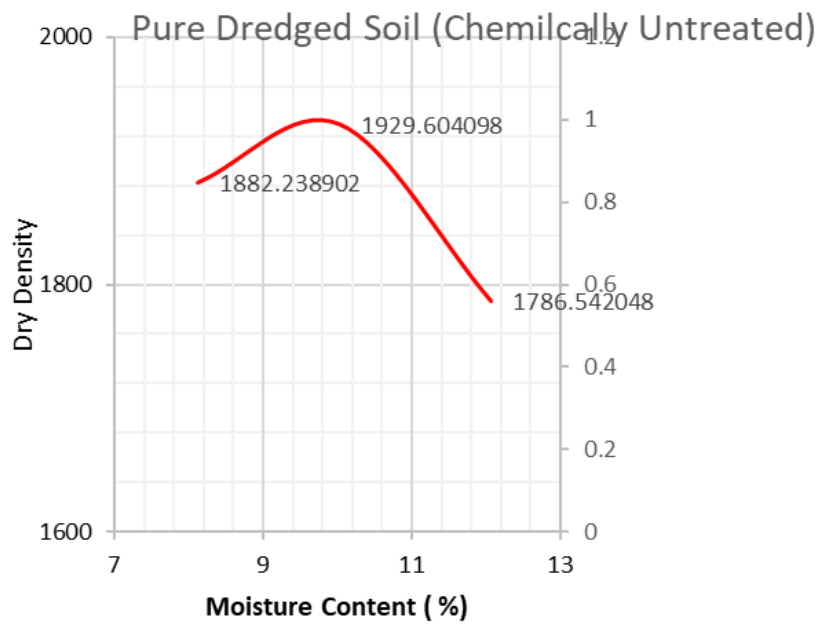
*Figure 2 : Pure Dredged Soil*

In higher percentage of fly ash, the dry density of the dredged soil sample is more compared with other samples and in lower percentages of lime, the dry density of the soil sample is lower. In conclusion these results convey that the fly ash has been able to improve the compact ability of the dredged sea soil. According to the obtained results the selected fly ash and lime mix proportion percentages are suitable to improve the compaction of dredged sea soil.

### *Effect of Fly Ash & CaO (Lime) on California Bearing Ratio*

CBR test was conducted for all six soil samples as five chemically treated soil samples and one pure dredged sea soil sample. The test was conducted under the standard guidelines.

Table 3: Results of CBR Test

| Sample | Fly Ash (%) | Lime (CaO) (%) | Penetration of plunger (mm) | Standard load | CBR value | Final CBR value |
|--------|-------------|----------------|-----------------------------|---------------|-----------|-----------------|
| 1 | 6.5 | 2.5 | 2.5 | 0.6921 | 5.2438 | 13.8438 |
|   |     |     | 5.0 | 2.7687 | 13.8438 | |
| 2 | 7.0 | 2.0 | 2.5 | 0.8075 | 6.1178 | 15.5743 |
|   |     |     | 5.0 | 3.1148 | 15.5743 | |
| 3 | 7.5 | 1.5 | 2.5 | 1.0382 | 7.8658 | 16.7280 |
|   |     |     | 5.0 | 3.3456 | 16.7280 | |
| 4 | 8.0 | 1.0 | 2.5 | 1.2690 | 9.6138 | 17.3048 |
|   |     |     | 5.0 | 3.4609 | 17.3048 | |
| 5 | 8.5 | 0.5 | 2.5 | 1.5574 | 11.7987 | 21.6310 |
|   |     |     | 5.0 | 4.3262 | 21.6310 | |
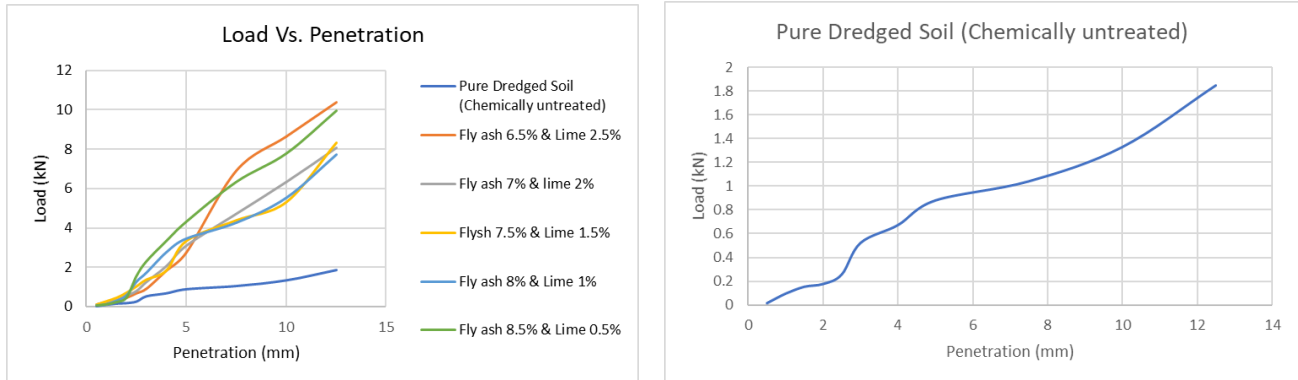
*Figure 3 : Load Vs. Penetration for Pure Dredged Sea Soil (CBR value = 4.3838)*

California Bearing Ratio (CBR) is a value to discuss the bearing capacity of particular soil sample. Therefore, CBR test is very important to have an idea about the bearing capacity of a soil sample.

*Graph 3* shows the variation between the load and the penetration. According to the obtained results from the CBR test, that shows when the fly ash percentage increases while CaO percentage decrease, the CBR value is higher compared to the lower fly ash percentages and higher CaO percentages. Therefore, it conveys that the bearing capacity of the soil has been increased compared to the CBR value of the chemically untreated dredged sea soil.

### Effect of Fly Ash & CaO (Lime) on Permeability property

Permeability Test was conducted to analyze the effect of Fly Ash & CaO (Lime) on soil permeability. Five different soil samples were used for the permeability test under the percentages as mentioned in the below table 4.

Table 4 : Co-efficient of Permeability of Samples

| Sample | Fly Ash (%) | Lime (CaO) (%) | Gradient (m) | K Co efficient of permeability |
|--------|-------------|----------------|--------------|--------------------------------|
| 1 | 6.5 | 2.5 | 0.0213 | $4.4517 \times 10^{-6}$ |
| 2 | 7.0 | 2.0 | 0.0190 | $4.4517 \times 10^{-6}$ |
| 3 | 7.5 | 1.5 | 0.0173 | $4.4517 \times 10^{-6}$ |
| 4 | 8.0 | 1.0 | 0.017 | $4.4517 \times 10^{-6}$ |
| 5 | 8.5 | 0.5 | 0.0155 | $4.4517 \times 10^{-6}$ |
| 6 | 0 | 0 | 0.0255 | $4.4517 \times 10^{-6}$ |
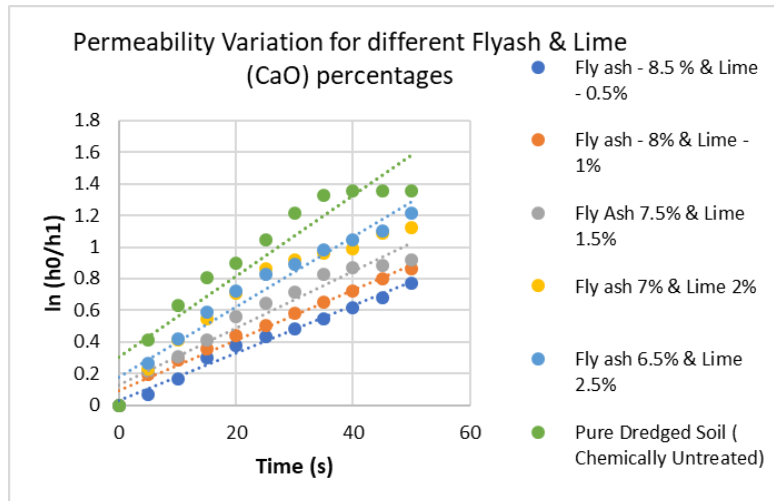
*Figure 4: Permeability variation for different Fly ash and Lime (CaO) Percentages*

Permeability is the ability of water to move through the soil. Generally, high permeable soil is not suitable for the construction purposes. Therefore, the dredged sea soil needed to be treated. According to the obtained results from the permeability test, Table 4 conveys that the permeability co-efficient has been reduced when the fly ash percentage is higher and lime percentage is lower. Therefore, the results convey that the under the proposed fly ash and lime percentage, the permeability is successful. Therefore, the mix proportion percentages are suitable for the improvement of the permeability of dredged sea soil.

**Conclusion and Recommendation**

The research findings show that using certain fly ash and lime (CaO) percentages improves bearing capacity metrics, permeability, and compatibility of dredged sea sand. This shows that these additions have the potential to improve the performance of maritime soils. Certain research limitations, however, must be noted. The fixed 0.5% variance in additive percentages for each sample limits the search for optimal mix proportions. Changing this variable might result in more nuanced and valuable results, providing for a more complete knowledge of the influence of fly ash and lime on dredging marine soil.

While the study's primary goal was to improve soil carrying capacity, it also identified potential for further laboratory testing. These tests, conducted with the same percentages of fly ash and lime, could further address various parameters affecting dredged sea soil quality. By extending the investigation beyond bearing capacity, the research aims to contribute holistic insights into the improvement of marine soil characteristics.

Civil engineering, typically regarded as the core of the construction industry, is critical in addressing issues linked to port city building, coastal development, and riverbank projects. The study proposes the use of cutting-edge civil engineering solutions that make use of the detected chemical components to stabilize and strengthen soil. The implementation of research-derived solutions to tackle complications encountered in many building situations, promoting creativity and resilience in the face of environmental and engineering constraints, has the potential to revolutionize the construction sector. Finally, the study hopes to have a revolutionary influence

on building techniques, enabling sustainable growth in maritime and riverbank construction projects.

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# IMPROVEMENT OF BEARING CAPACITY OF COASTAL SANDY SOIL BY STABILIZING GRANITE DUST-WASTE RUBBER POWDER MIXTURE

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**Abstract**

This research investigates the improvement of the bearing capacity of the coastal sandy soil by stabilizing Granite dust-waste rubber powder mixture. The Granite dust and waste rubber powder were mixed with percentage 1:1 of the weights. And the Granite dust- rubber powder mixture was mixed to the weight percentage of the sandy soil 4%, 8%, 12%, 16% and 20%. There were several laboratory testings were done to obtain the research aim. According to the results of permeability test, the coefficient of permeability value was reduced from $0.01024 cms^{-1}$ to $0.00845 cms^{-1}$ by increasing the mix proportion up to 20%. According to the test results of proctor compaction test, the maximum dry density value was increased by mixing 20% of mixture and the value is $2.083 g/cm^{-3}$. The optimum moisture content value was also generated from 20% of mixture mixed with sandy soil, and the value is 7.1%. The CBR value also increased when the mix proportion is increased up to 20% and the value is 26%. Granite dust-waste rubber powder mixture can be used to stabilize the coastal sandy soil.

**Keywords:** Bearing capacity, coastal sandy soil, granite dust, waste rubber powder, stabilizing, shear strength, permeability, compaction.

**Introduction**

With the quick growth of human population in the earth, the favorable space for living is being limited. People have to moved places where hard to living. As an example, a country such as Sri Lanka, there are lot of lands around the coastal areas. But most of the areas there are no big cities or villages have been developed due to some sorts of issues. People cannot build their habitats by using these spaces. Thus, people need to identify this situation and need to find a way to develop coastal areas up to the livable places. Therefore, there is a need to design proper structures with including high rise, mid-rise, low-rise buildings, roadway systems, bridges and other required infrastructures etc. But there are several problems can be identified regarding the exposure condition and the geological conditions are, mostly affected those constructions in the coastal areas (Naeimabadi, A., 2012).

The soil type of the coastal areas can be classified as sandy soil which is having with poor characteristics such as, high permeability, low shear strength, lack of compaction, low bearing capacity ect, which are unfavorable for those construction works which are mentioned above (El-Nagar, D. A., Mohamed, R. A. A., 2019). According to the problem a proper soil improvement technique is required to prevent the construction failures at the coastal areas (Santhos, K et al.2013). In this research project focus on what are the main issues regarding

the soil profile of coastal areas and a new technique to improve some soil properties of sandy soil in coastal areas. Thus, this research mainly aims to improve to bearing capacity of the coastal sandy soil in the coastal areas of north western part of Sri Lanka.

**Research Methodology**

In this research, there is a solution which proposed to improve the soil properties of the coastal sandy soil such as, permeability, shear strength, bearing capacity by using granite dust-waste rubber powder mixture which is stabilized with the coastal sandy soil in the north western part of Sri Lanka. This research is a quantitative research where the improvement of above soil properties is measured by conducting geo-engineering laboratory testing according to the ASTM standards.

The properties of the materials which are sandy soil, Granite dust and rubber powder were found through referring previous research projects as the literature reviews. As well as the probability of mixing the materials is much important facts, because of the chemical properties and reactions when the materials were being mixing found by reviewing the literature reviews. There were five different mix proportions used (Table 1 and 2) in this study, from the lowest weight percentage to the highest weight percentage of Granite dust-waste rubber powder mixture. When mixing materials, firstly granite dust and rubber powder were mixed to the weight percentage of 1:1 weight to create the granite dust waste rubber powder mixture.

Table 1: mixing weight percentages of Granite dust-rubber powder

| Materials | Weight percentage |
|---|---|
| Granite dust | 50% |
| Waste rubber powder | 50% |

Table 2: Mixing proportions of sandy soil with granite dust-rubber powder mixture

| Sample no | 01 | 02 | 03 | 04 | 05 |
|---|---|---|---|---|---|
| Granite Dust-Waste rubber powder mixture | 4% (of soil weight) | 8% (of soil weight) | 12% (of soil weight) | 16% (of soil weight) | 20% (of soil weight) |

After preparing the mixtures as per the above-mentioned mixing proportions, laboratory tests were done to determine the different properties of Granite dust-waste rubber powder mixture, mixed with sandy soil.

Finally, all the results were calculated which were collected through the separate laboratory testing as per the test standards. Obtained results were analyzed one by one sample where tested at the laboratory by using a computer software, Microsoft Excel. The variations of the permeability, optimum moisture content, maximum dry density and CBR values were evaluated and the values were discussed by comparing one by one testing whether there is an

improvement or not of the coastal sandy soil when mixing the granite dust- waste rubber powder mixture.

**Results and Discussion**

*Particle Size Distribution of Materials*

In this research, there are three samples were tested individually including, sandy soil, granite dust and rubber powder by using a set of sieve which has been included six different sieves with different mesh sizes according to the order of 4.75mm, 2.36mm, 2.00mm, 0.425mm, 0.075mm and 0.045mm. the final results were added to the semi logo metrical graphs by individually.
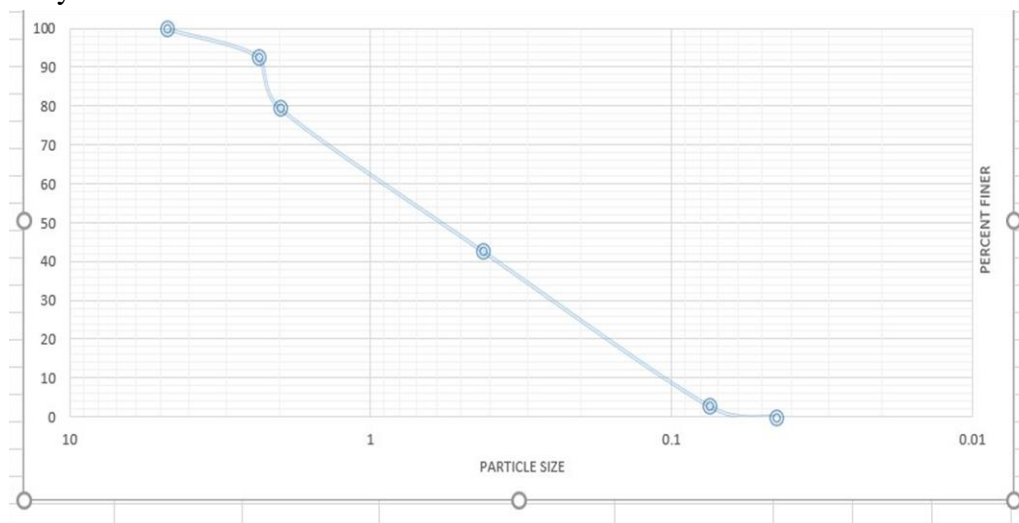


*Figure 1 : Particle size distribution curve of sandy soil*

According to the distribution curve of the sandy soil, the effective particle size is 0.10mm and the coefficient of uniformity value is 9. As well as the coefficient of curvature value is 0.69.
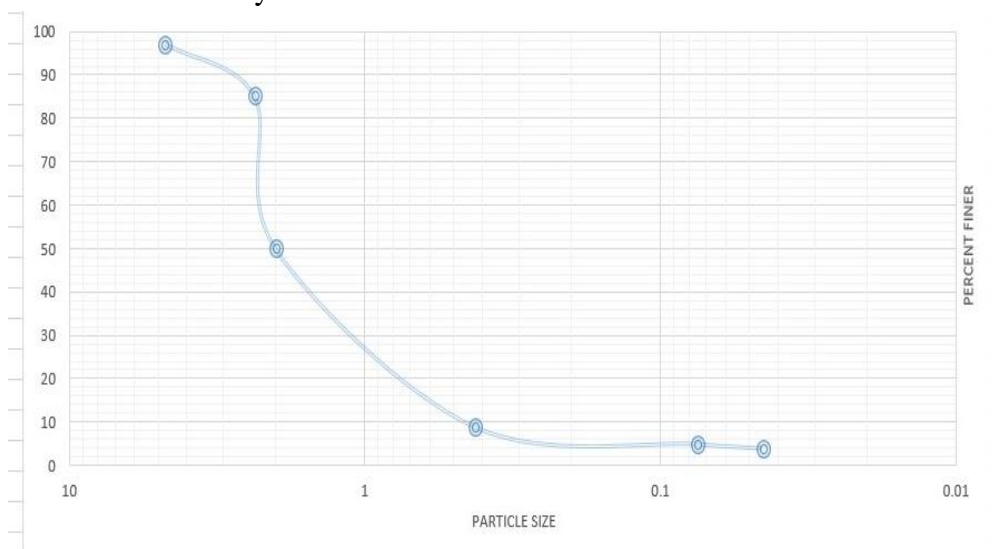


*Figure 2 : Particle size distribution curve of Granite dust*

According to the distribution curve of the sandy soil, the effective particle size is 0.42mm and the coefficient of uniformity value is 5. As well as the coefficient of curvature value is 1.25.
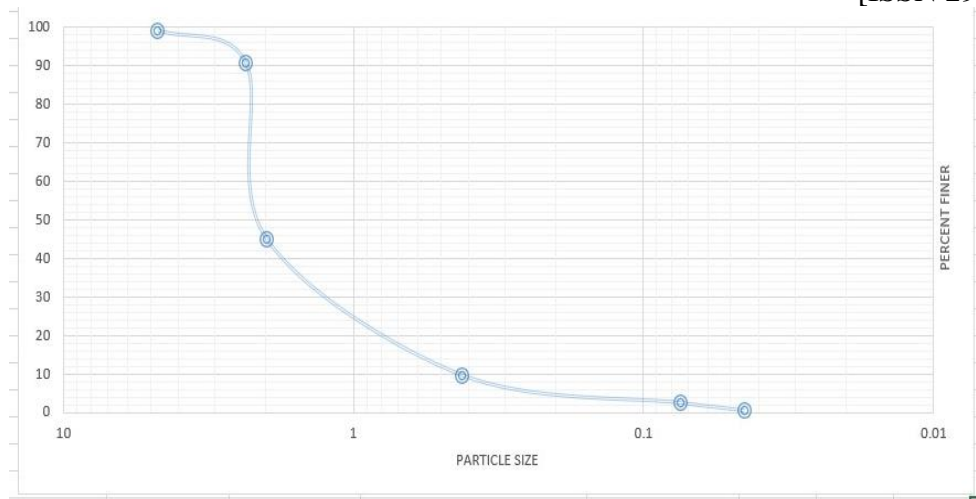
*Figure 3 : Particle size distribution curve of rubber powder*

According to the distribution curve of the sandy soil, the effective particle size is 0.41mm and the coefficient of uniformity value is 5.12, as well as the coefficient of curvature value is 1.41. According to the particle size distribution curve of the sandy soil sample, the curve is represented the gravel-sand region. But the soil sample is not representing all the particle size regions, therefore*, it* is about particle size distribution curve of the sandy soil is poorly graded. According to the size distribution curve of granite dust sample, the curve is represented the gravel sand region and the curve shape is gap graded. The soil sample is not represented all the particle size regions and there are clear gaps were shown between some particle sizes. Therefore, it is about the particle sizes distribution curve of the granite dust is poorly graded. According to the size distribution curve of rubber powder sample, the curve is represented the gravel sand region and the curve shape is gap graded. The rubber powder sample is not represented all the particle size regions and there are clear gaps were shown between some particle sizes. It is about the particle sizes distribution curve of the rubber powder is poorly graded.

***Effect on Specific Gravity of the Testing Samples***
According to the specific gravity laboratory testing results of the sandy soil, 4%,8%,12%,16% and 20% sand-granite dust-rubber powder mixture are accordingly,2.703, 2.710, 2.732, 2.740, 2.748 and 2.769.
According to the specific gravity values there was a clear improvement can be seen. The critical specific gravity value is 2.769 which was generated at the 20% mixture mixed with sandy soil sample. When the increment of the mixing proportion the specific gravity was also increased. Therefor the density of the soil has been increased when the specific gravity increase.

***Effect on Permeability of testing the samples***
In this research the coefficient of permeability values was calculated of the sandy soil, 4% mixture mixed sample, 8 % mixture mixed sample, 12% mixture mixed sample. 16% mixture mixed sample and 20% mixture mixed sample, according to the testing results. According to

the permeability laboratory testing results, the coefficient of permeability of the sandy soil sample is 0.01024 cms[-1].
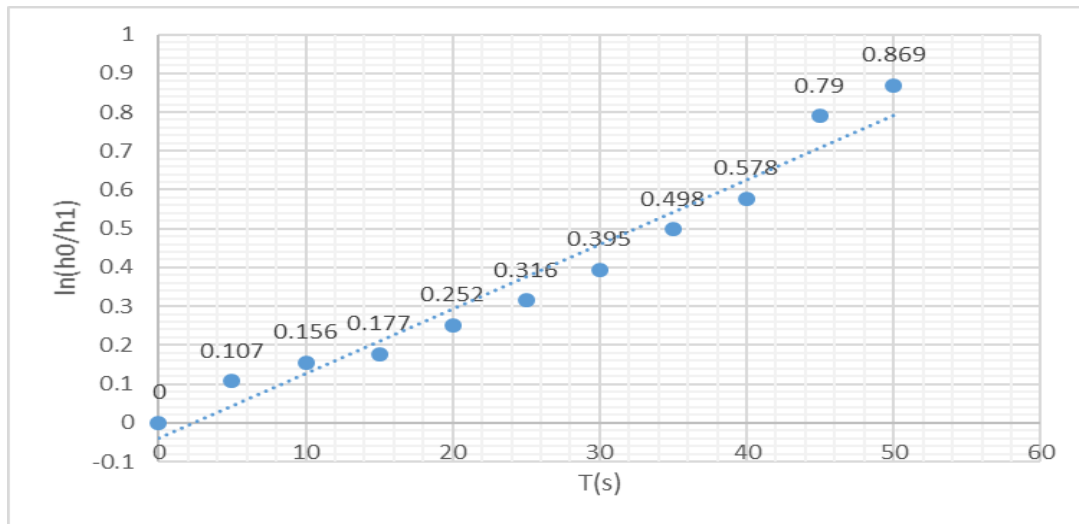


*Figure 4 : Permeability graph of Sandy soil*

According to the permeability laboratory testing results, the coefficient of permeability of the 4% mixed sample is 0.00947 cms[-1].
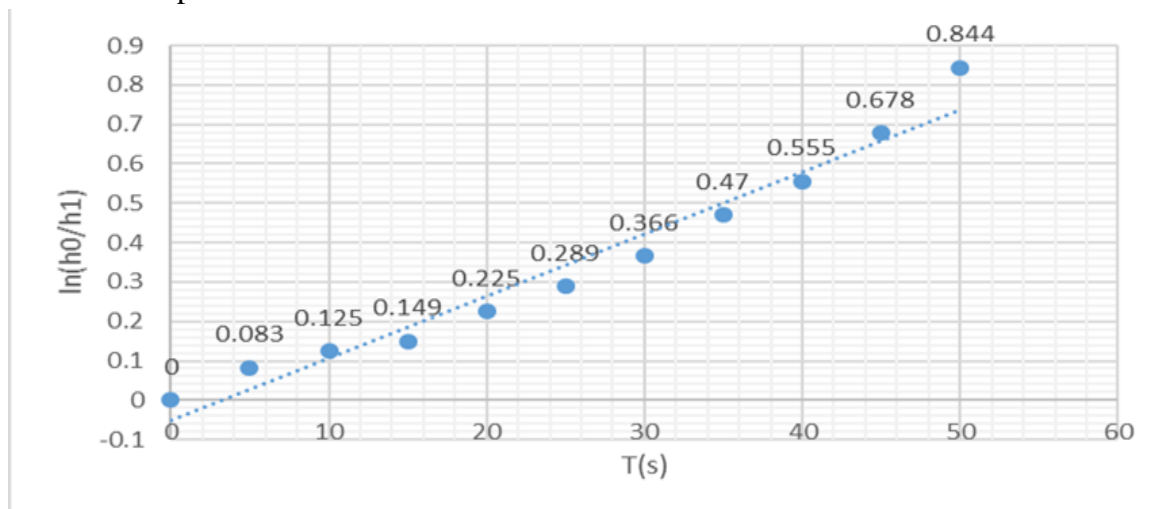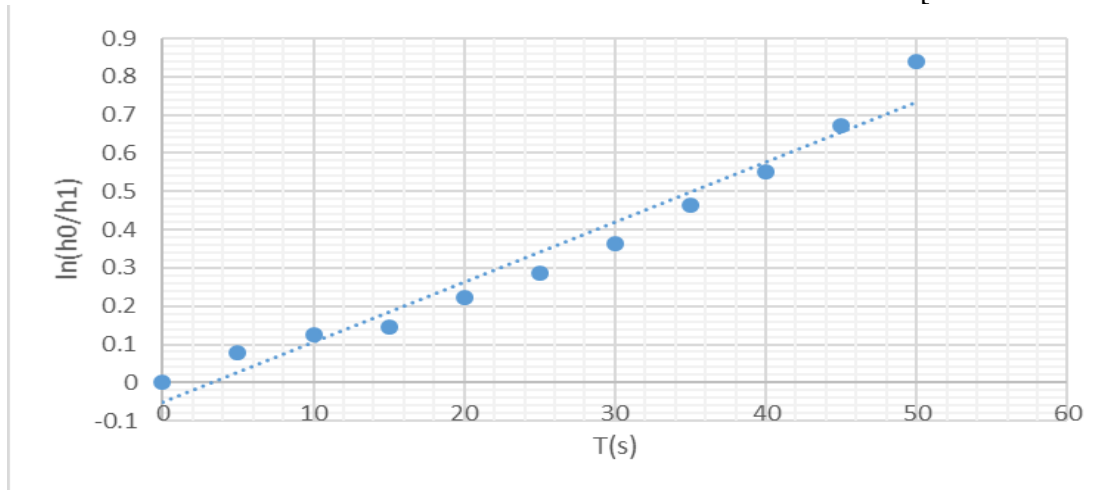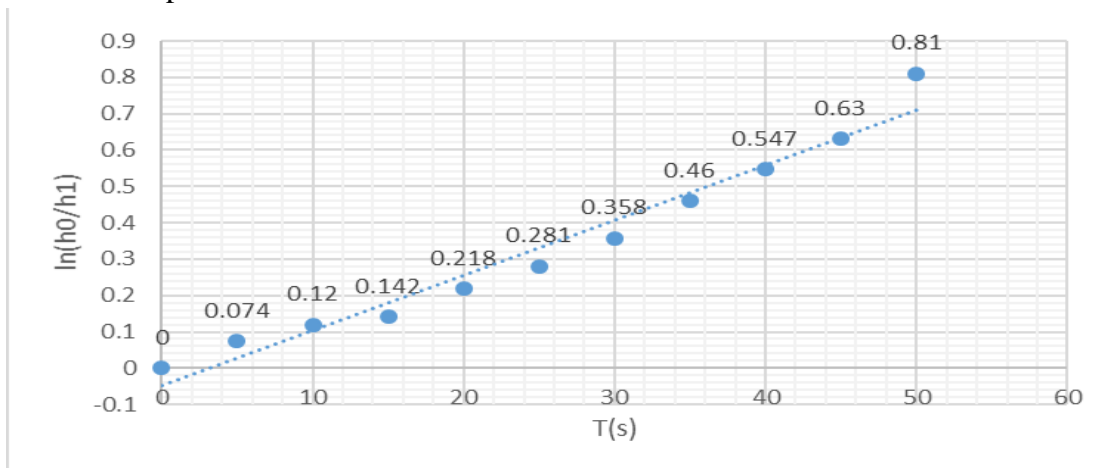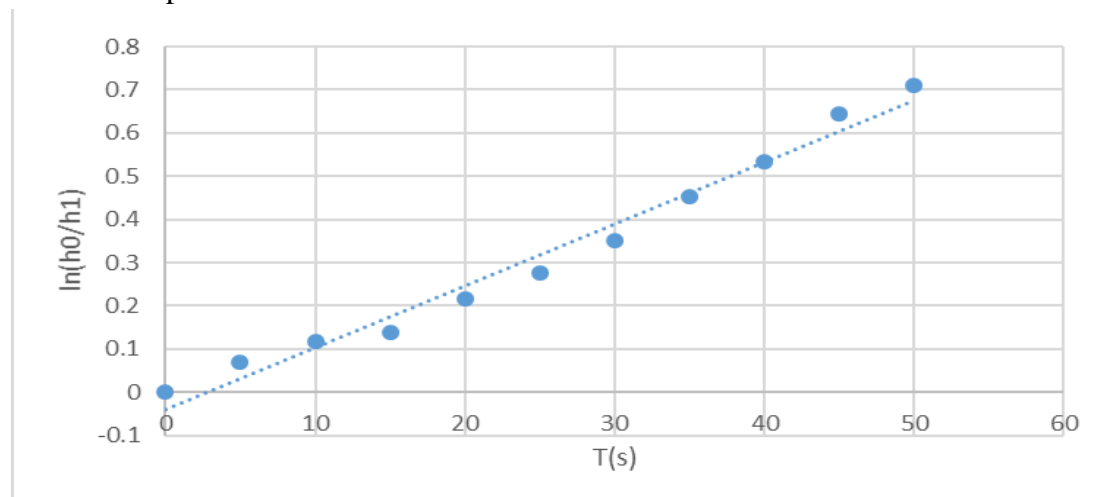


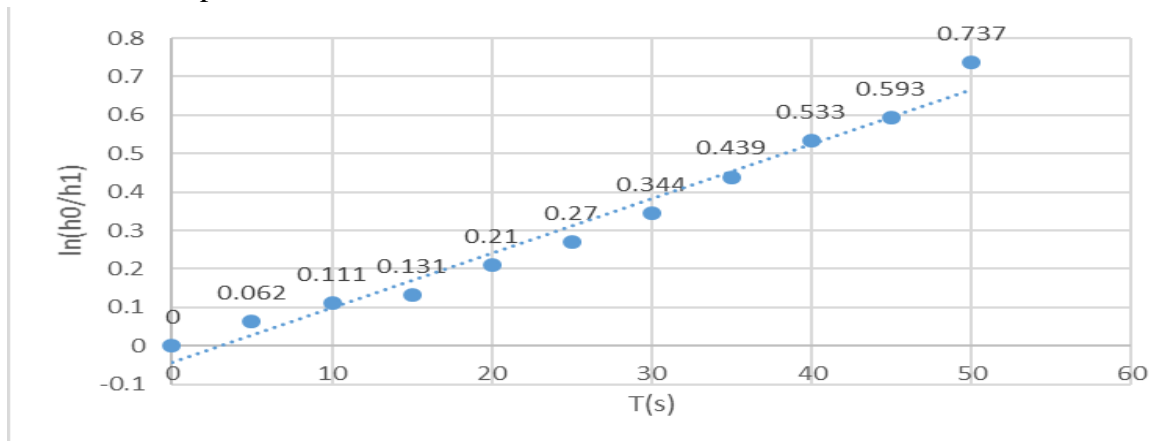*Figure 5 : Permeability graph of 4% mixed sample*

According to the permeability laboratory testing results, the coefficient of permeability of the 8% mixed sample is 0.00922 cms[-1].

*Figure 6 : Permeability graph of 8% mixed sample*

According to the permeability laboratory testing results, the coefficient of permeability of the 12% mixed sample is 0.00896 cms$^{-1}$.



*Figure 7 : Permeability graph of 12% mixed sample*

According to the permeability laboratory testing results, the coefficient of permeability of the 16% mixed sample is 0.00870 cms$^{-1}$.



*Figure 8 : Permeability graph of 16% mixed sample*

According to the permeability laboratory testing results, the coefficient of permeability of the 20% mixed sample is 0.00845 cms$^{-1}$.



*Figure 9 : Permeability graph of 20% mixed sample*

According to the analysis, the K value has been reduced by 0.01024 cms$^{-1}$ to 0.00845 cms$^{-1}$. K value has been reduced by 0.00179 cms$^{-1}$. Therefore, it is when increasing the mixing proportion of granite dust – rubber powder mixture the soil is become low permeable material where cannot easily more though the soil sample.

### *Proctor compaction of the testing samples*

Proctor compaction test is given the data about the optimum moisture content and the maximum dry density of the samples.

According to the testing results the optimum moisture content of the sandy soil is 12 % and the maximum dry density (MDD) is $1.762 g/cm^3$. As well as the optimum moisture content (OMC) and maximum dry density of the 4%,8%,12%,16% and 20% sand-granite dust- rubber powder mixture are accordingly, 9.3% and $1.943 g/cm^3$, 9.0% and $1.983 g/cm^3$, 8.5% and $2.025 g/cm^3$, 7.9% and $2.056 g/cm^3$ , 7.1% and $2.083 g/cm^3$.

When the increment of the mixing ration of mixture up to 20% with sandy soil, the MDD value has been increase form 1.762 g/cm3 to 2.083 g/cm3 the OMC value has been reduced from 12.2 % to 7.1%. According to the results analysis the optimum moisture content value has been reduced of the point of point highest maximum dry density, where the 20% of granite dust-waste rubber powder mixture mixed. Therefor the conclusion is the critical mixing ratio of the mixture is 20%. Therefor there is a clean improvement can be seen of the compaction of sandy soil, mixing with granite dust- rubber powder mixture.

### *CBR of the testing samples*

According to the laboratory testing results the CBR value of the sandy soil is shown by below table.

Table 3:CBR value table of sandy soil

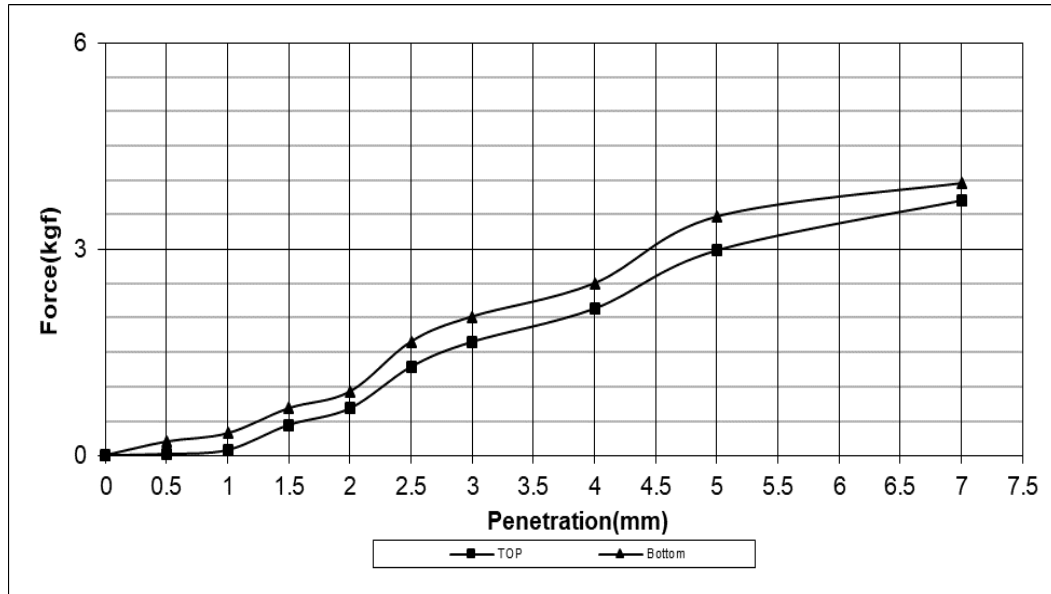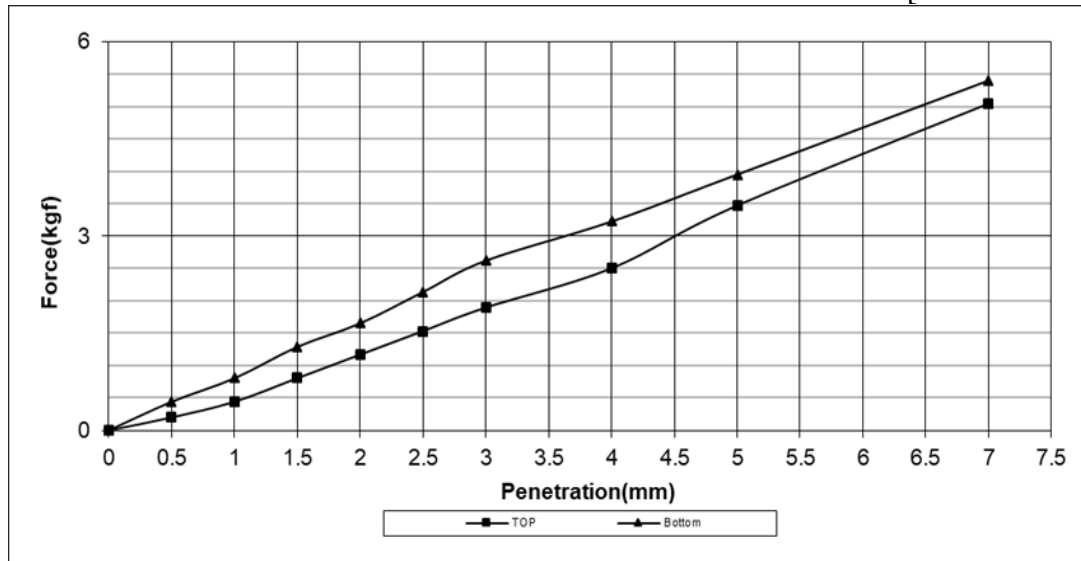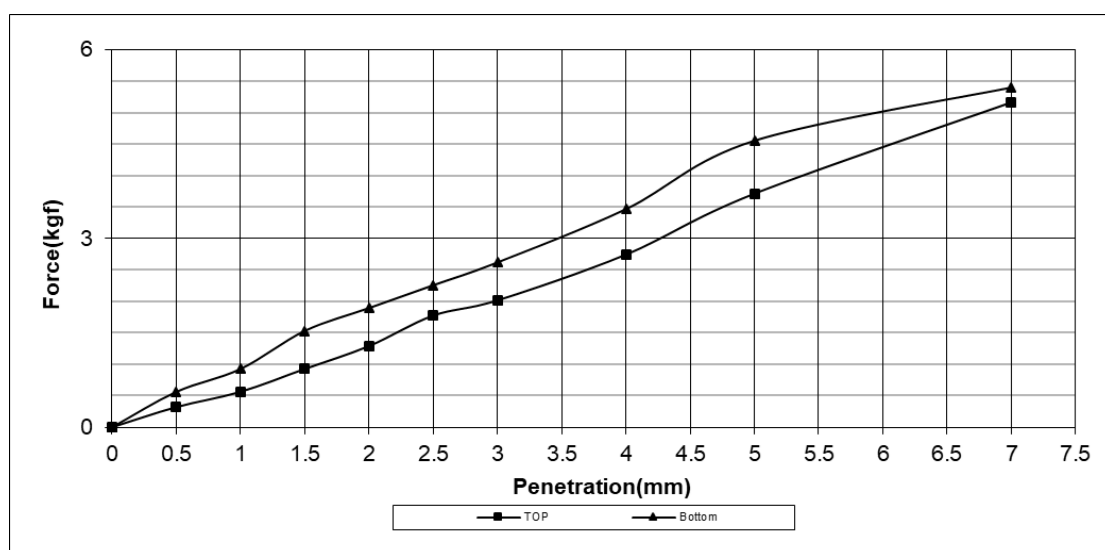| DOC % | Dry density (g/cm³) | CBR (%) | | | |
|---|---|---|---|---|---|
| | | Top | | Bottom | |
| | | 2.5 mm Pen. | 5 mm Pen. | 2.5 mm Pen. | 5 mm Pen. |
| 100 | 1.762 | 10 | 15 | 12 | 17 |
| CBR (%) | 14 | | | | |



*Figure 10 : CBR value graph of sandy soil*

According to the laboratory testing results the CBR value of the 4% mixture mixed sample is shown by below table.

Table 4: CBR value table of 4% mixture mixed sample

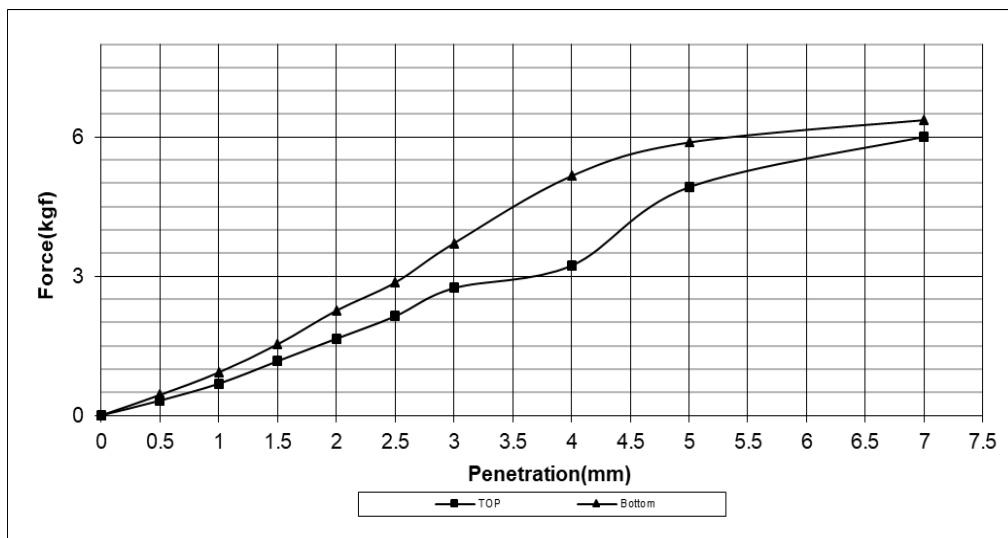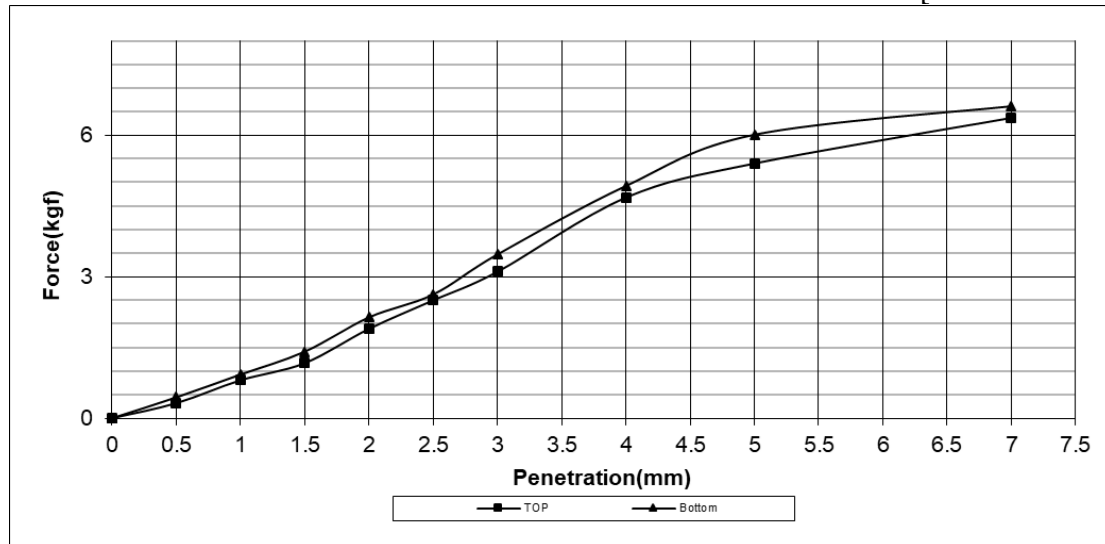| DOC % | Dry density (g/cm³) | CBR (%) | | | |
|---|---|---|---|---|---|
| | | Top | | Bottom | |
| | | 2.5 mm Pen. | 5 mm Pen. | 2.5 mm Pen. | 5 mm Pen. |
| 100 | 1.934 | 12 | 17 | 16 | 20 |
| CBR (%) | 20 | | | | |

*Figure 11: CBR value graph of 4% mixed sample*

According to the laboratory testing results the CBR value of the 8% mixture mixed sample is shown by below table.

Table 5: CBR value table of 8% mixture mixed sample

| DOC % | Dry density (g/cm³) | CBR (%) | | | |
|---|---|---|---|---|---|
| | | Top | | Bottom | |
| | | 2.5 mm Pen. | 5 mm Pen. | 2.5 mm Pen. | 5 mm Pen. |
| 100 | 1.983 | 13 | 19 | 17 | 23 |
| CBR (%) | | 20 | | | |



*Figure 12 : CBR value graph of 8% mixed sample*

According to the laboratory testing results the CBR value of the 12% mixture mixed sample is shown by below table.

Table 6: CBR value table of 12% mixture mixed sample

| DOC % | Dry density (g/cm³) | CBR (%) | | | |
| --- | --- | --- | --- | --- | --- |
| | | Top | | Bottom | |
| | | 2.5 mm Pen. | 5 mm Pen. | 2.5 mm Pen. | 5 mm Pen. |
| 100 | 2.025 | 16 | 25 | 22 | 29 |
| CBR (%) | | 23 | | | |



*Figure 13 : CBR value graph of 12% mixed sample*

According to the laboratory testing results the CBR value of the 16% mixture mixed sample is shown by below table.

Table 7:CBR value table of 16% mixture mixed sample

| DOC % | Dry density (g/cm³) | CBR (%) | | | |
| --- | --- | --- | --- | --- | --- |
| | | Top | | Bottom | |
| | | 2.5 mm Pen. | 5 mm Pen. | 2.5 mm Pen. | 5 mm Pen. |
| 100 | 2.056 | 19 | 27 | 20 | 30 |
| CBR (%) | | 24 | | | |

*Figure 14 : CBR value graph of 16% mixed sample*

According to the laboratory testing results the CBR value of the 20% mixture mixed sample is shown by below table.

Table 8:CBR value table of 20% mixture mixed sample

| DOC % | Dry density (g/cm³) | CBR (%) | | | |
|---|---|---|---|---|---|
| | | Top | | Bottom | |
| | | 2.5 mm Pen. | 5 mm Pen. | 2.5 mm Pen. | 5 mm Pen. |
| 100 | 2.083 | 22 | 28 | 24 | 30 |
| CBR (%) | | 26 | | | |
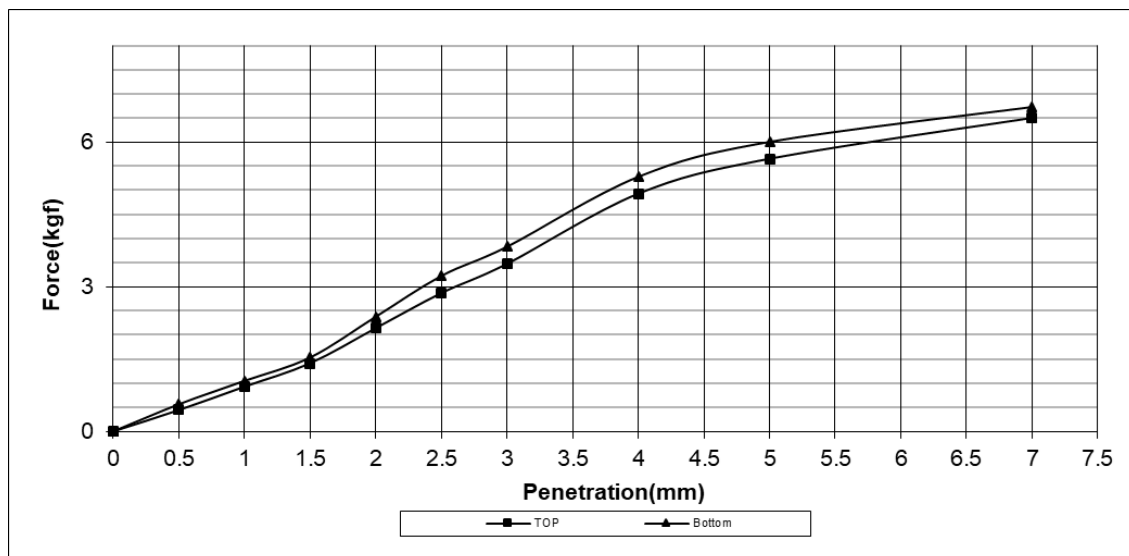


*Figure 15 : CBR value graph of 20% mixed sample*

According to the calculation of results the highest CBR value has been generated by the 20% of granite dust-waste rubber powder mixture mixed sandy soil sample. According to the test

results there is a relationship can be identified between the maximum dry density and the CBR value, if the maximum dry density is increased, the CBR value is also increased at a particular material. The critical CBR value has been generated by the 20% mixture mixed sample and also there is a proper improvement of the CBR value can be displayed from 14% to 26%.

## Conclusion and Recommendation

In the country surrounded by the ocean, there are many coastal areas did not use yet to build up the settlements due to some environmental issues. One of the main reasons for that issue, the coastal environment is highly affected for the construction industry, such as exposure condition, soil texture of the coastal areas. This study presented to research the improvement of bearing capacity of coastal sandy soil by stabilizing granite dust-waste rubber powder mixture by conducting several laboratory testings. The test results were shown positive improvement of the soil properties which were tested according to the research methodology. According to the research, when it comes to the larger construction industry, it can be developed as a method to design a pad footing foundation according to the improved CBR value of coastal sandy soil by reducing the cost which might take to a deep foundations or high cost foundation types to the mid-rise buildings. As well as a subgrade design can be developed according to the CBR value that has been improved.

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## EXPERIMENTAL STUDY ON IMPROVING GEO-TECHNICAL PROPERTIES OF SANDY-SOIL USING NaOH ACTIVATED RECYCLED AGGREGATES & CaCO₃

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**Abstract**

Problematic soils with poor engineering properties often requires to improve their characteristics; mainly its bearing capacity. Among the other problematic soil types, improving the sandy soil has become a significant requirement as a result of the increasing demand rate on land in order to compensate the increasing population. This experimental study investigates the improvement of bearing capacity and geo-technical properties of problematic sandy soil by incorporating construction demolition waste combined with NaOH as a cementitious material. Additionally, calcium carbonate powder is added to shrink and improve the bond between sand particles.  Major benefits can be achieved from this experimental research approach, including environmentally friendly geotechnical improvements.

Combining CDW with NaOH, initiates a chemical reaction, forming a gelatin structure that reduces sand porosity. Consequently, permeability decreases, and bearing capacity improves. Furthermore, the addition of $CaCO_3$ enhances soil particle binding by introducing calcite to fill pores.

**Key Words:** Calcium Carbonate, Chemical Activator, Construction Demolition Waste, Sandy Soil Improvement

**Introduction**

The improvement of the geo-technical properties of other soil types has become a major concern today with the limitations on the availability of suitable soil for engineering purposes. As sandy soil has higher availability in land areas among other soil types, the significance of improving the geo-technical properties of it has been highlighted in modern civil engineering industry (Bagriacik, 2021).

Although the higher availability of sandy soil can serve as an effective solution for the above problem, (Saray,2021) suggests that sandy soil may consist of other geo-technical issues such as higher permeability and less compressive strength. Therefore, it has become imperative to improve the engineering properties of sandy soil by stabilizing it. According to Mohammadinia (2015), to address these challenges, traditional methods involve altering soil classification through the addition of binders like fly ash, lime, or cement, inducing a chemical reaction to create bonds among soil particles. However, a major disadvantage of using a cement as a traditional binder, is the indirect effect of increasing the carbon emission up to 5%-7% in the atmosphere. (Robbins, 2021).

In response to these drawbacks, several research studies have explored sustainable alternatives. Alkali-activated materials, as proposed by recent studies, offer a promising substitute for traditional binders, emphasizing environmental sensitivity and lower carbon emissions

(Miftah, 2020). Additionally, the introduction of an aqueous solution of calcium carbonate also have been used to improve soil strength (Park, 2014).

Identifying a knowledge gap in current research on soil improvement methods, this research introduces a novel approach. It combines construction demolition waste (CDW) as a cement substitute, activated with NaOH to reduce sand porosity and settlements. Simultaneously, the addition of CaCO3 introduces calcite, enhancing soil bearing capacity (Arab, 2019). The primary aim of this research is to assess the effectiveness of these techniques in improving engineering properties of sandy-soil, with experimental procedures to validate their viability.

### Literature Review

Komnitsas et al. (2019) found that mixing construction and demolition waste (CDW) with concrete, red-clay bricks, and ceramic tiles increased compressive strengths with different curing temperatures. Adding NaOH and Na2SiO3 increased the compressive strength of red clay brick waste by 626% after 28 days of curing at 25°C. Adding 10% and 20% cement to the NaOH and Na2SiO3 activators respectively further increased the strength.

Adding calcium to soil improves its stabilization performance (Park, 2014). Mohammadinia et al. stabilized CDW using lime kiln dust, 8 M NaOH, and 2 M Na2SiO3, with recycled concrete aggregate products achieving compressive strengths of 1.4 MPa after seven days, 1.8 MPa after 28 days, and 2.0 MPa after 90 days (Mohammadinia et al., 2018).

Rios et al. found that silty sand and an alkaline activator solution (Class F - Na2SiO3 and NaOH) significantly improved strength and stiffness in the road, resembling a cement-soil combination (Rios et al., 2016). Based on shear box tests with various ratios, the optimal CDW ratio for the experimental study is determined as 16%, considering maximum cohesion and internal frictional angle (Bagriacik, 2021).

The optimal NaOH molarity for CDW performance is 10 Mols. To strengthen soft sandy soil, researchers have used a calcium carbonate solution. 8% CaCO3 dust resulted in the highest compressive strength. Although the impact of chemically activated recycled aggregates on sandy soil is not well studied, this research examines the improvement of sandy soil using NaOH-activated CDW as a sustainable substitute for cement and CaCO3 as a stabilizer.

## Methodology

### Research Approach

Utilization of industrial wastes such as construction demolition waste (CDW) combined with alkali activated sodium hydroxide (NaOH) and using calcium carbonate (CaCO3) powder to increase the bearing capacity while reducing the permeability can be a sustainable and optimum solution for reducing carbon footprint of the construction activities by replacing traditional cement binder. Hence, this quantitative research employs an optimized assessment of various CDW, NaOH, and CaCO3 blends to improve soil particle bonds in problematic sandy soil. Numerical outcomes from experimental procedures are showcased in tables and graphs, ensuring a clear and impactful presentation of the research findings.

The research methodology follows following key steps to attain the goals and objectives.
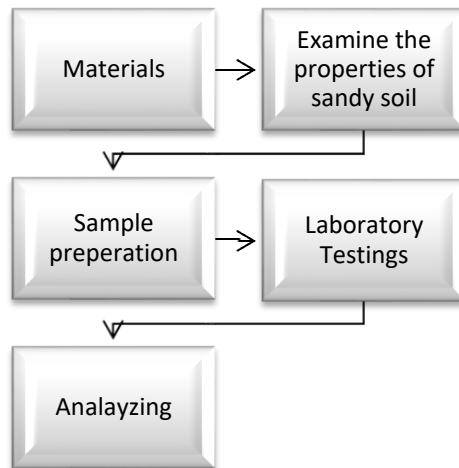
*Figure 01: Flow of the Methodology*

### Materials

Sandy soil samples were extracted from the land side of Elakanda-beach (Wattala), Sri Lanka, at a depth below 3-feet to avoid contaminants. Collected samples were sun-dried for two-days to eliminate moisture before testing.



*Figure 02: Sun-drying process*

CDW which was obtained from a house-renewal project in Ja-Ela, Sri-Lanka, contained concrete, bricks, plaster, paint, and tiles, was pulverized with a manual hammer and stored in an air-tight bag to prevent moisture contact.



*Figure 03: Pulverized CDW*

### Examine the Properties of the Sandy Soil

These obtained sandy soil samples & CDW samples were processed through sieve analysis test in order to classify their grain-size-distribution by using ASTM D 6913-04 2009 standard method.
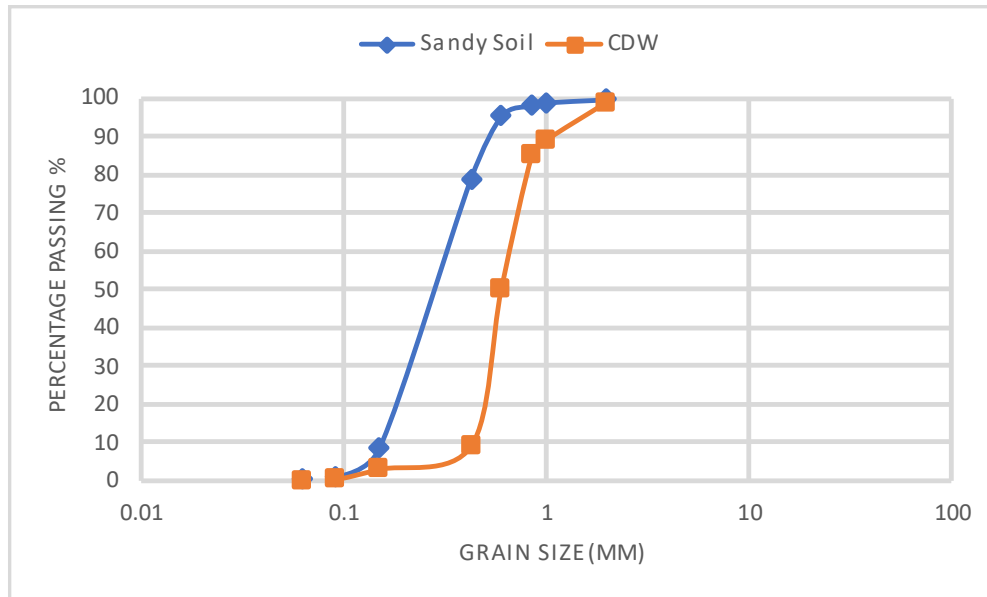
*Figure 04: Particle sizes of soil & CDW*

Figure 04 shows the particle size distribution of sandy soil and CDW used in the study. Sandy soil was poorly graded with a Coefficient of Uniformity (CU) of 6.46 and a Coefficient of Curvature (CC) of 0.88. Its specific gravity was 2.65, coefficient of permeability 8.13 X 10-5 ms-1, and CBR was determined using heavy compaction and penetration methods. Optimum moisture content and maximum dry unit weight were measured using the ASTM D698 standard proctor compaction.

Table 01: Physical properties of sandy soil

| PHYSICAL PROPERTIES OF THE SANDY SOIL | | |
|---|---|---|
| No. | Properties of Soil | Results |
| 1 | Grade Type | Poorly Graded |
| 2 | Specific Gravity | 2.65 |
| 3 | Coefficient of Permeability | $8.13 \times 10^{-5}$ ms$^{-1}$ |
| 4 | Optimum Moisture Content | 10.46% |
| 5 | Maximum Dry Unit Weight | 1900.78 kgm$^{-3}$ |
| 6 | CBR % | 16.5 |

***Sample Preparation***

Experimental soil specimens were produced by mixing air-dried sandy-soil with defined proportions of CDW, NaOH, & CaCO3. CDW was introduced as pulverized solid, NaOH as a liquid solution, and CaCO3 as a solid-dust, following literature-derived percentages. This involves 4 soil-sample types, including 3 experimental mixtures and one untreated soil sample, for subsequent testing.

Table 02: Mixture proportions

| Specimen No. | Sand (%) | CDW (%) | NaOH (Mols) | CaCO3 (%) |
|---|---|---|---|---|
| 1 | 100 | - | - | - |
| 2 | 84 | 16 | - | - |
| 3 | 84 | 16 | 10 | - |
| 4 | 76 | 16 | 10 | 8 |

***Testing Methods of Treated Soil Specimens***

Laboratory tests adhered to ASTM standards. Proctor compaction tests determined optimum moisture content and maximum dry density for each specimen, which is crucial to make uniform mixtures in CBR testing. The proctor compaction test was applied to all three treated soil-types.



*Figure 05: Proctor compaction test*

Permeability tests were conducted for the prepared soil samples, to determine the coefficient of permeability. The flow rate of the water passes through the different soil specimens were determined by performing the falling head permeability test.



*Figure 06: Falling head permeability test*

CBR tests were conducted to determine the soil bearing capacity and mechanical strength, essential for foundations and road sub-bases. Soil samples for the CBR test was prepared with the optimum moisture content of each specimen, which was determined by the proctor

compaction test. And these soil specimens were compacted using heavy method and then load was applied at 1.25mm/min.



*Figure 07: CBR penetration test*

Each sample underwent curing for one day and three days. Following these periods, CBR tests were performed with the same procedure. Exceeding a 3-day curing period resulted in the treated soil hardening in the mold, making CBR tests challenging. Hence, CBR tests were conducted at specimen preparation, after one day, and after three days.

Table 03: Testing at different curing periods

| Specimen Type | As soon as prepared | After 1 day curing | After 3 days curing |
|---|---|---|---|
| Soil + CDW | Permeability | CBR | CBR |
| | Proctor Compaction | | |
| | CBR | | |
| Soil + CDW + NaOH | Permeability | CBR | CBR |
| | Proctor Compaction | | |
| | CBR | | |
| Soil + CDW + NaOH + CaCO3 | Permeability | CBR | CBR |
| | Proctor Compaction | | |
| | CBR | | |

***Data Representation & Analyzing***

After obtaining test results, values for the key parameters are being calculated and summarized using tables under their relevant mix proportions & curing periods. According to those tables, graphs can be plotted for each type of soil specimens against their enhanced geo technical properties. The most effective specimen, exhibiting the highest enhancement rate compared to untreated sandy soil, is identified through graph evaluation.

## Results & Discussion

Test results were individually assessed, followed by a comparative analysis to identify the most effective mixture proportion.

### *Permeability Test*

Permeability tests were done on four soil samples and their graphs were used to calculate coefficients of permeability. Figure.08 shows the water flow graph for soil sample 01 (untreated sandy-soil) with the calculated coefficient of permeability of 7.885x10-5 ms-1.
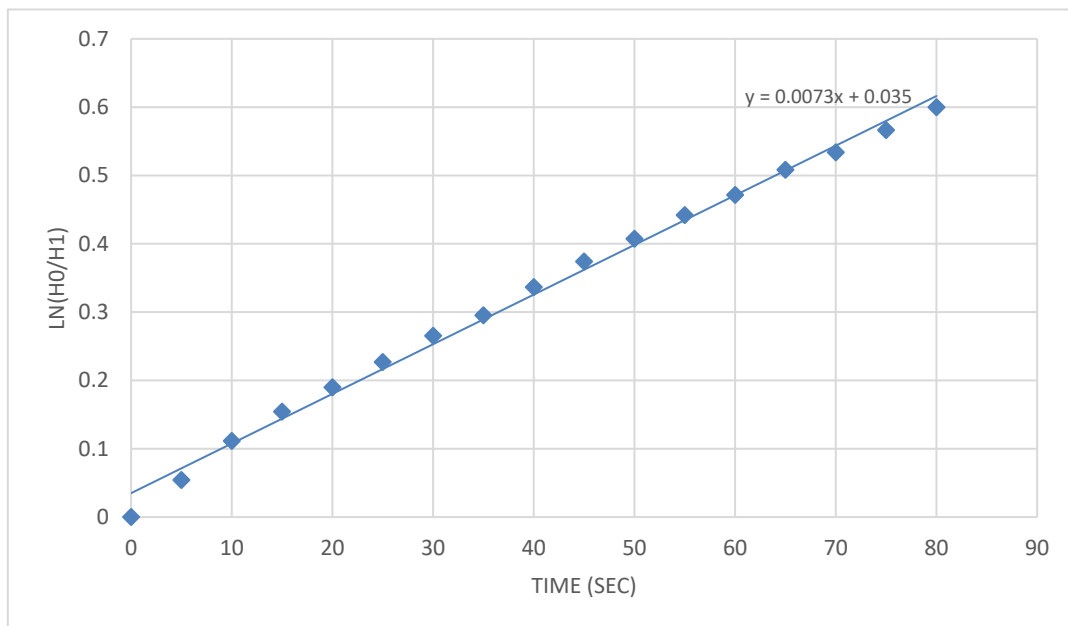


*Figure.08: Untreated Sandy soil Permeability*

The Figure.09 shows the plotted graph for the flow-rate of water passed through the specimen-02 (sandy soil+CDW). The coefficient of permeability of this specimen was calculated as $4.797 \times 10^{-5} ms^{-1}$.
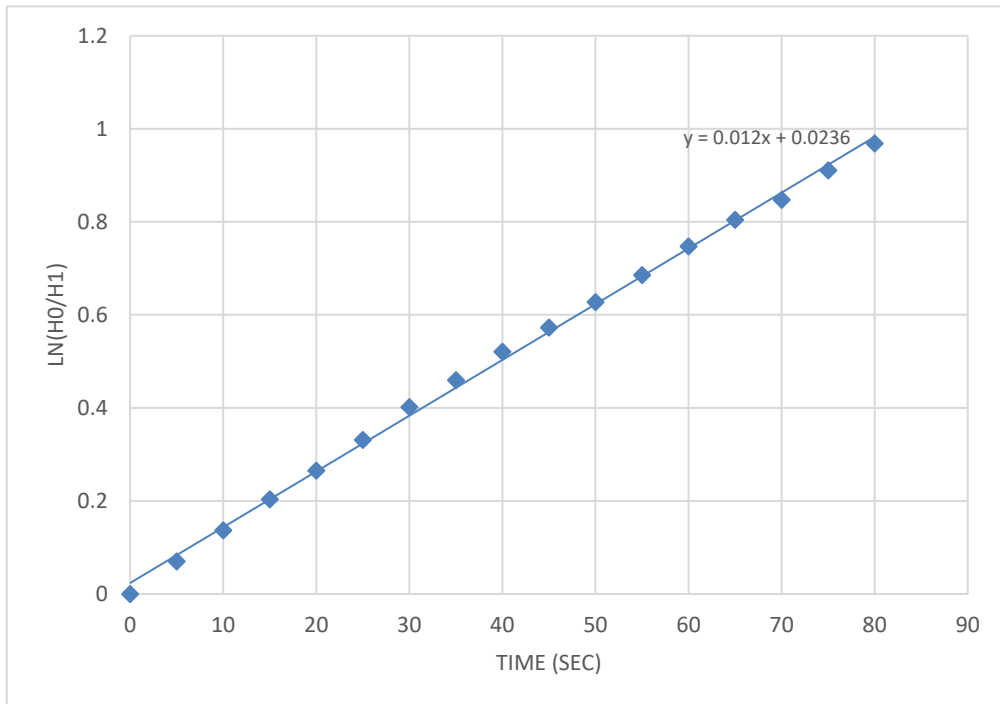
*Figure 09: Soil+CDW Permeability*

The Figure.10 shows the plotted graph for the flow rate of the water passed through the specimen-03 (soil+CDW+NaOH). The coefficient of permeability of this specimen was calculated as $3.548 \times 10^{-5}$ ms$^{-1}$.
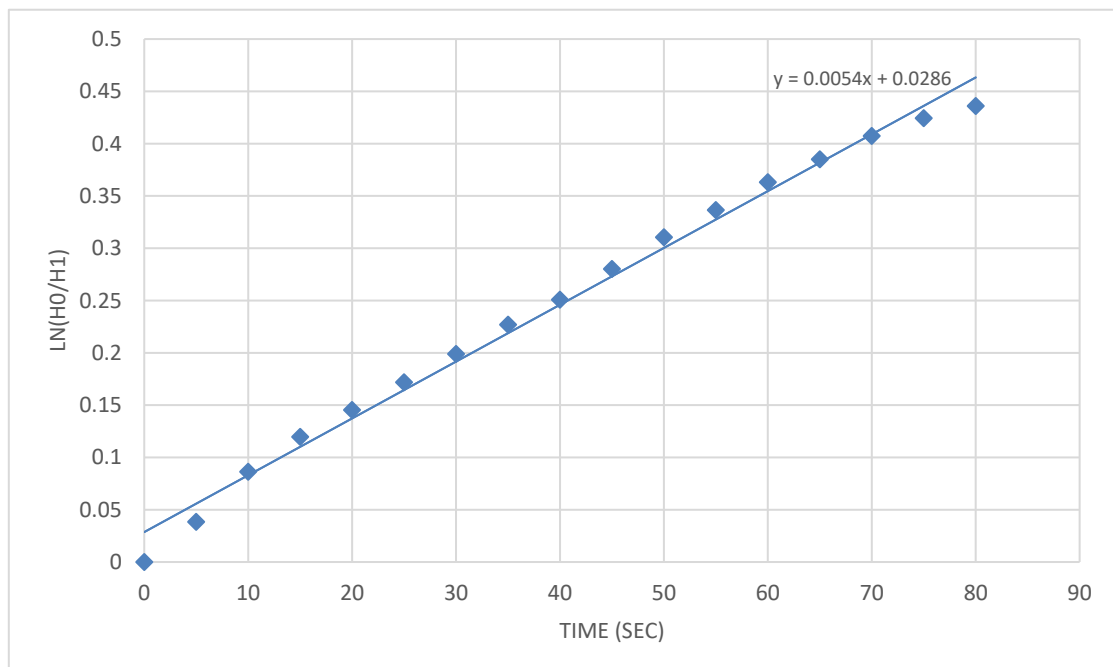


*Figure 10: Soil+CDW+NaOH Permeability*

Figure.11 depicts the graph of water flow rate through specimen-04 (Soil+CDW+NaOH+CaCO$_3$). The calculated coefficient of permeability for this specimen is $2.497 \times 10^{-5}$ ms$^{-1}$.
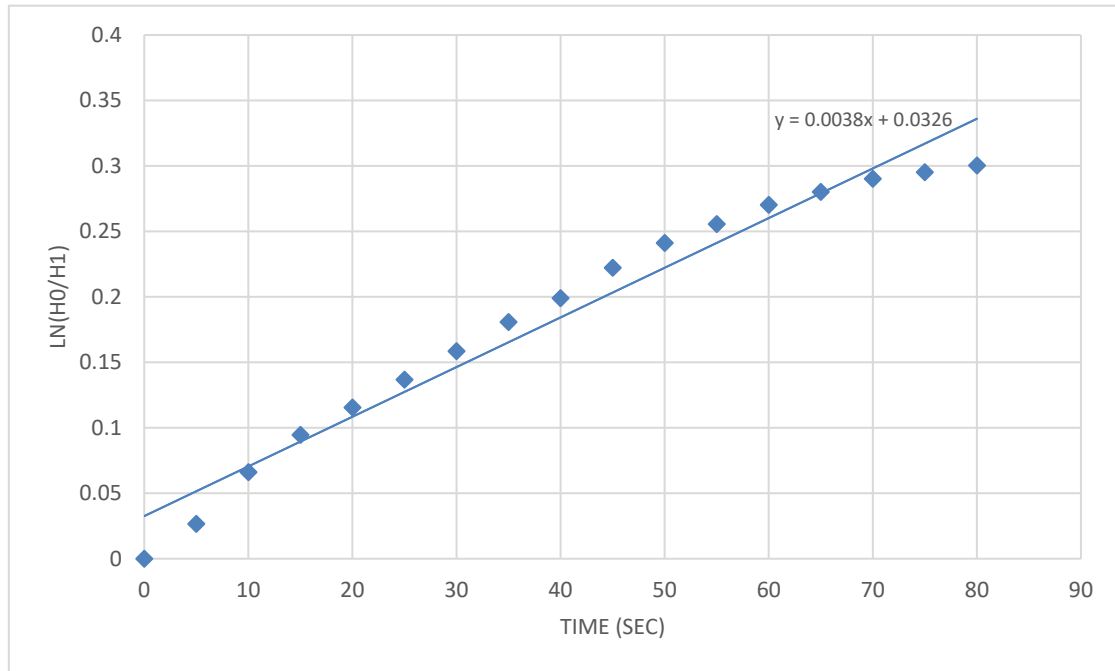
*Figure 11: Soil+CDW+NaOH +CaCO₃*

As a conclusion, Permeability f sandy-soil decreased from $7.885 \times 10^{-5}$ ms$^{-1}$ to $2.497 \times 10^{-5}$ ms$^{-1}$ with the addition of 16% CDW, 10 Mols NaOH, and 8% CaCO3. Specimen No. 04 showed the lowest permeability. Figure.12 shows the summary of permeability reduction in the soil specimens.

Table 04: Coefficients of Permeability

| Specimen No. | Specimen Type | Coefficient of Permeability (K) |
|---|---|---|
| 01 | Sandy Soil | $7.885 \times 10^{-5}$ms$^{-1}$ |
| 02 | S. Soil + CDW | $4.797 \times 10^{-5}$ms$^{-1}$ |
| 03 | S. Soil + CDW + NaOH | $3.548 \times 10^{-5}$ms$^{-1}$ |
| 04 | S. Soil + CDW + NaOH + CaCO3 | $2.497 \times 10^{-5}$ms$^{-1}$ |
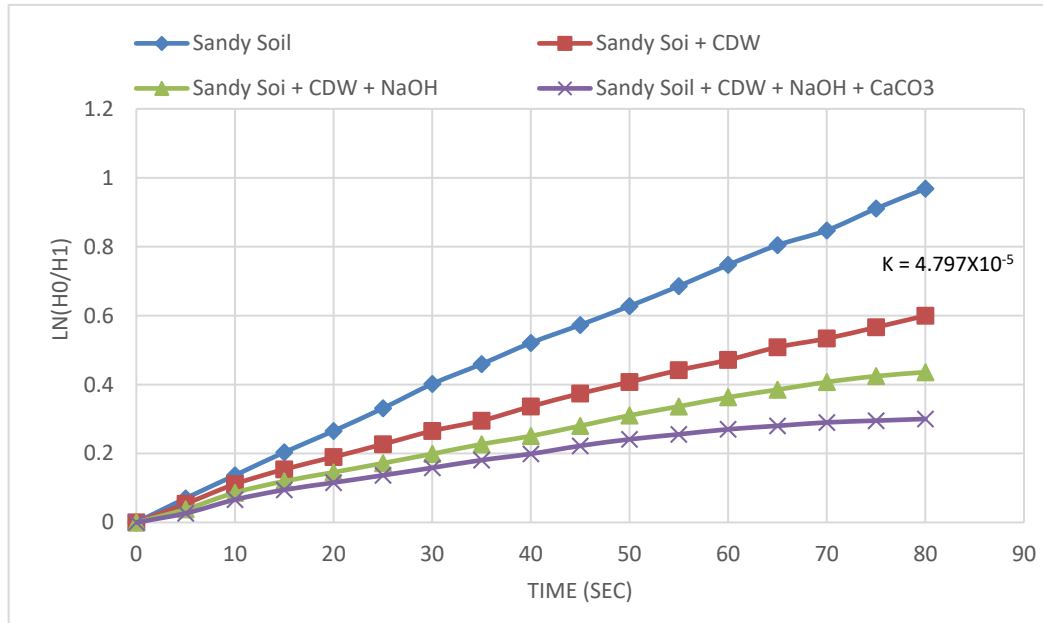
*Figure 12: Permeability Variations*

The incorporation of CDW modifies pore size and grain distribution in sandy soil. Combining CDW with alkaline-activated NaOH further reduces pore size. Additionally, the introduction of $CaCO_3$ contributes to binding soil particles, leading to a significant decrease in permeability

***Proctor Compaction Test***

The standard Proctor compaction test was conducted to assess the impact of CDW, NaOH, and $CaCO_3$ on the optimum water content and maximum dry density of treated soils. Figure.13 shows the moisture content and dry density of specimen-01 (untreated-sandy-soil).
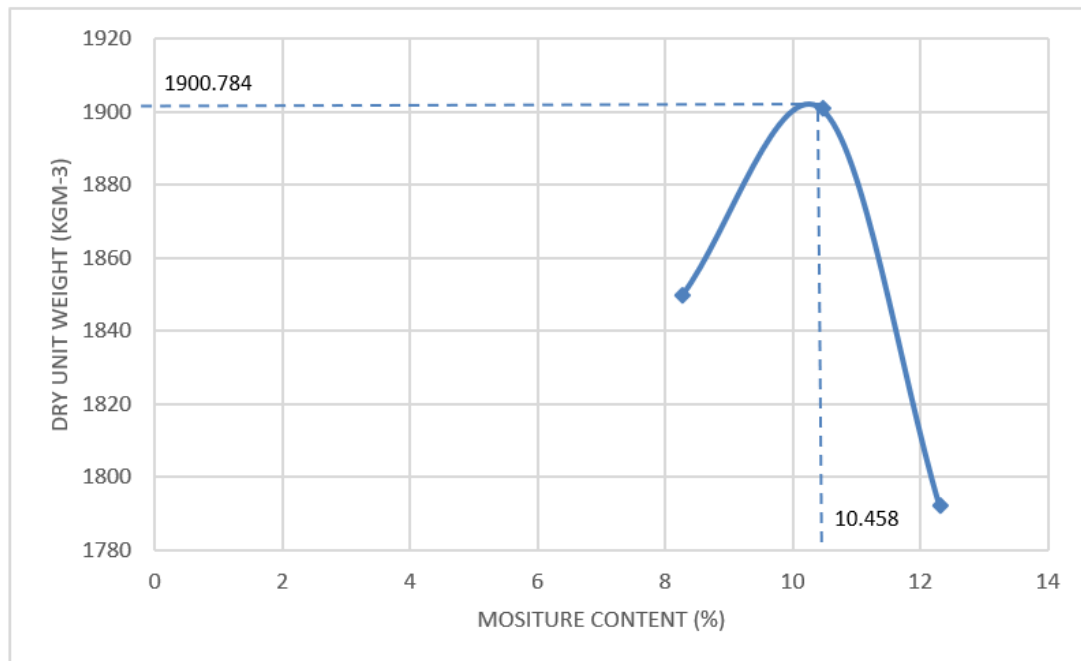


*Figure 13: OMC – Sandy Soil*

Figure.14 displays the graph representing the moisture content and dry density of soil specimen-02 (soil+CDW). Moisture content increased from 10.458% to 12.143%, and dry density also increased from 1900.78 $gm^{-3}$ to 1999.752 $gm^{-3}$.
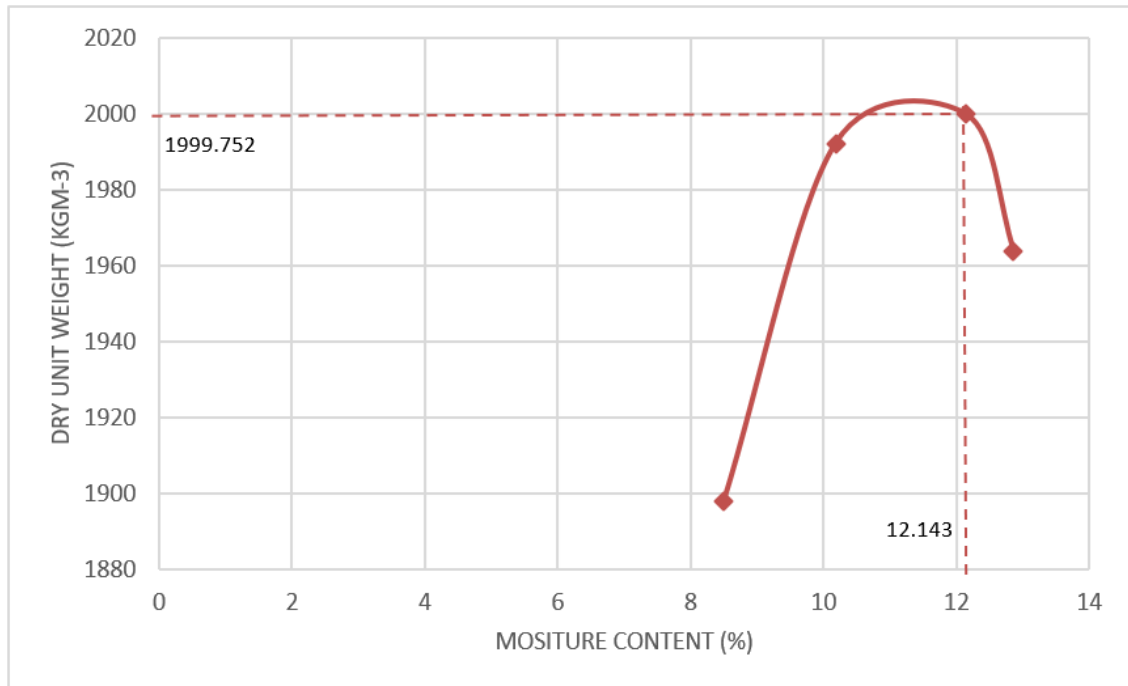


*Figure 14: OMC – Sandy Soil + CDW*

The Figure.15 shows the plotted graph for the moisture content & the dry density of the soil specimen 03. When NaOH is added to the soil+CDW mixture, dry density has increased while the moisture content has been decreased than the untreated soil. Moisture content has been affected due to the addition of liquid solution of NaOH.
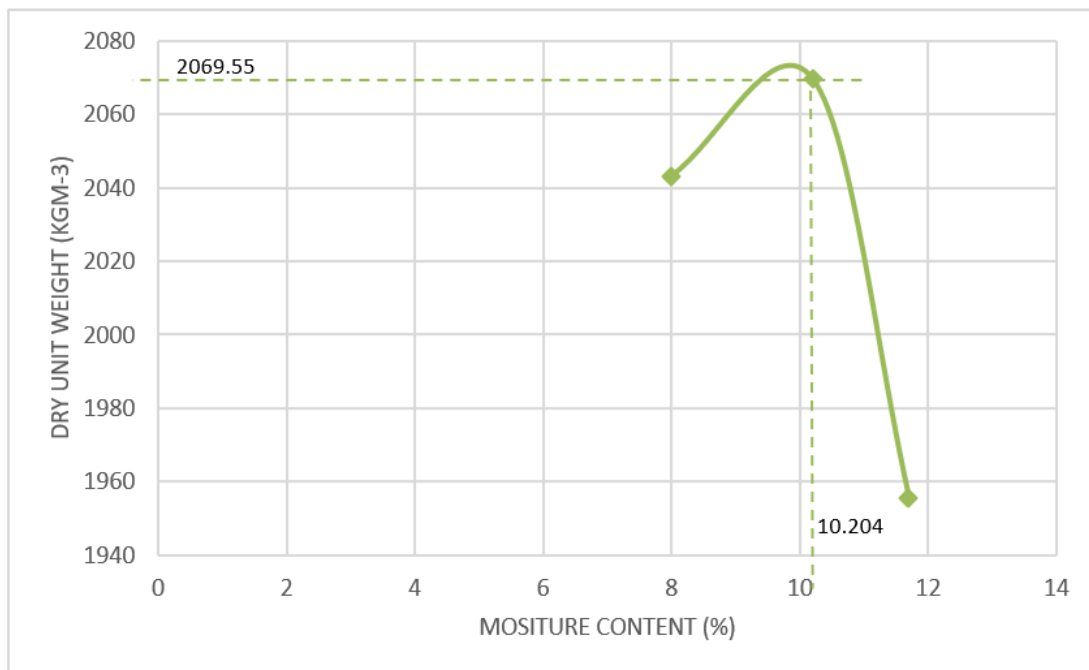


*Figure 15: OMC - Sandy Soil + CDW+ NaOH*

Figure.16 displays the relationship between moisture content and dry density of soil specimen-04. Moisture content has increased significantly, and dry density has also increased. CaCO3 boosts binding between sand particles and reduces pore size in sandy soil.
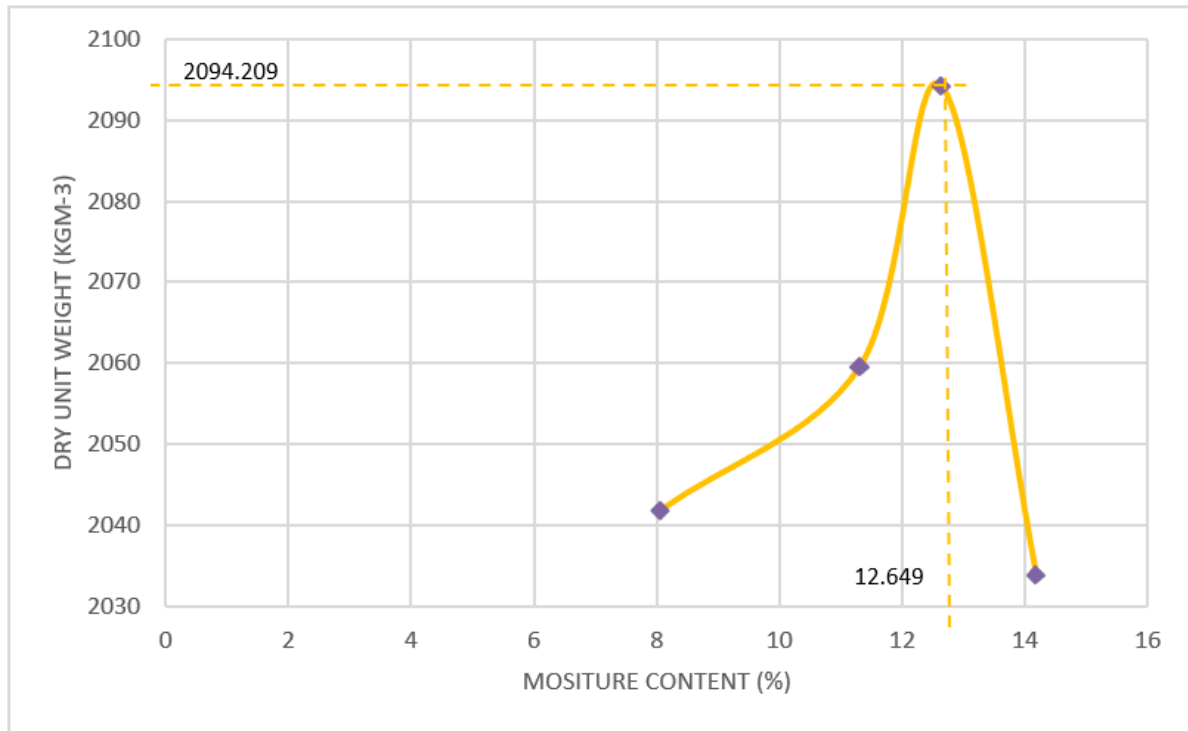


*Figure 16: OMC - Sandy Soil + CDW+ NaOH + CaCO₃*

Based on the proctor compaction results of each specimen, OMC & MDD values are summarized in the following Table. 05.

Table 05: OMC & MDD Variations

| Specimen No. | Specimen Type | Optimum Moisture Content % | Max. Dry Unit Weight |
|---|---|---|---|
| 01 | Sandy Soil | 10.458 | 1900.783 |
| 02 | S. Soil + CDW | 12.143 | 1999.752 |
| 03 | S. Soil + CDW + NaOH | 10.204 | 2069.549 |
| 04 | S. Soil + CDW + NaOH + CaCO3 | 12.649 | 2094.209 |

Using the above discussed values, a summarized moisture content against the dry density graph was plotted for all the four types of soil specimens.
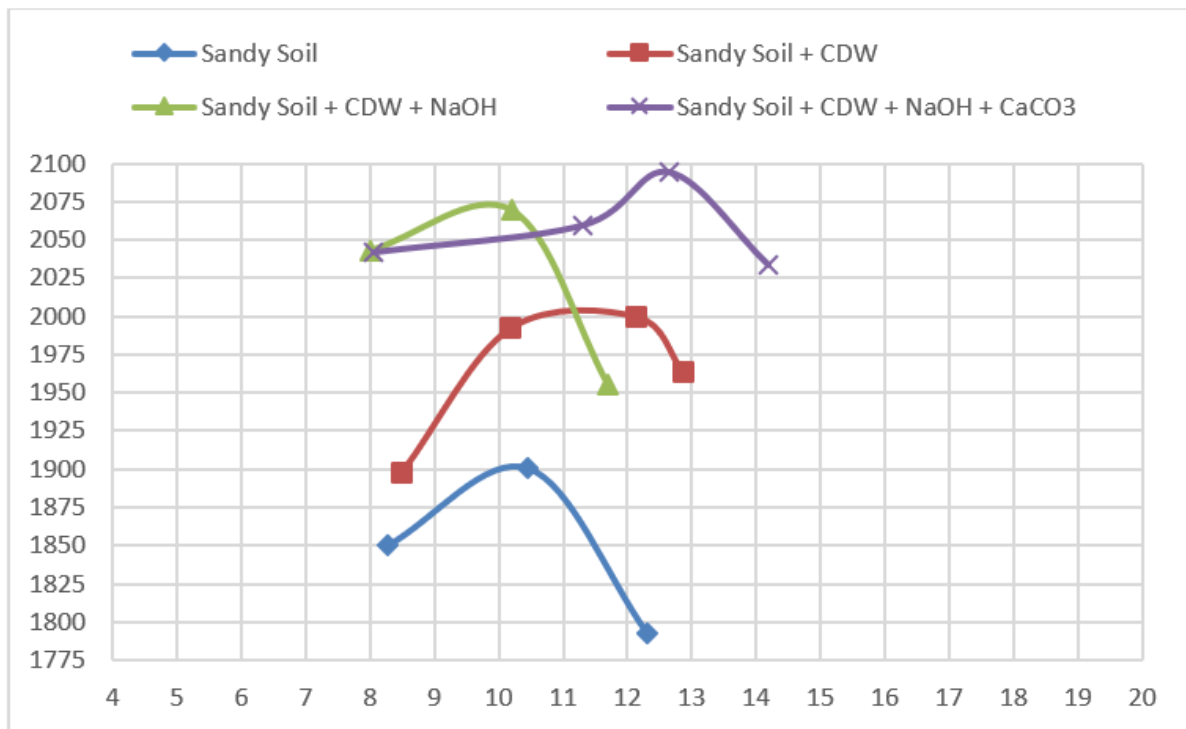


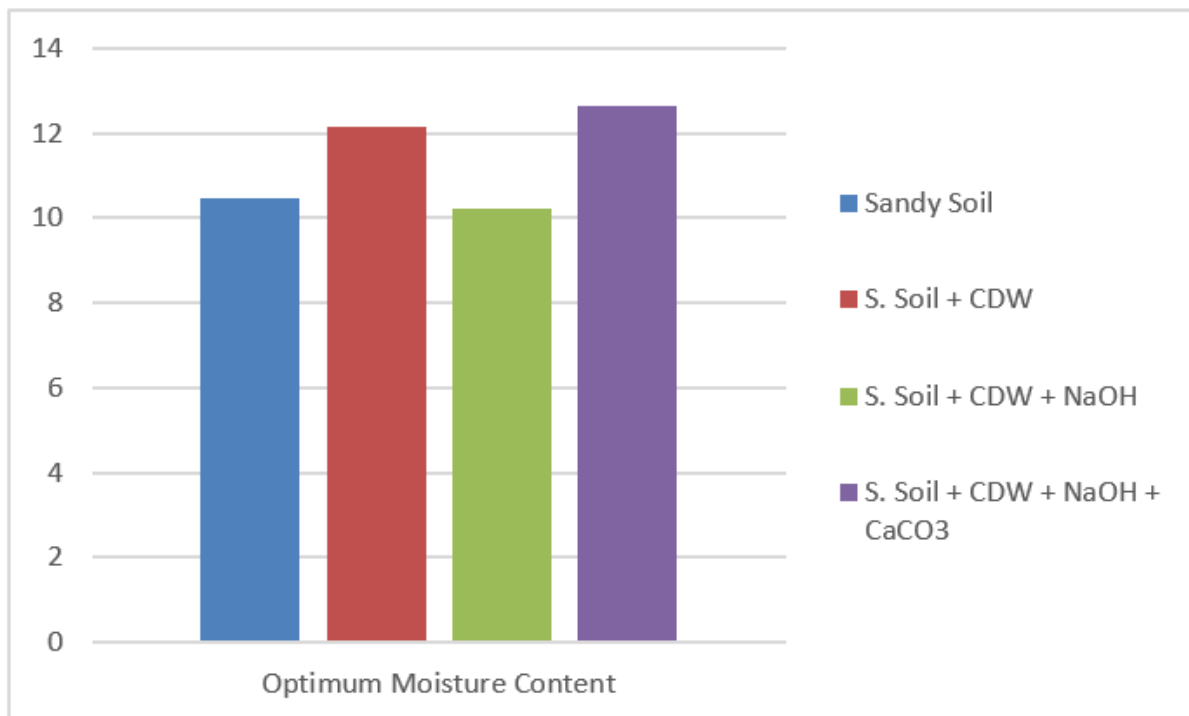*Figure 17: Summarized moisture content against dry density*



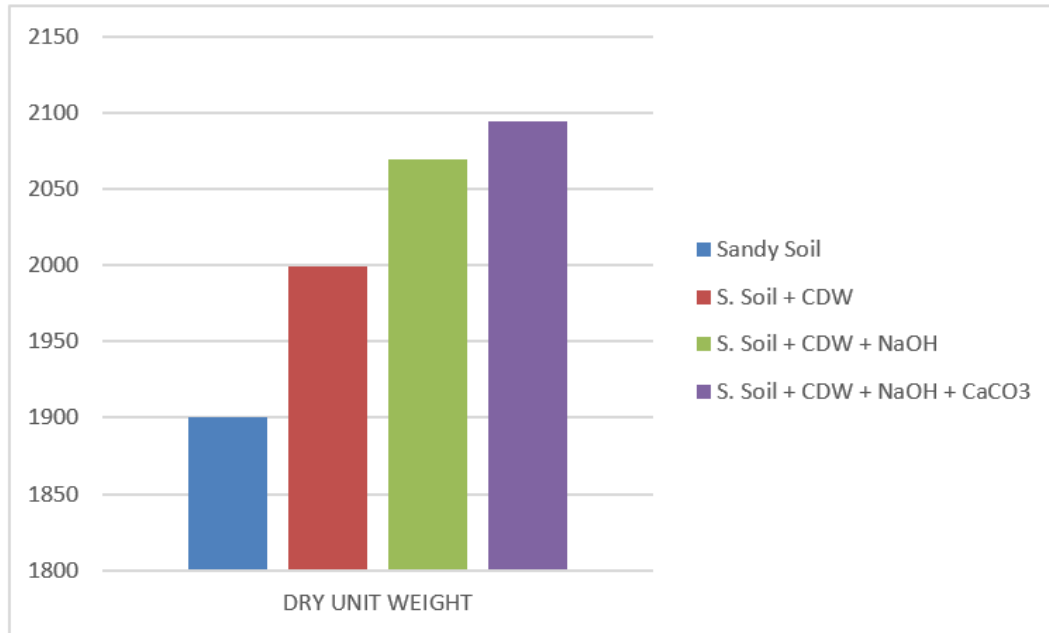*Figure 18: Optimum moisture content variations of 04-specimen types*

*Figure 19: Max. dry unit weight variations of 04-specimen types*

Therefore, specimen no. 04, (Soil+CDW+ NaOH+CaCO3), yielded the highest optimum moisture content & dry density. These alterations significantly increased optimum moisture content & maximum dry density.

### *California Bearing Ratio Test*

CBR tests were conducted for all four specimen types immediately after preparation. The results for untreated sandy soil are shown in Figure 20, with a bearing ratio of 16.15% at a 5mm penetration.
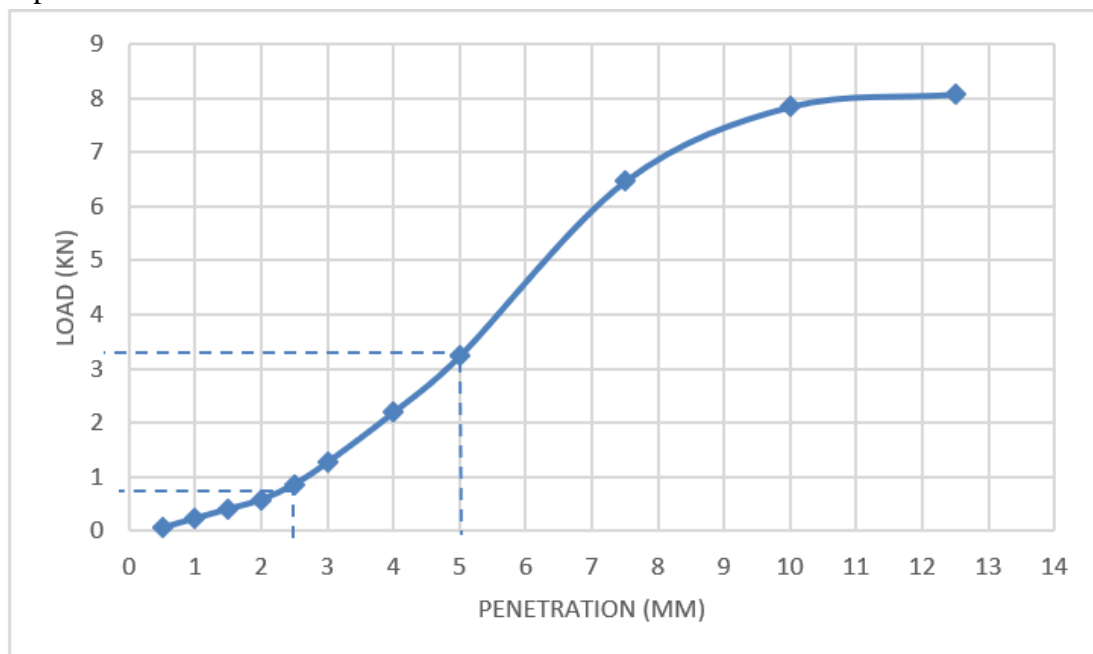


*Figure 20: CBR – Sandy Soil*

Figure 21 displays the CBR test results for specimen no.02. The calculated bearing ratio for this specimen at 2.5mm penetration is 40.20%, indicating a 243% increase compared to the untreated soil.
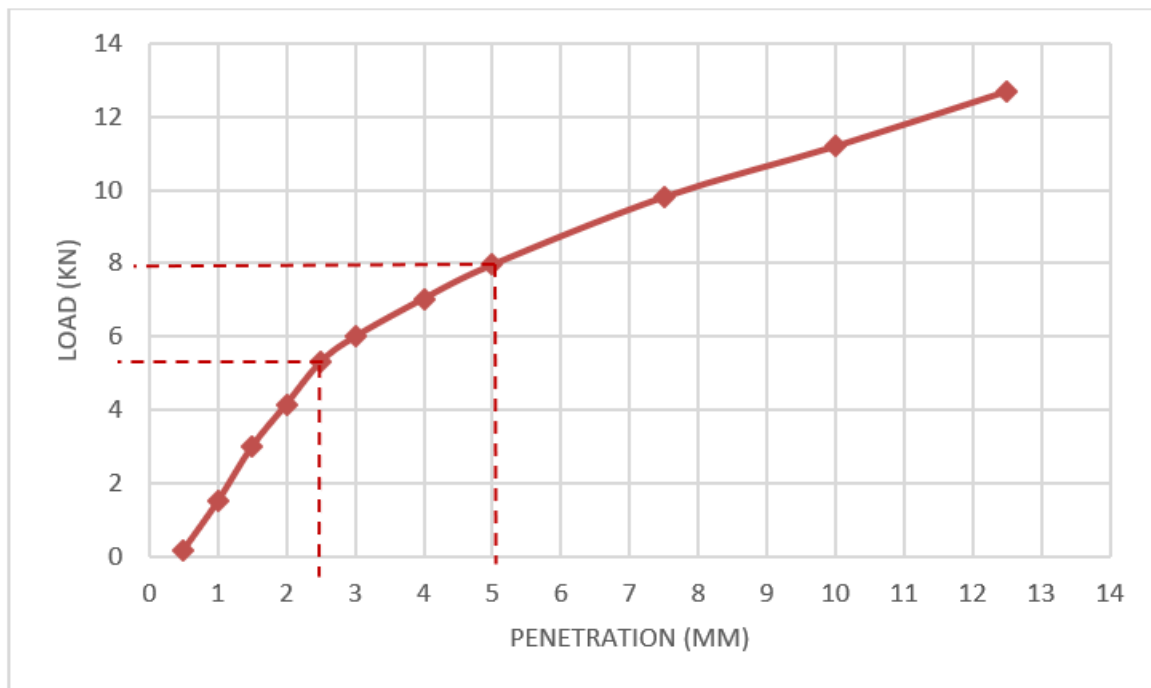


*Figure 21: CBR – Soil + CDW*

Figure.22 depicts the CBR test results for specimen no.03. The calculated bearing ratio for this specimen at 5mm penetration is 55.38%, indicating a 335% increase compared to the untreated soil.
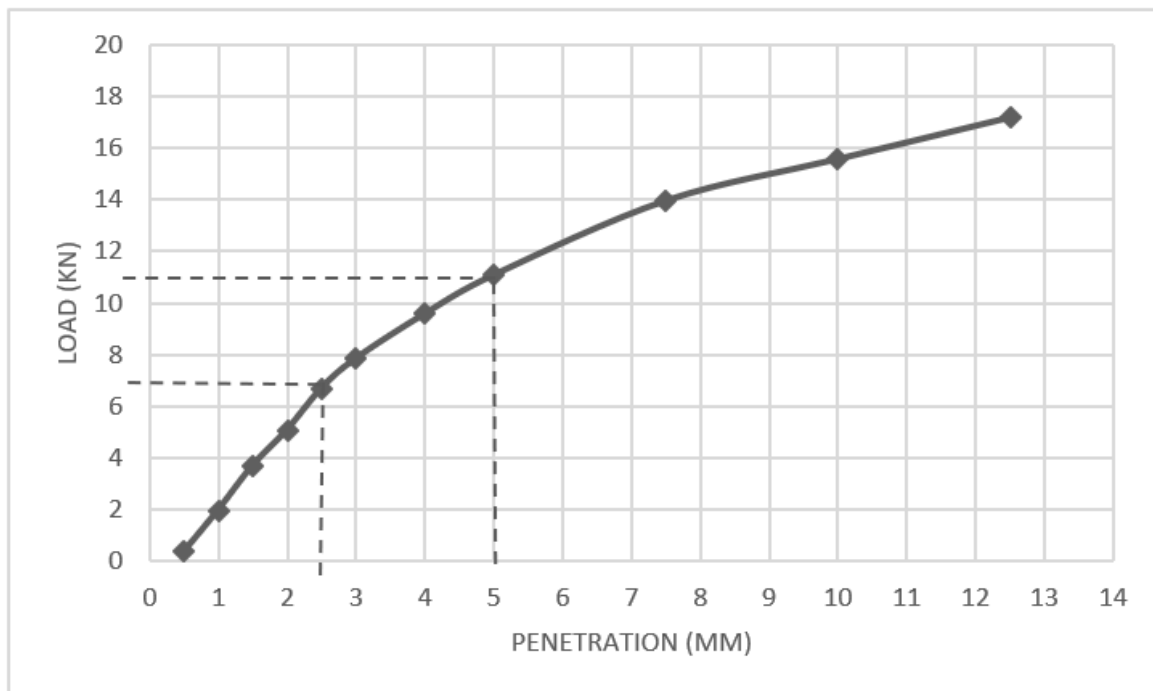


*Figure 22: CBR – Soil + CDW + NaOH*

Figure 22 showcases the CBR test results for specimen no.04. The calculated bearing ratio for this specimen at 5mm penetration is 81.33%, indicating a 503% increase compared to the untreated soil.
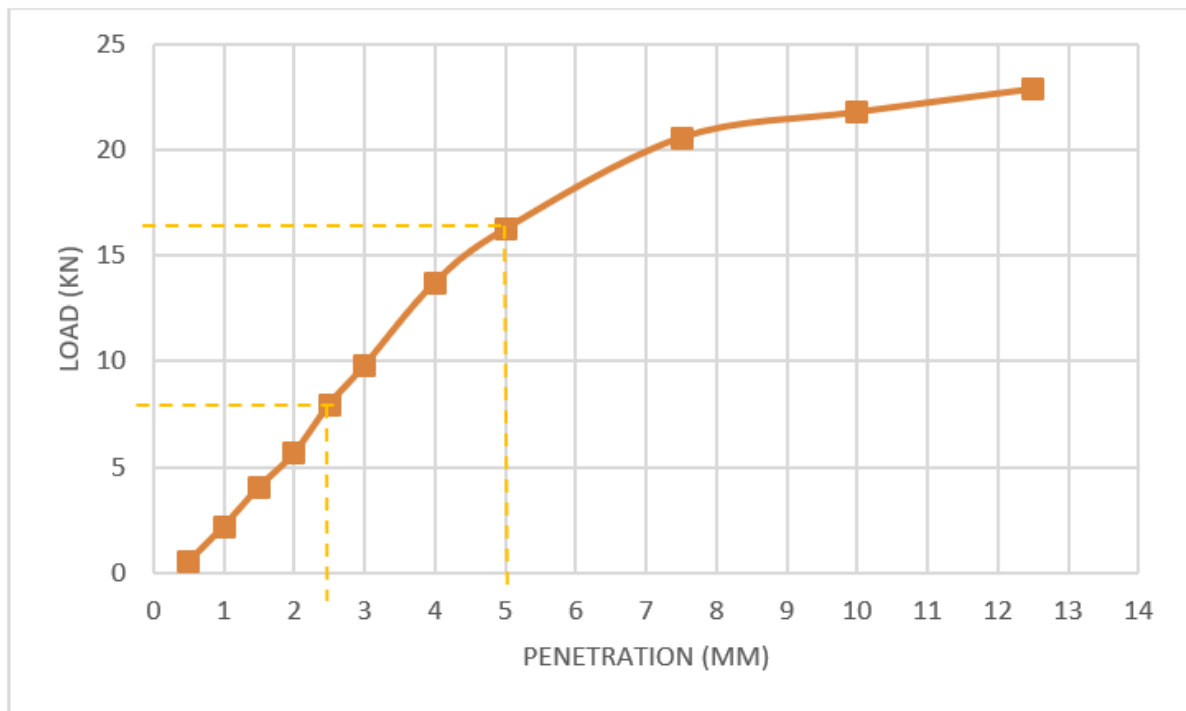


*Figure 22: CBR – Soil + CDW + NaOH + CaCO₃*

Using the obtained load values relative to penetration, California Bearing Ratios were calculated and summarized in Table 06.

Table 06: CBR Value Variations

| Specimen No. | Specimen Type | CBR % |
|---|---|---|
| 01 | Sandy Soil | 16.15 |
| 02 | S. Soil + CDW | 40.2 |
| 03 | S. Soil + CDW + NaOH | 55.38 |
| 04 | S. Soil + CDW + NaOH + CaCO3 | 81.33 |

The addition of CDW, NaOH, and CaCO3 significantly increased the bearing capacity ratio. Utilizing the mentioned CBR values, summarized CBR ratio graphs for all four soil specimen types are showed in figures below.

*Figure 23: CBR Results Variations*



*Figure 24: CBR Variations of Four Specimens*

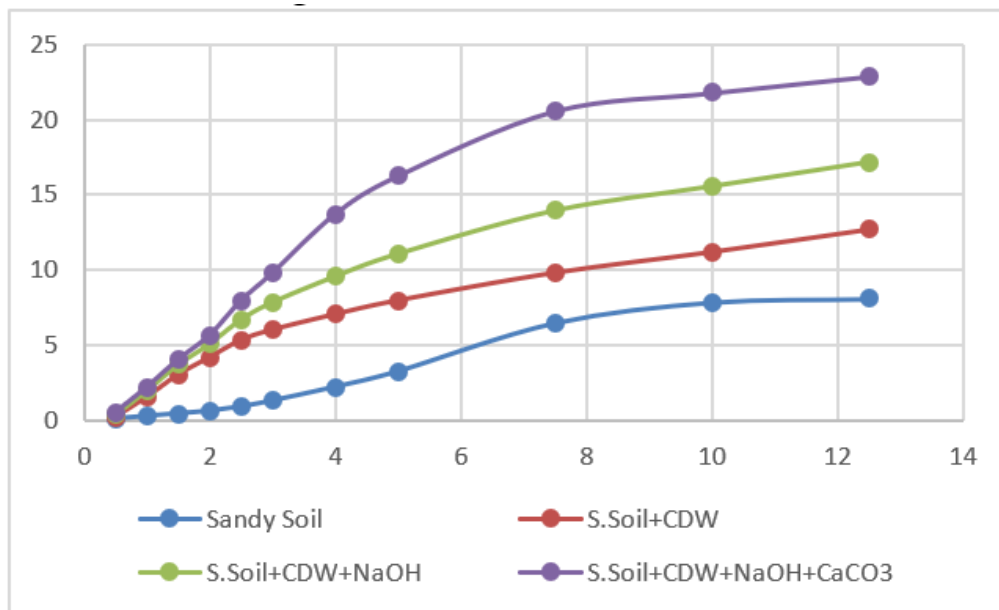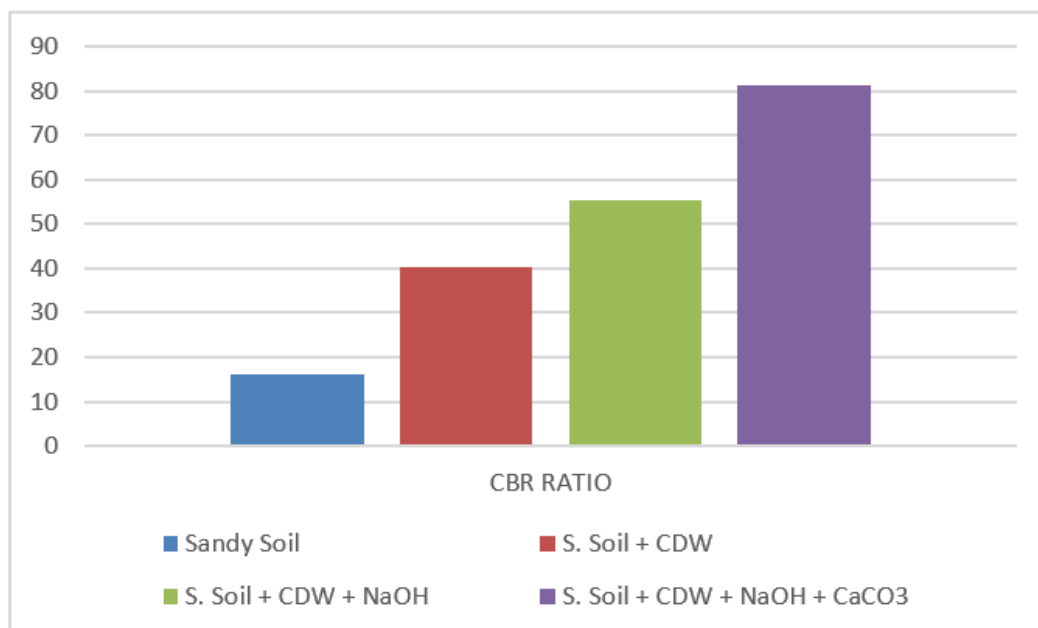Figures 23 and 24 show that the highest bearing ratio was achieved by specimen no. 04, comprising Soil+CDW+NaOH+CaCO3. This modification, substantially enhanced the CBR values by altering the soil grade and engineering properties of the sandy-soil.

Table 07: CBR Value Variations with Relevant to Curing Ages

| Specimen Type | CBR at 0 Days (%) | CBR After 01 Day (%) | CBR After 03 Days (%) |
|---|---|---|---|
| Sandy Soil | 16.15 | - | - |
| S. Soil + CDW | 40.2 | 45.01 | 46.32 |
| S. Soil + CDW + NaOH | 55.2 | 65.18 | 68.64 |
| S. Soil + CDW + NaOH + CaCO3 | 81.33 | 88.25 | 90.56 |

Furthermore, the treated soil specimens (No.02, 03 & 04) were directed to the CBR testing again at 1 day and 3 days curing ages. The obtained CBR-ratios are summarized in the above Table.07. The curing time for treated soil samples significantly influences bearing ratio results, indicating an increase in bearing capacity with prolonged curing. This is attributed to the time required for the alkaline activation reaction between CDW and NaOH to reach its maximum benefit.
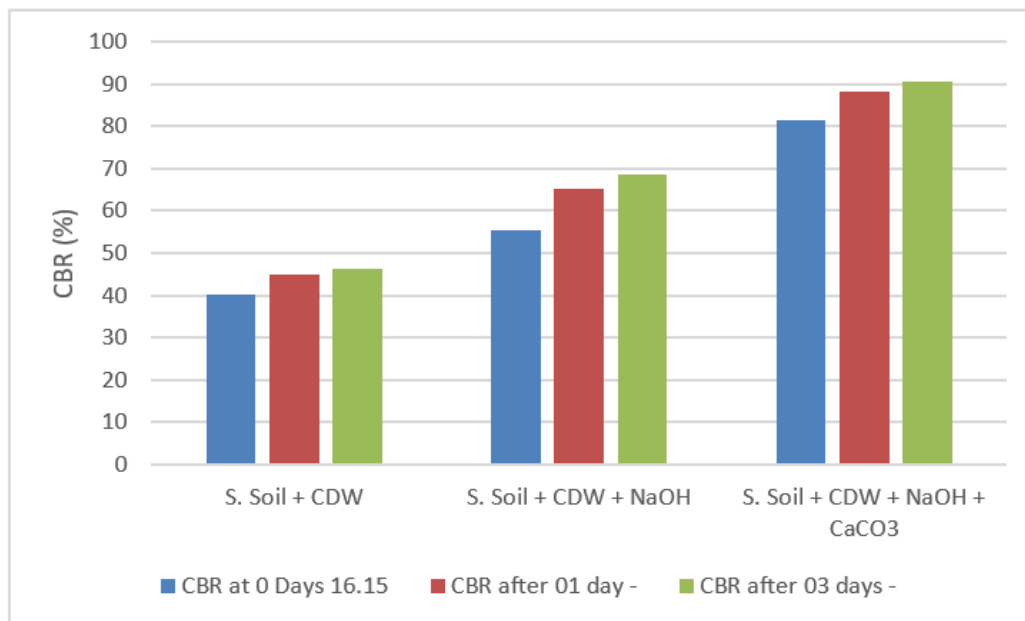


*Figure 25: CBR Results Variations*

**Conclusion**

The findings of this research work were concluded based on the obtained and calculated results as follows;

The Soil + CDW + NaOH + CaCO3 mix improved the sandy soil's bearing capacity from 16.15% to 81.33% (California-Bearing-Ratio).

Permeability reduced with the addition of CDW, NaOH, and CaCO3. CDW filled pores

between sand particles, and CaCO3 impacted sand particles' binding.

Alkaline-activated NaOH affects sandy soil's permeability and bearing capacity. Alkaline-activated CDW & CaCO3 combo is more effective than NaOH-activated CDW alone.

The geo technical properties of the problematic sandy soil are influenced with the curing time. The bearing capacity ratios are increased as the curing durations are increased.

Optimum CDW ratio was 16%, NaOH was 10 Mols & $CaCO_3$ was 8% from the total weight of the soil specimen.

CDW, NaOH, and CaCO3 can stabilize poorly graded sandy soil by reducing permeability and increasing bearing capacity. This approach is more cost-effective, and also reduces carbon emissions by reducing the usage of cement.

### Recommendations

To improve the research, extend testing beyond the current maximum of 3 days to at least 28 curing days. This will likely improve bearing capacity. For large-scale ground improvements, explore alternative alkaline activators to NaOH or address difficulties associated with it.

To improve this research, extending the testing-duration to at least 28 days could provide a more comprehensive understanding. The current findings, limited to a maximum of 3 curing days, suggest that bearing capacity could further improve with extended curing. Additionally, for large-scale ground improvements, potential complications with handling NaOH may arise. Therefore, exploring alternative alkaline activators to NaOH or address difficulties associated with it.

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# EVALUATING THE PERFORMANCE AND PROPERTIES OF RECYCLED AERATED CONCRETE BLOCK

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## Abstract

This research aims to evaluate the performance and properties of recycled aerated concrete (RAAC) for sustainable construction. The objectives include studying Autoclaved Aerated Concrete (AAC) properties, developing RAAC cubes, measuring mechanical properties, and recommending the optimum RAAC percentage. The methodology involves a literature review, AAC waste collection, crushing, cube casting, and mechanical property measurement. Results are discussed in comparison with literature findings, focusing on compression strength, particle distribution, and water absorption. Compression tests reveal a decrease in strength with increasing RAAC percentage, especially prominent from 0% to 10%. Particle distribution analysis indicates a significant impact on compression strength due to coarse aggregate replacement with RAAC. Water absorption remains within acceptable limits (10-15%) for RAAC cubes. This study provides insights into utilizing RAAC in construction with an optimal percentage.

**Keywords:** Aerated Concrete, Concrete strength, RAAC and Recycle.

## Background

AAC is a precast, lightweight building material with superior thermal insulating capabilities. Fine aggregates, cement, lime, gypsum, aluminum powder, and water are the main ingredients. By introducing gas bubbles throughout the manufacturing process, the cellular structure is generated. The steps involved in producing AAC are mixing, aerating, casting, and autoclaving. The procedure results in an air-filled, porous structure that reinforces the AAC and develops its cellular structure. Lightweight, thermal insulation, fire resistance, acoustic insulation, environmental friendliness, and design flexibility are just a few benefits of AAC. It is applied in a variety of ways, such as wall blocks, floor and roof panels, cladding, and other structural components in residential and commercial buildings. A binder created during traditional concrete curing, calcium silicate hydrate, is also formed as a result of the production process (Dejtiar, 2019).

While using aerated concrete such as AAC panels, a huge amount of materials is wasted. This is while adjusting AAC panels to specific locations that needed to be cut or break-off few parts in the process of transporting, loading and unloading. These broken materials are not at all used in anyway and are considered as construction waste. One of the examples is while constructing the Ooredoo Maldives Data Centre (OMDC) which is the first ever tier-3 ready data centre so far build in Maldives. It was constructed in 2021 and the outer walls were constructed using AAC panels. Hence, due to above mentioned reasons, many materials were wasted. The fact OMDC wanted a specific thickness for the wall for proper insulation for the server rooms, even

a small damage and removal of small area on an AAC panel was considered a problem. Hence, some panels were even unable to use for the construction (Rehan, 2022).

 AAC panels must be handled with care, installed by a professional, and handled properly because to their fragility and low weight. They have concerns with jointing and sealing, porousness, dampness, and shrinkage. Their tensile strength, chemical compatibility, and surface polishing must all be considered by structural engineers. For some applications, special surface treatments or coatings may be necessary. AAC panels may not be as readily available or as inexpensive as conventional building materials in some areas (Deloney, 2022).

The main goal of this research study is to assess the performance and properties of recycled aerated concrete. To achieve the main goal, there are four objectives and they are to study the properties of AAC with respect to sustainable construction, to develop recycled aerated concrete included cubes, to determine the mechanical properties of developed cubes and to evaluate the results and recommended optimum percentage of recycled aerated concrete to be used.

## Methodology

The methodology includes a literature review, how AAC waste collected, crushed, cube casted and how mechanical properties is going to be measured. The first step involves understanding AAC characteristics and current methods for dealing with AAC waste. Secondly, waste collection from construction sites, crushing the materials to achieve the optimum coarse aggregate size, and casting the cubes using standard concrete components. The mechanical properties of the developed cubes are measured using compressive strength tests, particle size distribution analysis, and water absorption tests. The results are evaluated to recommend the optimum percentage of RAAC for construction projects.

Prior to recycling, it is essential to conduct research on the characteristics of AAC to make sure the procedure is efficient, long-lasting, and secure. It complies with legal and regulatory standards, permits the prudent use of resources, and improves the performance and quality of building materials.

The literature review method is one way to obtain information. Examining previous studies, journals, books, websites, and publications was the method used. This is due to the significance of understanding AAC characteristics and being able to locate current AAC waste management techniques. Additionally, it provides information on the ratio, proportion, and sizes of the particles in the concrete mix. This strengthens the research's aim as understanding the properties of AAC will aid in determining whether recycling is practical. Additionally, it assists in determining the ideal AAC crushing sizes as well as the ideal mix ratio for creating RAAC cubes.

Three steps make up this section of the methodology: collecting AAC wastes, crushing AAC and cube casting. Construction sites provide the waste, which is collected to provide representative samples for evaluation and analysis.

*AAC Waste Collection*

The waste material collected is from an ongoing construction site in Colombo 06, in Sri-Lanka by the company Metro Habitat Pvt Ltd where they are using AAC to mainly reduce the dead-load of the building.

*Crushing AAC*

This step supports the research's aim by ensuring that the resulting recycled material meets the desired size and quality standards for construction applications. The range of AAC aggregate used are from 15mm to 20mm in size.


*Figure 1 : Crushed AAC*

*Cube Casting*

In the method of cube casting, essential tools and materials such as standard concrete mixing components (including Portland cement), suitable fine aggregate, recycled coarse aggregate, water, mixing equipment, and a weighing scale are employed. The ratio used as per the literature review is 1:2:3 as per the volume. The Table 1 shows the percentage of RAAC used in each cube and the relative weight of other components in it (Mahajan, 2023).

BSEN 12390-3-2000 was followed which the process for evaluating concrete cubes, including their preparation, curing, and testing techniques to ascertain their compressive strength, is outlined in this standard. In the field of civil engineering and construction, it is extensively acknowledged and utilized for evaluating the effectiveness and caliber of concrete. Cube volume :150mm x 150mm x 150mm = 0.003375 m$^3$.

Table 1 : Cubes with the weight of each component

| Cube No | RAAC % | Cement (kg) | Fine Agg (kg) | Coarse Agg (Kg) | RAAC (kg) |
|---------|--------|-------------|---------------|-----------------|-----------|
| 1 | 0 | 1 | 2 | 3 | 0 |
| 2 | 10 | 1 | 2 | 2.7 | 0.2 |
| 3 | 20 | 1 | 2 | 2.4 | 0.4 |
| 4 | 30 | 1 | 2 | 2.1 | 0.55 |
| 5 | 40 | 1 | 2 | 1.8 | 0.64 |
| 6 | 50 | 1 | 2 | 1.5 | 0.72 |

The compressive strength test was measured the strength of concrete cubes, vital for construction projects. The particle size distribution analysis was conducted to analyze material particle size distribution, enhancing quality assurance and product development. The water absorption test, using a large water container and weight scale, evaluated the concrete's performance, durability, and overall quality.

This comparative analysis was used as it aids in determining the optimum percentage of RAAC for various applications. By benchmarking against existing research and identifying the desired properties, the study can make informed recommendations regarding the most effective RAAC utilization. Furthermore, this comparison supports the aim of the research by providing insights into the outcomes, opportunities for improvement, and potential directions for future research.

**Results and Discussion**

In this section, the data collected based on the tests are presented in both numerically and visually. The results from this research are compared with the findings from literature and other reliable sources of information related to concrete properties, sustainability and recycling. Main highlighted areas were comparison of compression of concrete with and without RAAC, how the changes observed with increased percentage of RAAC. Another thing is how the particle distribution affected the result, how the water absorption changed with change in the amount of RAAC and finally how the data can be utilized in construction application with optimum percentage RAAC.

*Sieve analysis for fine aggregate*

The workability, strength, durability, and general quality of concrete are all directly and significantly impacted by the particle size distribution, which can be characterized and controlled via sieve analysis for fine aggregate. Through examination and refinement of the fine aggregate's particle sizes, experts can guarantee that concrete fulfills required parameters and functions as planned in building applications.
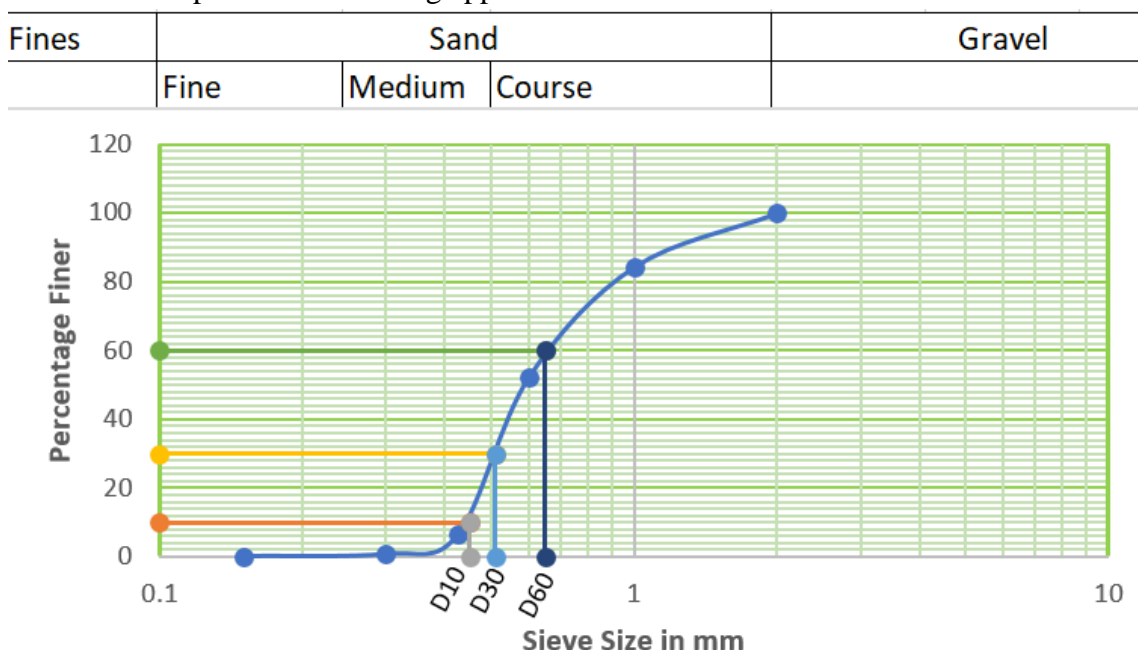


*Figure 2 : Soil distribution graph*

The Particle distribution for fine aggregates shows that it is poorly graded which is not the recommended types for good quality concrete, (Grading of aggregates in concrete spreadsheet 2020) however, hence the same aggregates were used in all the samples including the control sample. Moreover, the coarse aggregate was also same to all the cubes with just change in percentage as they were replaced by the RAAC. It seems that replacement of coarse aggregate has a significant effect on the compression strength of the cube as they withstand most of the compressive forces.

*Effect on Compressive Strength*

For assessing the characteristics of RAAC cubes, compressive strength tests are essential. They guarantee safety, regulatory compliance, performance evaluation, research and development, quality assurance, structural integrity, and comparative analysis. Comprehending the compressive strength of RAAC facilitates the assessment of its ability to withstand loads and stresses in construction settings, enhances mix design and manufacturing procedures, and aids in well-informed decision-making in construction projects. Here are the cube details with the test results after 7 days of casting:

Table 2 : Compressive Strength for the cubes

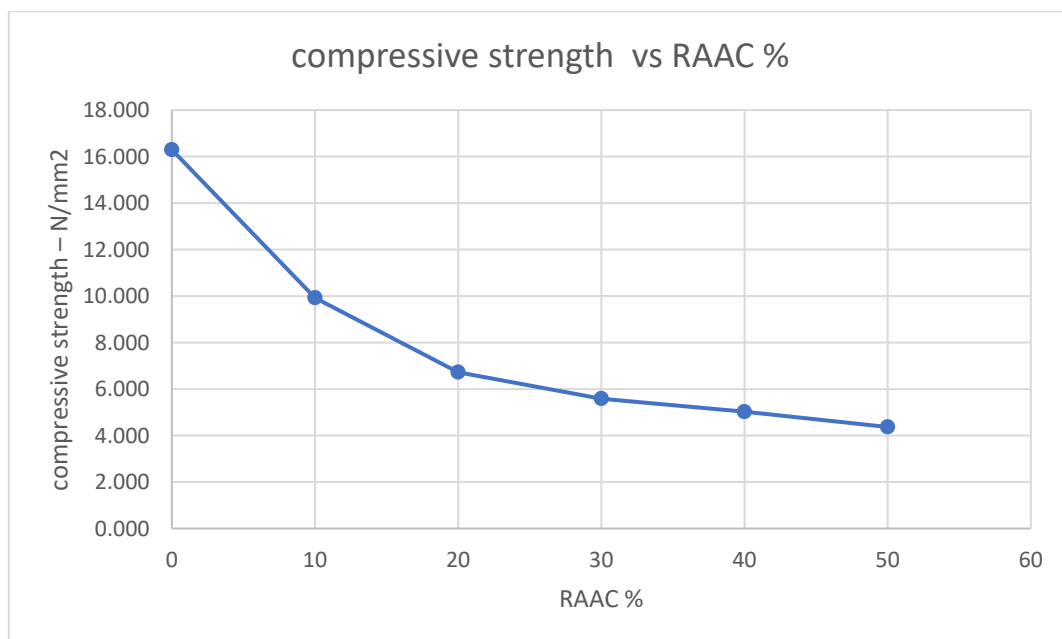| Cube No | RAAC % | Weight (kg) | Max Applied Load (KN) | Compressive Strength (N/mm$^2$) |
|---|---|---|---|---|
| 1 | 0 | 6.63 | 366.65 | 16.296 |
| 2 | 10 | 6.4 | 223.24 | 9.922 |
| 3 | 20 | 6.15 | 151.21 | 6.720 |
| 4 | 30 | 5.96 | 125.69 | 5.586 |
| 5 | 40 | 5.94 | 113.05 | 5.024 |
| 6 | 50 | 5.87 | 98.26 | 4.367 |



*Figure 4 : Graph of compressive strength to parentage RAAC included*

When cement, sand, and coarse aggregates are mixed in a 1:2:3 ratio, the strength of the general concrete after seven days is usually 60–65% of the strength after twenty-eight days. (Kumar, 2020) Hence, with the above-mentioned ratio, the general strength for 28 days is between 17MPa and 25Mpa. (Mahajan, 2023) Therefore, for 7 days it is predicted to have the strength around 16.25MPa. When compared to the initial cube (Cube 1) with no RAAC, the result shows almost same value for strength (16.29MPa). The percentage difference is around 0.25%. Therefore, the control cube is good to compare with the other cubes with RAAC included.

As seen on the figure 10 the compressive strength of the cubes decreases exponentially with increased percentage of RAAC. The biggest drop is seen from RAAC with 0% to 10% which decreased the strength almost to half of the original strength. Moreover, with each additional 10%, the strength seems to be decreasing but at a lower rate.

*Effect on Water Absorption*

A crucial part of testing concrete is the water absorption test, particularly for determining RAAC. It offers vital information that guides decisions about the choice of materials, quality assurance, durability evaluation, and structural design, all of which are ultimately responsible for the safe and successful completion of building projects. Here the cubes were tested for water absorption.

Table 3 : Percentage Water absorbed for each cube

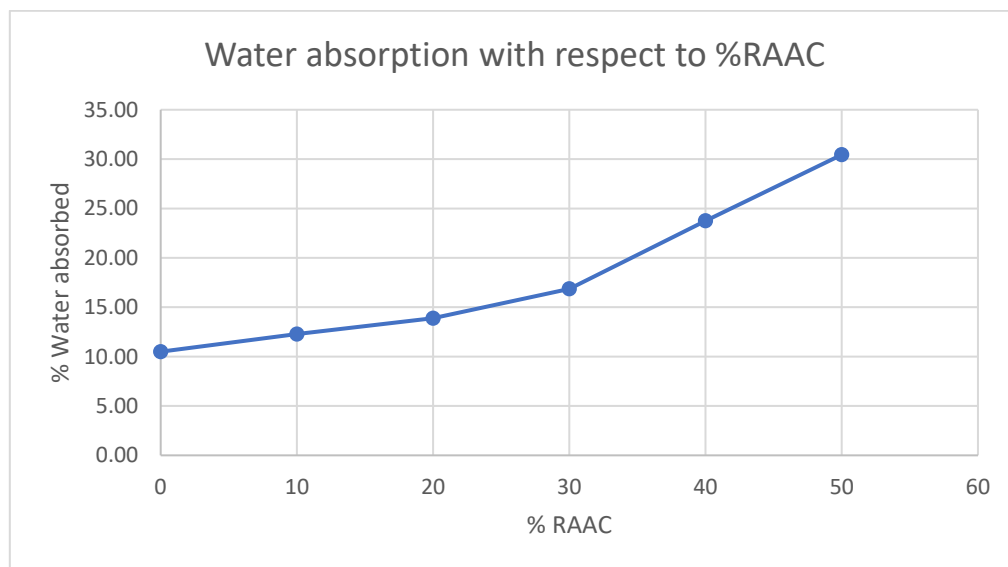| Cube No | Weight (kg) | Weight saturated(kg) | Water absorbed (kg) | % water absorbed |
|---------|-------------|----------------------|---------------------|------------------|
| 1 | 6.2 | 6.63 | 0.61 | 10.50 |
| 2 | 5.9 | 6.4 | 0.8 | 12.28 |
| 3 | 5.5 | 6.15 | 0.75 | 13.89 |
| 4 | 5.2 | 5.96 | 0.86 | 16.86 |
| 5 | 4.9 | 5.94 | 1.14 | 23.75 |
| 6 | 4.6 | 5.87 | 1.37 | 30.44 |



*Figure 5 : Graph for Water absorption with respect to %RAAC*

The strength of the cube decreases exponentially with increase in percentage of RAAC in the concrete cube. All the failures in the cube appears to be through the RAAC coarse aggregate. General water absorption for concrete is considered to be 10 to 15 percentage. The control cube shows the properties of a general concrete cube where the water absorption was around 10 percent. Moreover, for the RAAC % of 10 and 20 (cube 2 and cube 3) also showed that water absorption was not more than 15 percent.

However, a number of variables, including as the materials' quality, the curing environment, and environmental circumstances, might affect the real strength.

## Conclusion and Recommendation

The research study on Recycled Aerated Autoclaved Concrete addresses environmental concerns related to waste generated by aerated concrete (AAC) in construction. The study aims to understand AAC properties, waste management, and concrete mix proportions. It tests mechanical properties of RAAC, including compressive strength, particle size distribution, and water absorption. Results show a significant decrease in strength as the percentage of RAAC in the mix increases and water absorption tests show that RAAC percentages of 10% and 20% exhibit acceptable water absorption. Hence, it is recommended to use 15% of RAAC based on the construction places which doesn't require extreme compression strength but beyond that is not recommended as the strength of the cube decreases a lot with increased RAAC.

The Cube 2 and 3 with 10% and 20% shows properties of M 15 which is ideal for construction of roads and sealing floors. Moreover, the compressive strength is low and therefore best use with non -RCC applications. Some of the suggested applications are leveling floor, ramp and garage.

For a variety of reasons, when the RAAC percentage rises, the compressive strength of concrete cubes falls. Particle distribution, curing and setting times, inhomogeneity un RAAC, and compatibility with the matrix of cement are a few of these variables in the material qualities of recycled RAAC. The addition of RAAC may result in irregularities in the material's characteristics, which could compromise the concrete's overall strength. Inconsistencies in the distribution and sizes of the particles may cause the interlocking between them to become weaker, thereby decreasing the overall strength. Concrete strength development can also be impacted by differences in setting time or inadequate curing. Consequently, the concrete's strength may be impacted by RAAC's compatibility with the cementitious matrix.

There are several recommendations for the construction industry to promote the adoption of RAAC as a sustainable alternative to traditional building materials. These include promoting RAAC adoption, improving handling and installation practices, researching surface treatments, standardizing RAAC production, and encouraging recycling of AAC waste. Further research and development should focus on optimizing mix proportions, ratios, and aggregate sizes for RAAC production. Real-world testing should be conducted to evaluate RAAC performance in construction scenarios. Collaboration among stakeholders, including researchers, builders, architects, and policymakers, should be encouraged. A comprehensive life cycle analysis of RAAC production and usage compared to traditional materials can provide a holistic view of its sustainability. Public awareness campaigns should be launched to educate consumers and builders about RAAC's benefits.

The study shows that a decline in compressive strength occurs with increasing percentages of RAAC in concrete mixes, underscoring the significance of taking structural factors into account. Concrete mixes should be selected by engineers and builders based on their intended use and characteristics; for example, RAAC mixes may be better suited in non-structural or lower compressive strength scenarios.

Hence, low-strength and low-weight concrete can commonly be used in construction for its lightweight and insulating properties. It is also used in Insulating Concrete Blocks (ICB), Precast Panels for Cladding, Lightweight Concrete Roofing Tiles, Vaud Fill and Backfill, Architectural and Decorative Elements, Hollow Core Concrete Panels, Geotechnical Applications, Floating Structures, Trench Fill and Underground Applications, and Garden and Landscape Elements. These concretes are easy to handle, provide good insulation, and can be molded into various elements for easier installation. However, it is crucial to ensure that the material meets the necessary structural and performance standards for the intended application. In order to improve overall strength and RAAC compatibility with the cementitious matrix, more research should be done on mix proportion optimization. To guarantee constant material qualities, quality control procedures should be put in place during production.

This study sets the stage for further investigation and innovation in the use of recycled aerated concrete in the construction industry. This research lays the foundation for more sustainable and environmentally responsible construction practices, contributing to the global effort to reduce the environmental impact of the building industry. It is recommended to do an analysis on the different sizes of RAAC coarse aggregate affects the concrete with the constant percentage replacement so the relationship between the size of RAAC as coarse aggregate against compressive strength can be identified.

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# AN EXPERIMENTAL STUDY ON THE PRODUTION OF CEMENT BRICK USING DISCARDEDWASTE: GLASS POWDER & SCRAPPED TINS

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**Abstract**

One of the biggest problems in today's construction industry is the rise in the price of materials and the difficulty in finding quality materials. This experimental study investigates the sustainable production of cement bricks using discarded waste materials, namely glass powder and scrapped tins. The objective is to assess the feasibility of incorporating these waste materials as partial substitutes for traditional raw materials in brick manufacturing. The study explores the effects of varying proportions of glass powder and scrapped tins on the mechanical and structural properties of the cement bricks. Through a series of laboratory experiments, including compressive strength, Splitting Tensile Strength tests and life-cycle-cost assessments, the research aims to identify optimal combinations that enhance both environmental sustainability and structural performance. The findings contribute to the development of eco-friendly construction practices by reducing reliance on conventional resources and repurposing waste materials, fostering a more circular and sustainable approach to brick production.

**Keywords:** Glass powder, Scrapped Tins, Tensile Strength, Mix design, Life-cycle-cost analysis

**Introduction**

The construction industry plays a pivotal role in global resource consumption, and the need for sustainable practices has become increasingly urgent. This experimental study addresses this imperative by exploring innovative approaches to cement brick production through the utilization of discarded waste materials. The focus of this research is on incorporating two specific waste components—glass powder and scrapped tins—as potential alternatives to traditional raw materials in the manufacturing of cement bricks. According to recent studies (Smith et al., 2020; Green Building Council, 2021), the construction sector contributes significantly to environmental degradation, necessitating novel methods to reduce its ecological footprint. The exploration of waste materials in brick production aligns with the principles of the circular economy, aiming to repurpose and reintegrate discarded resources into construction processes (Jones & Greening, 2019). Through a series of systematic experiments, including compressive strength, splitting tensile strength assessments and the life cycle cost analysis. This seeks to swap out the current mix design for a more potent mix design at a more affordable price (Harrison, Berenjian, and Seifan, 2020). New mix designs are made by using waste materials in different percentages, and selecting the best mix design with higher strength (Fuller, 2016) by aiming to establish a robust understanding of the mechanical and structural properties of cement bricks incorporating glass powder and scrapped tins, contributing to the advancement of sustainable construction practices.

*Aim of the Study*

➢ This study is aiming to increase the tensile strength of currently used mix design of cement bricks by introducing glass powder and scrapped tins to proper recycling for discarded harmful materials.

*Objectives*

1. To identify the use of Aluminum waste and Glass powder in concrete construction by referring the literature & gather information from industry.

2. To investigate the best cement bricks sample by adding Glass powder & Scrapped tins in varying weight percentages the workability by checking compression and splitting tensile strength properties via performing standard laboratory tests.

3. To evaluate the durability of new mix by performing laboratory testing and life cycle cost analysis in comparison with conventional concrete-cement brick.


*Significance of the Study: Greening Construction - Unveiling the Sustainable Tapestry in Cement Brick Production*

This comprehensive review delves into the transformative potential of incorporating waste into cement-based materials, scrutinizing its impact on both the fresh and hardened properties of mortars and concretes. This study delves into innovative modifications in cement brick mix design, specifically focusing on the addition of glass powder and scrapped tins to enhance the material's properties. Drawing from the findings of Harrison, Berenjian, and Seifan (2020), the research explores the impact of varying glass powder additions at 5%, 10%, and 15%. Notably, Letelier's research (2020) suggests a limit of 20% glass powder addition due to a decline in tensile strength with higher percentages, a trend that this study challenges by incorporating more than 20% glass powder and introducing another waste material to counterbalance potential drawbacks.

In parallel, the investigation extends to modifications in scrapped tins addition to the cement brick mix design, as inspired by Shoag and Rahman's work in 2021. The aspect ratio is maintained at 20:100, and the diameter range spans from 0.25 to 0.75mm. Drawing from aluminum fiber concrete literature, the study contemplates percentages of 0% to 3% for aluminum fiber reinforced concrete. Considering aluminum's recyclability, the potential to reduce overall structural weight is explored. In contrast to Shoag and Rahman's use of tin fibers, this research employs scrap tins without threads, presenting a distinctive approach to leverage this waste material in cement brick manufacturing. By unlocking the intricacies of waste glass integration, this research charts a course toward a commercially viable and environmentally sustainable future for cement-based materials across diverse construction applications.


**Methodology**

This comprehensive methodology integrates literature review, experimental investigation, and performance evaluation to achieve a holistic understanding of the utilization of aluminum waste and glass powder in concrete construction and to determine the optimal composition for cement bricks with improved properties.

*Literature Review and Industry Information*

Conduct an extensive literature review to understand the existing applications, benefits, and challenges associated with incorporating aluminum waste and glass powder in concrete. Gather information from industry sources, such as construction companies and material suppliers, to understand current practices, innovations, and potential challenges.

*Material Selection and Preparations*

In this study, Ordinary Portland Cement was used as the binding agent. Natural sand served as the fine aggregate in this investigation, and particles exceeding 4.75 mm were excluded through a thorough sieve analysis. Throughout the research, the preparation and curing of concrete involved the use of municipal water. This critical parameter is determined by the water-to-cement ratio. In the context of fibrous mixtures, it is imperative to meticulously manage water-cement ratios. Typically, water-cement ratios falling within the range of approximately 0.35 to 0.50 are considered standard for this category. The precise control of these ratios is essential for ensuring the desired properties and performance of the concrete, emphasizing the importance of maintaining an optimal balance in the mixing process.



*Figure 1: Glass Powder*　　　　　　*Figure 2: Scrapped Tin*

Waste glass is broadly classified into three main types, each characterized by distinct chemical compositions, as Soda-lime glass, Borosilicate glass and lead glass. Notably, soda-lime glass commonly employed in the production of container glass (such as beverage bottles) takes center stage in this context, given its prevalence as the primary material in glass containers, thereby emerging as a major contributor to waste glass sources.

Those were collected free of other contaminants such as drinks, foods and dirt. And, heads and feats are removed for crushing diameter range spans from 0.25 to 0.75 mm (Figure 1) to use as a replacement to fine aggregates.

Scrapped tins (without threads) were collected from discarded aluminium tins without contaminants. Utilizing scrapped tins as a substitute for steel fibres in concrete, the aspect ratio (l/d) was established within the range of 50–60 (Figure 2), aligning with the specifications outlined in ACI 544.3R-93. This choice was guided by the inherent material properties of the waste steel scrap, mirroring those of the primary tin materials, chosen for its accuracy and simplicity in implementation.

*Concrete Mix Design*

The formulation of a concrete mix aimed at attaining precise ratios of cement, sand, and aggregates was undertaken with a primary focus on ensuring structural integrity. The objective

was to identify an optimal and practical combination of materials, readily accessible, to produce concrete that meets performance criteria under distinct usage conditions. The process of concrete proportioning involved a meticulous evaluation of the proportional quantities of materials, aiming to achieve the required workability, as well as the desired attributes of strength, volume consistency, durability, and cost-effectiveness. A critical aspect of this mixture design was ensuring the even dispersion of fibers to prevent issues such as fiber segregation or clumping, acknowledging the importance of a homogenous distribution for the overall effectiveness of the concrete composition.

Table 1: Mix Design and Proportions

| Reference | Cement [%] | Reduced percentage [%] | Sand [%] | W/C | Glass powder [%] | Scrapped tins [%] |
|---|---|---|---|---|---|---|
| $P_0$ | 16.7 | | 83.3 | 0.45 | 0 | 0 |
| $P_1$ | 16.7 | 40 | 49.9 | 0.45 | 24.9 | 8.3 |
| $P_2$ | 16.7 | 45 | 45.8 | 0.45 | 28.1 | 9.4 |
| $P_3$ | 14.5 | 50 | 41.7 | 0.45 | 31.2 | 10.4 |
| $P_4$ | 14.5 | 55 | 37.5 | 0.45 | 34.4 | 11.5 |

*Laboratory Tests and Analysis*
- Conduct standard laboratory tests, including slump tests for workability, compression tests for strength properties, and splitting tensile strength tests to assess structural integrity.
- Evaluate and compare the results to determine the most suitable composition for achieving desired properties.
- Perform life cycle cost analysis by considering initial construction costs, maintenance costs, and potential long-term savings or benefits with referring to, Whole Building Design Guide (WBDG), National Institute of Standards and Technology.
- Compare the durability and life cycle cost analysis results with those of conventional concrete-cement bricks to determine the overall feasibility and sustainability of the new mix.
- Draw conclusions regarding the performance, feasibility, and sustainability of the cement bricks incorporating glass powder and scrapped tins.

**Results**

*Optimization of Cement Brick Samples:*
The investigation advances to determining the most effective cement brick composition. Glass powder and scrapped tins are introduced in varying weight percentages to identify the optimal blend, evaluating workability, compression, and splitting tensile strength through standardized laboratory tests.
Based solely on the true slump, we can draw conclusions and classify the outcome within a range based on the slump value: Too little workability: a decline of 0 to 25 mm. Low workability: 25 to 50 mm is the record value (Table 2).

Table 2: Slump Test Results on Testing Samples

| Reference | Slump value (mm) | | | Average slump (mm) | Type of slump |
|---|---|---|---|---|---|
| | Sample 1 | Sample 2 | Sample 3 | | |
| $P_0$ | | | | 75 | TS |
| $P_1$ | 46 | 50 | 38 | 45 | TS |
| $P_2$ | 65 | 72 | 67 | 68 | TS |
| $P_3$ | 39 | 27 | 46 | 37 | TS |
| $P_4$ | 42 | 33 | 21 | 32 | TS |

Table 3: Compressive Strength Test Results on Testing Samples with Average Weights

| Reference | Compressive strength (kN) | | | Average strength (kN) | Average strength (MPa) | Average weight (kg) |
|---|---|---|---|---|---|---|
| | Sample 1 | Sample 2 | Sample 3 | | | |
| $P_0$ | 156.1 | 113.7 | 192.4 | 154.1 | 0.154 | 6.37 |
| $P_1$ | 46.4 | 270.2 | 178.3 | 165 | 0.165 | 6.479 |
| $P_2$ | 122 | 186.7 | 246.8 | 185.2 | 0.185 | 6.583 |
| $P_3$ | 89 | 273 | 152.6 | 171.5 | 0.172 | 6.469 |
| $P_4$ | 226.3 | 91.8 | 107.7 | 141.9 | 0.142 | 6.407 |

Table 4: Splitting Tensile Test Results on Testing Samples

| Reference | Tensile strength (MPa) | | | Average tensile strength (MPa) |
|---|---|---|---|---|
| | Sam 1 | Sam 2 | Sam 3 | |
| $P_0$ | 8.3 | 10.5 | 13.2 | 10.7 |
| $P_1$ | 1.2 | 0.8 | 1.7 | 1.2 |
| $P_2$ | 9.4 | 11.1 | 15.6 | 12 |
| $P_3$ | 8.2 | 12.1 | 7.6 | 9.3 |
| $P_4$ | 6.3 | 8.1 | 5.9 | 6.8 |

The results indicated promising outcomes in achieving the desired mechanical properties of the cement bricks. The incorporation of glass powder and scrapped tins exhibited a notable impact on workability (Table 2) and strength characteristics (Table 3 & 4), contributing to the feasibility of utilizing these waste materials in construction practices. From the primary results show that increasing the waste glass replacement for natural sand has a decreasing effect on the slump. Although glass is smooth, this is attributed to the lighter weight of the samples as glass has a lower specific gravity than that of sand.

It was noticed that the workability of concrete reduced on increasing of the steel scrap content. As shown in Table 2, the value of slump reduced from 75 mm at 0% steel scrap content to 32 mm at 11.5 % steel scrap content. The presence of waste steel scrap in the concrete mix induces a property of rigidity as a result of the interlocking of each waste steel scrap in the concrete mix. This condition results in strength on fresh concrete.

*Durability Assessment and Cost Analysis:*

Subsequent stages focus on evaluating the durability of the newly formulated mix. Rigorous laboratory testing is conducted, and a life cycle cost analysis is performed, comparing the outcomes with those of conventional concrete-cement bricks. This step aims to provide insights into the long-term performance and economic feasibility of the innovative mix.

$$LCC = I + Repl — Res + E + W + OM\&R + O: \text{(WBDG, 2019)}$$

**LCC** - Total Life-Cycle-Cost in present-value

**I** - PV investment costs

**Repl** - PV capital replacement   costs

**Res** -PV residual value less disposal costs

**E** - PV of energy costs

**W** - PV of water costs

**OM&R** - PV of non-fuel operating, maintenance and repair costs

**O** - PV of other costs

(PV) - Rupees of a given alternative

Using the above formula (upon reviewing to Whole Building Design Guide (WBDG), National Institute of Standards and Technology and retailed prices for Building Code, 2019), the life-cycle cost was calculated separately for the conventional mix design and separately for the new mix design introduced through this research.

*LCC for the selected sample based on fresh and harden properties $P_2$:*

$$LCC = \text{Rs. } (30.00 + 15.00 – 18.00 + 7.00 + 13.00 + 4.00) = \text{Rs. } 77.00$$

**Conclusion**

Building on the comprehensive testing and analysis, crucial findings emerge to solidify the conclusion of this research. The slump tests affirm that all mixtures exhibit true slumps, indicating favorable workability. Notably, the second mix proportion ($P_2$) emerges as a standout performer, surpassing conventional brick strength in both compressive and tensile evaluations.

In the compression test, the second mix proportion attains the highest strength, outperforming conventional bricks. Similarly, the splitting test reveals superior tensile strength for the second mix proportion, further solidifying its position as the optimal mix.

This research challenges existing perceptions by incorporating more than 20% glass powder, traditionally deemed detrimental to strength. The introduction of aluminum tin pieces in this unique mixture, however, results in a groundbreaking mix design, showcasing higher strength and resilience. The study establishes that glass powder can be effectively integrated up to 28.1%, beyond which strength begins to decline.

A critical aspect of the conclusion is the life-cycle cost analysis, indicating the cost-effectiveness of the new mix design. With a price of Rs. 77.00 per unit, significantly lower than the current market range of Rs. 80.00 to Rs. 90.00, the innovative cement brick presents a compelling economic advantage.

In essence, this research not only identifies a high-strength mix design but also challenges limitations in glass powder incorporation. The incorporation of aluminum tin pieces not only

mitigates strength reduction but also positions the new mix as a cost-effective alternative, showcasing its potential for sustainable and economically viable construction practices.

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# THE CHALLENGES ENCOUNTERED BY CONSTRUCTION WORKERS WHEN DEVELOPING GREEN BUILDING CONCEPTS FOR BUILDINGS IN SRI LANKA

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**Abstract**

The building industry's depletion of natural resources poses long-term consequences for society, the economy, and the environment. Sustainable building practices are crucial for improving living conditions and mitigating negative impacts. This study explores current green construction techniques and contractor concerns across various building types. Despite challenges, such as cost and awareness issues, the long-term benefits make green buildings a sound investment. The research emphasizes the need for enhancing green construction principles to maximize cost-effectiveness and performance efficiency. The findings aim to inform strategies for overcoming barriers and promoting sustainable building concepts in the local construction industry.

**Keywords:** Challenges, Construction Industry; Green Building Concepts, Sri Lanka, Western Province

## Introduction

The global construction industry significantly affects the environment, social development, and economy. Enhancing living quality, enabling people to live in the healthiest environment possible, and improving social, environmental, and economic situations for future generations are all part of sustainable development. Sustainable building is seen as a way for the building sector to support the push toward sustainable development. Green architecture is part of the idea of promoting sustainability. Furthermore, it is clear that green buildings have an impact on the building's long-term financial advantages (Martinez, 2005).

The idea of developing green buildings has lately become more popular in Sri Lanka's construction sector as interest in sustainability has grown on a worldwide scale.

Sri Lanka confronts several challenges as a developing country while constructing a green construction idea.

### *Problem Identification*

Forty percent of the entire amount of energy consumed is attributable to the building construction industry (Abidin, 2010). On the other hand, in order to ensure the wellbeing of future generations, it is anticipated that the amount of energy used and greenhouse gas emissions will be cut. On the other hand, an adaptation of the green idea is taking place, resulting in a greater starting cost in the construction of buildings. On the other hand, there is a void in the research literature about the identification of the complete life cycle cost decreasing in the green construction industry. The life cycle, green construction and costing

are all topics that are discussed at the international level; however, these topics are not implemented in the Sri Lankan context (Schiavoni, et al., 2015). As a result, the purpose of this research is to fill up the knowledge vacuum about the acceptance of the green concept for the reduction of the complete life cycle of the building construction process that means challenges encountered by construction workers (Directors, Project Managers, Engineers, Quantity Surveyors, Technical Officers, Architectures and so on) and give some solutions how to overcome those.

*Research Objectives*

- To identify the green building concept, its developments and its present status around the globe, in Sri Lanka and in western province.
- To investigate the challenges that construction workers face when developing green building concepts for buildings in western province.
- To suggest solutions for overcoming those challenges when developing green building concepts for buildings in western province.

**Research Methodology**

The research methodology establishes a scientific approach for achieving study objectives through research philosophy, approach, and methodologies. A literature assessment on sustainable and green building development explores distinctions and challenges, aiming to uncover innovative management strategies applicable to Sri Lanka for improved understanding (Hwang, 2012).

In addition, many other questions and challenges are expected to be collected from many people and a brief overview of how to obtain such information is provided below.

*Data Collecting Methods*

To make sure that every respondent had the necessary expertise, authority, and experience in green building principles, the questionnaire survey was done among professionals in the sector who were specifically chosen using the purposive sampling approach. As a result, a questionnaire with 20 items was given to 37 survey participants, and 29 questionnaires that were returned within the allotted survey period were qualified for consideration in the comprehensive analysis. Additionally, a lack of replies was brought on by time restrictions and the difficulty in reaching green building specialists. Table 1 provides a breakdown of the respondents' demographics.

Table I: Summary of responses

|  |  | Percentage (%) |
|---|---|---|
| **Profession** | Quantity Surveyor | 72.09 |
|  | Civil Engineer | 11.63 |
|  | Architectures | 13.95 |
|  | Other | 2.33 |
| **Current Job Type** | Contract | 65.12 |

| | Consultant | 11.63 |
|---|---|---|
| | Client | 4.65 |
| | Other | 18.60 |
| **Academic Qualification** | Up to BSc. Level | 46.51 |
| | Up to Diploma Level | 51.16 |
| | Other | 2.33 |
| **Professional Experience for Construction Industry** | < 6 Months | 6.98 |
| | < 1 Year | 4.65 |
| | 1 - 5 Years | 41.86 |
| | 5 - 10 Years | 34.88 |
| | > 10 Years | 11.63 |
| **Experience with Green Building Projects** | No Experience | 9.30 |
| | Less Experience | 25.58 |
| | Some Experience | 44.19 |
| | Experienced | 18.60 |
| | Very Experienced | 2.33 |
| **Respondent's overall idea regarding the Green Building Concept is implemented in Western Province** | Extremely Low | 11.63 |
| | Low | 34.88 |
| | Average | 30.23 |
| | High | 20.93 |
| | Extremely High | 2.33 |

The relative importance index (RII) was used to analyze quantitative data collected from the questionnaire survey. RII is a well-known statistical technique used to rank and assess the relative importance of several qualities (Wilfred and Sharafudeen 2015). Based on their RIIs, which were determined using Equation 01, the hurdles to applying the sustainable piling building technique that have a substantial impact on the Sri Lankan construction sector were identified. The impact of each barrier group with RII values as Very High (RII > 0.8), High (RII 0.8-0.6), Average (RII -0.6-0.4), and Less (RII 0.4), according to Khaleel and Nassar (2018).

$$\text{RII} = \Sigma Wn / (A*N)$$

W- Rating of each factor given by the respondent,
n - Frequency of the responses,
N - Total number of responses,
A - Highest weight.

RII values for Environmental consideration of green building concept have calculated as shown below.

Table II: Environmental consideration of green building concept

| Environmental consideration of green building concept | | | | | |
|---|---|---|---|---|---|
| Question | 1 (Extremely Low) | 2 (Low) | 3 (Moderate) | 4 (High) | 5 (Extremely High) |
| Does the Green Concept conserve environmental resources? | 2 | 4 | 15 | 11 | 11 |
| How does green building contribute to environmental sustainability? | 1 | 2 | 8 | 15 | 17 |

Table III: RII Calculation

| 1 x 1 | 2 x 2 | 3 x 3 | 4 x 4 | 5 x 5 | Total | A | N | A x N | RII (Total/A x N) | Rank |
|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 8 | 45 | 44 | 55 | 154 | 5 | 43 | 215 | 0.716279 | 2 |
| 1 | 4 | 24 | 60 | 85 | 174 | 5 | 43 | 215 | 0.809302 | 1 |

**Research Findings & Discussion**

Analytical research findings and findings from the literature are critically compared to determine the study's importance. The following subsections explain the study's main findings.

*Awareness of Environmental and Sustainable Consideration of Green Building Concept*

The idea of green buildings is well liked all throughout the world. The development of the green building idea is greatly influenced by the damaging effects of construction on the environment. This proposal is a desperate attempt to address building-related environmental and health problems and decrease the damaging effects of the construction sector on both people and the environment. In corporate planning and performance procedures, including energy conservation, the notion of green building takes environmental and social conservation into account.

Figure 1 & 2 shows the respondents' broad knowledge of the importance of the environment and sustainability in the idea of green buildings. The degree of awareness is determined by, Extremely low, low, moderate, high, and extremely high.
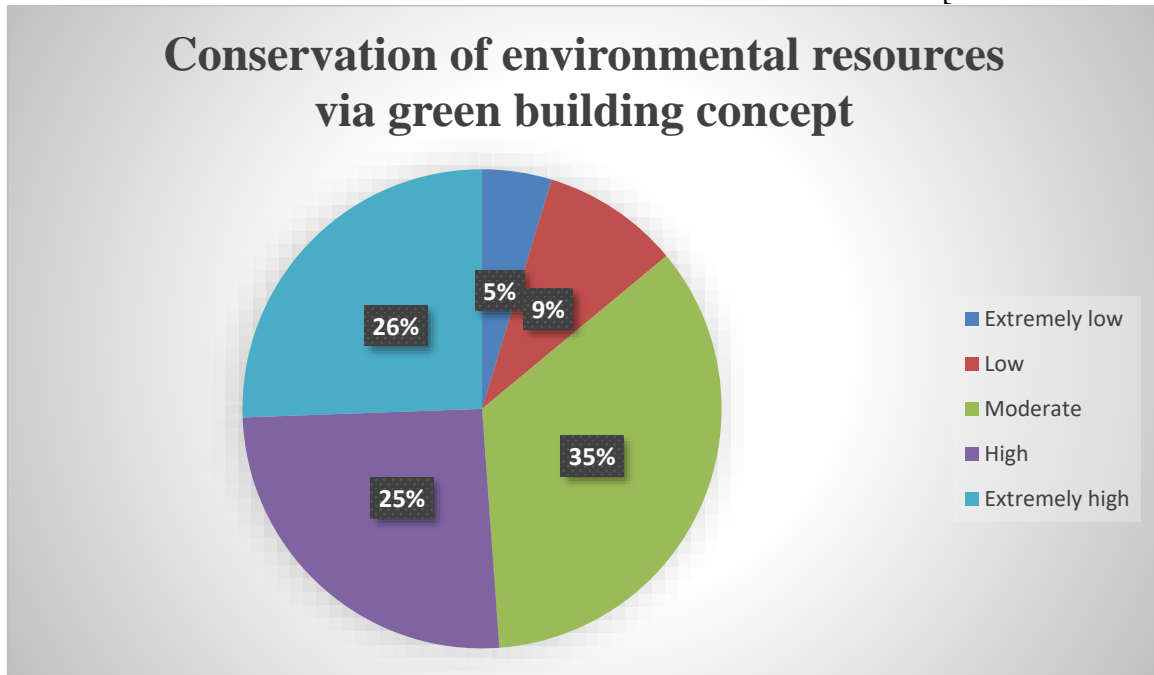
## Conservation of environmental resources via green building concept

- Extremely low
- Low
- Moderate
- High
- Extremely high

*Figure I: Awareness regarding the conservation of environmental resources via green building concept*
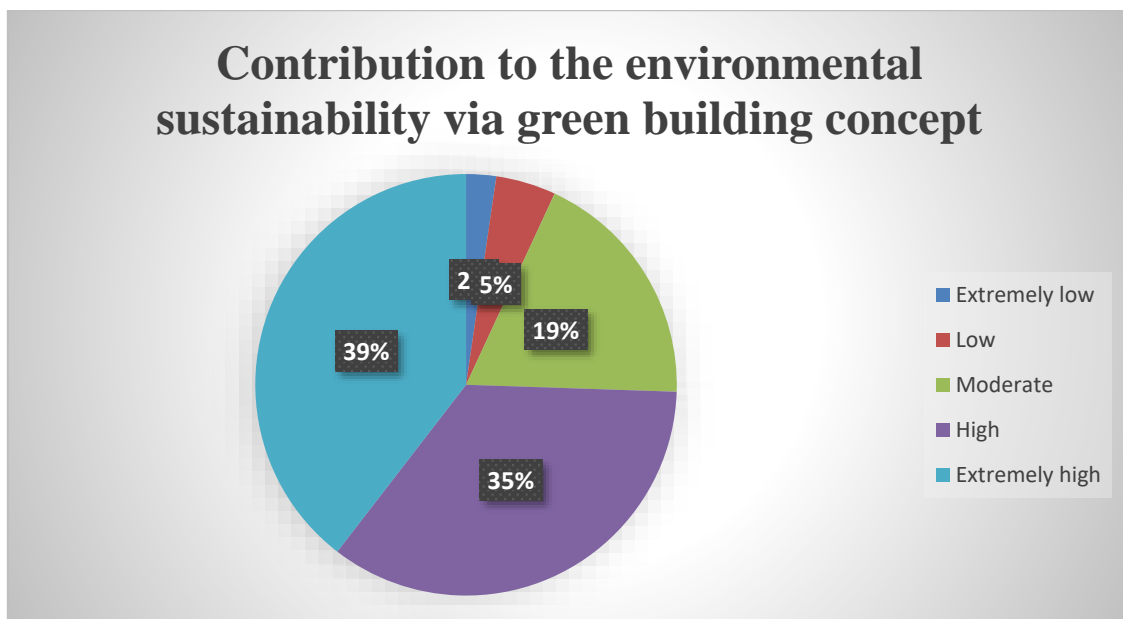


## Contribution to the environmental sustainability via green building concept

- Extremely low
- Low
- Moderate
- High
- Extremely high

*Figure II: Contribution to the environmental sustainability via green building concept*

As shown below, the respondents have mentioned that the green building concept makes a high contribution regarding the environmental consideration of green building concept.

Table IV: Table IV

| Environmental consideration of green building concept | Question | RII Value | Importance |
|---|---|---|---|
| | Does the Green Concept conserve environmental resources? | 0.716279 | 2 |
| | How does green building contribute to environmental sustainability? | 0.809302 | 1 |

***Economic Benefits and Cost of Green Building Concept***

Saving the environment also means saving money, so everyone benefits. It offers a number of economical and economic advantages. Reduced operational expenses, improved occupant productivity, and lower utility expenditures for tenants are a few of them. Additionally, it improves earnings and return on assets thanks to operational cost savings. Finally, because green buildings are constructed using sustainable materials, they require less upkeep, which raises the value of the building. Figure 3 & 4 shows the respondents' broad knowledge of the economic benefits and cost in the idea of green buildings. The degree of awareness is determined by, extremely low, low, moderate, high, and extremely high.
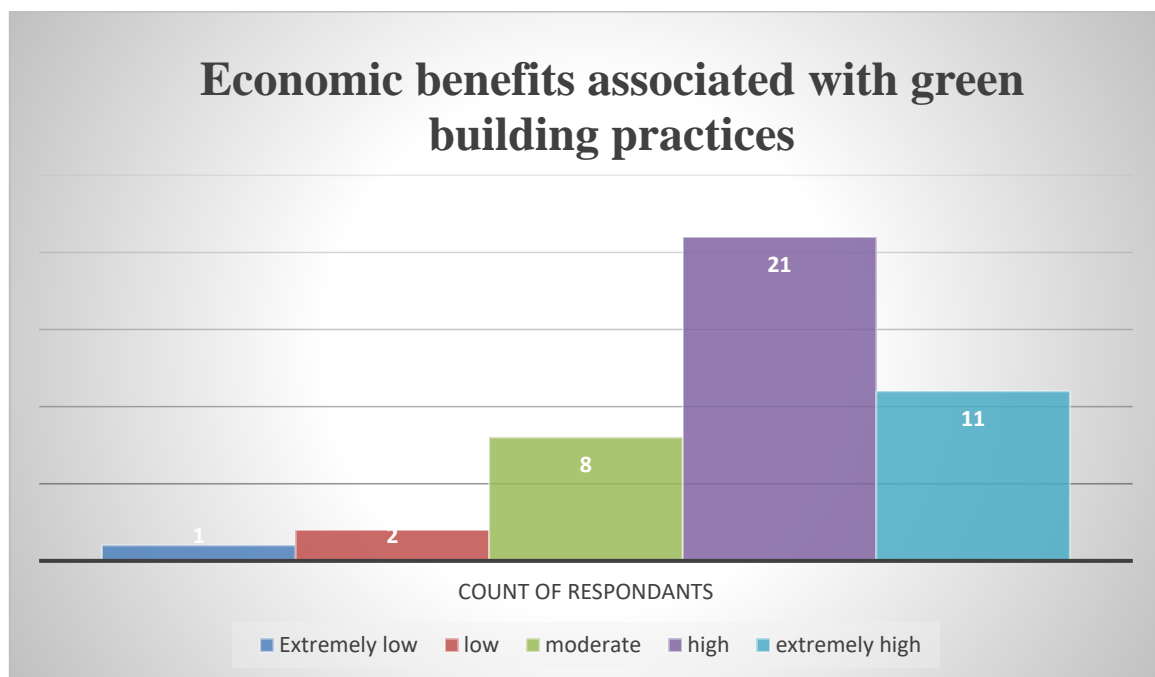


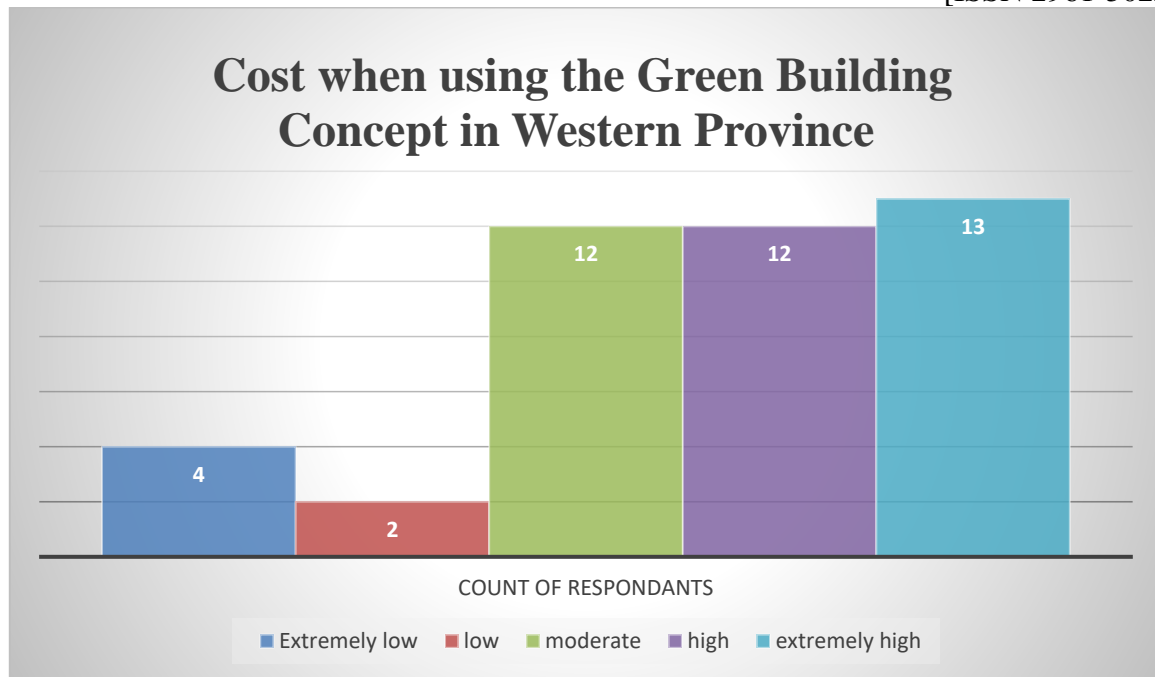*Figure III: Economic benefits associated with green building practices*

*Figure IV: Cost when using the green building concept in western province*

As shown below, the respondents have mentioned that the green building concept makes a high contribution to economic benefits and cost.

Table V: Table V

| | Question | RII Value | Importance |
|---|---|---|---|
| **Economic benefits and cost of green building concept** | Are there, economic benefits associated with green building practices? | 0.781395 | 1 |
| | On your opinion, how about the cost when using the Green Building Concept in Western Province? | 0.730233 | 2 |

***Challenges That Construction Works Face When Developing Green Building Concepts for Buildings in Western Province***

If successful implementation of green construction is to be achieved, it is imperative to address the following issues: the maintainability problems associated with green building components; the limited availability of site workers with green building skills; the increasingly expensive nature of green building materials; and the lack of relevant technology for capacity development. For the green building idea to be effectively adopted in construction, the issues must be dealt with and eliminated.
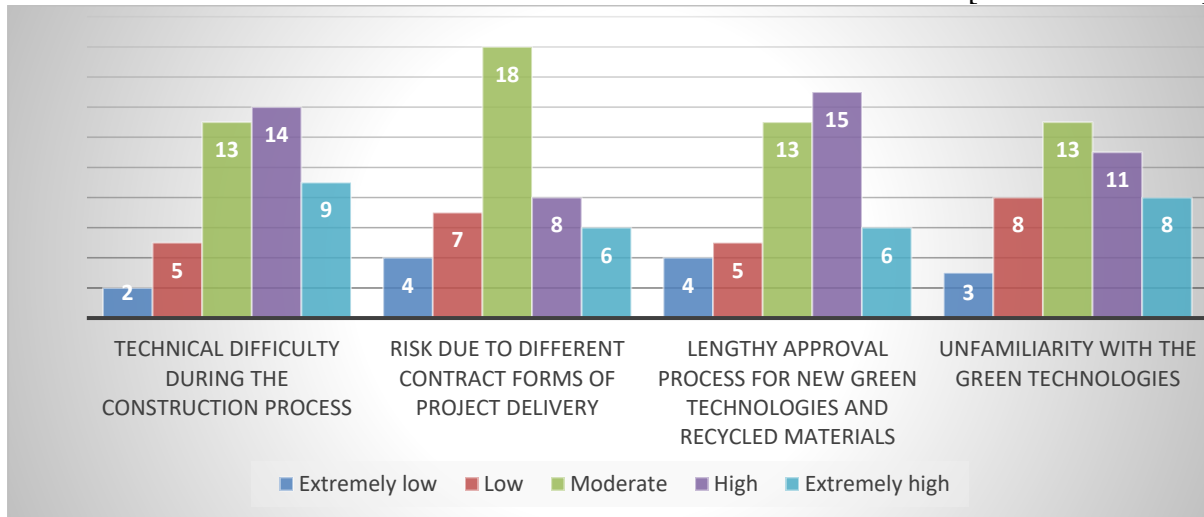
*Figure V: Challenges that construction workers face when developing green building concepts for buildings in western province*

Figure 5 shows the respondents' broad knowledge of the Challenges that construction works face when developing green building concepts for buildings in western province. The degree of awareness is determined by, extremely low, low, moderate, high, and extremely high.

Among the above challenges, 15 respondents have mentioned the lengthy approval process for new green technologies and recycled materials as a high value. Fourteen (14) respondents have mentioned the technical issues throughout the building process as a high value. Unfamiliarity with the green technologies and the risk due to different contract forms of project delivery have become as a moderate position according to the respondents' opinions.

As shown below, the respondents have mentioned that the technical issues throughout the building process makes a high contribution among the challenges that construction works face when developing green building concepts for buildings in western province.

Table VI: Table VI

| | Question | RII Value | Importance |
|---|---|---|---|
| **Challenges that construction works face when developing green building concepts for buildings in western province** | The technical issues throughout the building process. | 0.706977 | 1 |
| | The risk due to different contract forms of project delivery | 0.623256 | 4 |
| | The lengthy approval process for new green technologies and recycled materials | 0.665116 | 2 |
| | Unfamiliarity with the green technologies | 0.660465 | 3 |

*Important Requirements for Green Building Construction*

This factor has measured according to the following two questions.

1. The increased cooperation and enthusiasm that project participants must demonstrate
2. How long it takes to put green building techniques into effect on a certain location

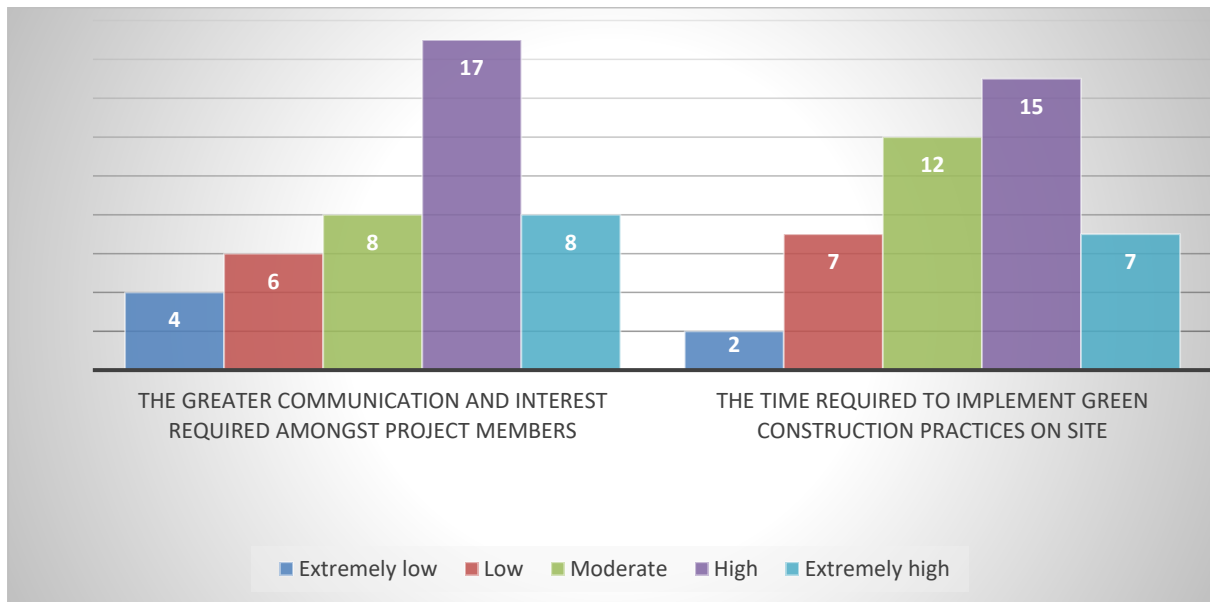The respondents have given their opinions as per following.



*Figure VI: Important requirements for green building construction*

As shown below, the respondents have mentioned that the increased cooperation and enthusiasm that project participants must demonstrate a high contribution among the Important requirements for green building construction.

Table VII: Table VII

| | Question | RII Value | Importance |
|---|---|---|---|
| **Important requirements for green building construction** | The increased cooperation and enthusiasm that project participants must demonstrate | 0.688372 | 1 |
| | How long it takes to put green building techniques into effect on a certain location | 0.683721 | 2 |

**Conclusion**

This study delves into the advantages of incorporating green building practices within Sri Lanka's thriving construction sector, drawing insights from experts. While recognizing the considerable potential for immediate and lasting benefits across social, economic, and environmental realms, the research underscores a gradual uptake and uncertain timeframes for fully realizing these advantages. The objective is to offer guidance to industry practitioners on

optimizing the positive effects of green building approaches in Sri Lanka. (Waidyasekara, 2022).

The study successfully achieved objectives, including assessing current green building practices, identifying adoption issues and success drivers, and showcasing innovative examples. Key findings emphasized the importance of integrating eco-friendly materials and practices during design and construction. Overcoming cost challenges is crucial for widespread acceptance of green building concepts.

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# AIRS' 23

## *Chapter 03:*
## ENGINEERING

# AUTONOMOUS BLOCK DETECTING PIPE ROBOT

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## Abstract

To tackle with frequent block formations in sewer pipes and to overcome the shortcoming of the current method used, a better solution is clearly in need. Hence, this research focuses on creating an autonomous wireless robot that moves through horizontal and L-bend pipeline configurations using visual technology. The main objective is to navigate and detect blocks while 3D mapping the route taken. To achieve this, hardware component of the body fabricated of arm like structures can be designed while the software set-up of the robot can be achieved using Arduino and Raspberry pi to pilot the robot through the pipeline and provide video output with 3D mapping. Once the structure and coding were completed, through testing it was possible to confirm that the robot works in both manual and auto modes while maneuvering through vertical and L-bends. Detection of blocks along with 3D mapping could also be obtained as a result.

**Keywords**: Arduino, Autonomous, 3D mapping, Visual inspection

## Introduction

Pipelines are one of the oldest and most efficient transportation methods used since early ages that are still in practice. Pipelines act as medium through which various forms of fluids can be transported depending on the density of the purpose ranging from domestic to industrial levels. In this report attention will be focused on sewer pipelines that can be seen almost everywhere to carry out a very important task. Sewer pipes aid society by moving and disposing of waste and residues coming out of houses and buildings into dump zones. Having hold of such an important task to cover, it's essential to maintain the infrastructure in an efficient functioning manner. But, in practical scenarios frequent problems of blockages arises in sewer pipes that obstruct its task of transportation, hence decreasing the overall efficiency resulting in creating problems to the society. After effects due to blocks results in the overflowing and seeping of sewer water into the surrounding areas creating an unhygienic atmosphere. This can possibly result in finally being mixed with nearby water sources harming people who use that water for cooking purposes. Therefore, the invention of a blockage detecting machine is in great necessity as a solution to problems that arise in sewer pipelines making it a valued asset.

Blockage detecting pipe robots have been introduced around the world to tackle this problem, but in some countries like Sri Lanka still manual methods of block detections are performed that includes human laboring. Therefore, it's essential to come up with an alternative to this issue which involves the invention of an automatic device that can detect blockages in pipelines via inspection, navigation, and intelligence skills.

The invention of this idea and machine can prove advantageous in numerous ways. Usually sewer pipes are found underground, so in terms of accessibility robots can do the job easily.

Using this high-tech equipment can also result in less infrastructural damage as manual methods require the breaking of walls to access the pipelines. Other serious benefits include the prevention of harm caused to workers' health due to the exposure to hazardous gases and unhealthy environment. Additionally, robots act as a cheaper and readily available substitute whenever a pipeline blockage scenario pops up. Hence the invention of this technology is of great demand in terms of both social and economic factors.

**Methodology**

The solution for the above problem can be overcome by fabricating a device that could be controlled by humans without the need for risking man labor and affecting economy. So, various research was conducted to find about similar problems in the past and how it has been tackled. Through research it was possible to review past workings by various people and organizations that included the fabrication of a robot that had the capability of overcoming the short comings of current block detecting mechanism.

Multiple resource papers, magazines and projects were reviewed in this process in order to get a clear understanding of the demanded solution. Firstly, the hardware structure of the robot was decided after a process of coming up with conceptual designs from which the best design was chosen based on accuracy, ease to work, payload and stability. Once the design was elaborated, using SolidWorks a 3D work of the structure was fabricated.
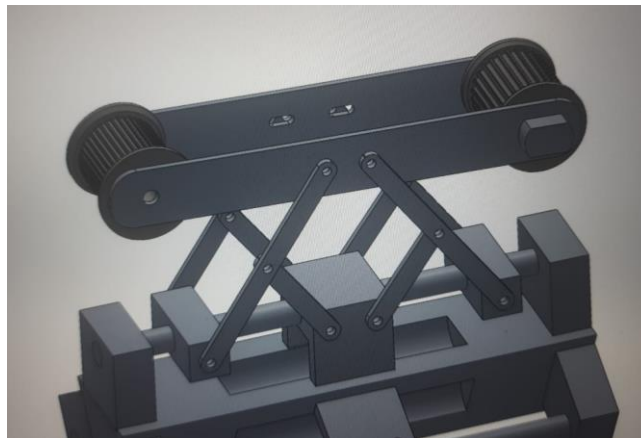


*Figure 1 : SolidWorks design*

Geared motor, motor controller, sensors, Arduino board, Raspberry pi zero, Gt2 belt and power supply was among the fixed components which had to be used to achieve the output required. Other than this, materials for the body parts were chosen considering factors like strength, durability and weight. Pulleys and stoppers for the structure was made from 3D printing using PLA material for its light weighted and strong characteristics while arms and covering were made of Epoxy sheet. Once the materials were confirmed, calculations were carried out to find the integrity of the robot. Calculations for radius, length and running duration of robot, length of belt, radius of pulley and force analysis were performed based on constraints such as pipe diameter, weight of materials and power requirements of components.

Along with this, multiple ideas for the software line up were also suggested from which the reasonable one was chosen which had the ability to satisfy the requirements. With this the circuit structure for the robot was also designed using Fritzing simulator.
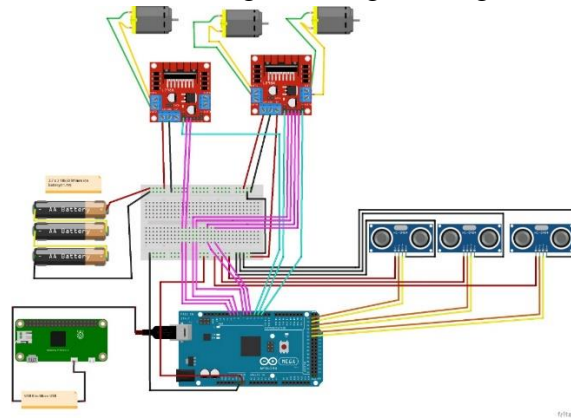


*Figure 2 : Circuit diagram*

**Results and Discussion**

*Results*

Once the hardware and software implementations were completed, testing had to be carried out. Several trials for the movement, block detecting, and visual inspections were carried out to give the below results;

Automatic operating of the robot through L-bends and vertical pipeline structures.

Successful block detection

3D mapping via python

Visual inspection through Raspberry pi



*Figure 3 : Fabricated robot*

**Discussion**

There were certain problems that cropped up during the testing part for which simple solutions were found as well.

Once the robot was fully completed and when visual inspection was carried out, it was noted that the thickness of the belt was slightly less than the flange diameter of the pulley. . This resulted in zero contact area for which to increase the belt thickness, a strip of tire rubber material with a thickness of 2mm was pasted on the Gt2 belt.
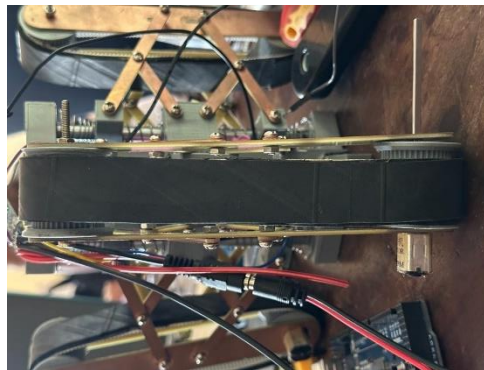


*Figure 4 : Improved belt system*

Secondly, there were problems with the spring constants as well. The tension in the springs was initially too high, which made contraction of arm linkage require more force than idealized. Therefore, pairs of springs with a lower constant value were instead used.

The stopping distance for the block detection was set to be at 10cm but practically due to jerk, slipping and frictional force of the body with pipe wall, the stopping distance wasn't accurate. Therefore, PID controller was used for a closed loop system to achieve smooth and accurate stopping distance. When tested and the results were observed, it was discovered that using proportional parameters was sufficient. the values obtained for $k_i$, and $k_d$ was zero while $k_p$ was 5.

**Conclusion and Recommendations**

*Conclusion*

The main aim and objective in this project is to build a wireless pipe inspection robot that can travel inside the pipe while detecting blockages and simultaneously mapping a 3D output of the route taken by the robot.

The idea, development, and implementation of this robot represents a significant advancement in the field of infrastructure maintenance and inspection. This project can demonstrate how robotics and wireless technologies can be used to solve pipe blockage problems in a variety of industrial and municipal situations. It reduces the requirement for labor-cost, costly manual operations and affect effect expenses caused due to damages. Furthermore, the robot's ability to operate remotely improves the inspection process safety by reducing human exposure to situations that could be hazardous.

In this project, a robot with a triangular shaped body and arms linked to it by a 120-degree angle, was designed and with the aid of Arduino and Raspberry Pi  which can moved inside an

8-inch diameter pipe while detecting blockages. As for the limitations, the pipe has a fixed friction value because of the calculation purposes and the robot will only move in horizontal and L-bend pipes.

## Recommendations

However, this study also pointed out areas that still needed improvements including strengthening the robot's adaptability to various pipe sizes and materials, extending its battery life for longer operations, and maximizing its data processing powers. Maximizing the robot's utility and economic potential will depend on addressing these issues in later versions.

Stronger body to carry power supply for extended battery life

Future research in this robot will aim for a self-checking system, an improved or more stabilized belt drive system, and a pressure sensing unit attached to it to find out if the robot is stuck.

Ability to travel through T bends with advanced programming techniques Infusing the robot to be waterproof to travel through wet terrains.

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# SMART ENERGY MANAGEMENT SYSTEM FOR COST-EFFECTIVE ELECTRICITY USAGE

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## Abstract

This Itsme Energy Management System is an IoT based power consumption controlling and monitoring system. It can help the Sri Lankan households to manage their electricity bill and minimize the high-cost electricity bill. The system is also capable of tracking energy consumption in real-time and shows the information as a chart. Based on the user's budget the system can control the electricity usage within the house by using the cloud-based mobile app Blynk with NodeMCU and other sensors. To optimize power using efficiency the Blynk Cloud Android interface allows users to monitor and modify consumption habits. This report provides a roadmap for the development of a system to save energy. The Energy Management System is developed with the help of modern technology. This report provides a detailed guideline for the purpose of developing the system. It needs further development steps and procedures to build the proposed system.

**Key Words:** Smart Energy Management System, Wireless Smart Meter

## Introduction

At present Sri Lanka is facing a lot of significant challenges in the electricity sector. That is because of the critical financial and fuel crisis which the Sri Lanka is currently facing. This financial crisis has a material impact on the price increments for electricity over 66% from 2022 to 2023 (CNBC NEWS, 2023). The situation has created considerable amount of challenges in managing the electricity sector while impacting middle-class families.

This research paper will be discussing building a system specifically tailored to address the Sri Lankan economic crisis. The aim of this project is to provide a cost-effective solution for managing electricity in a budget friendly manner. Since all Sri Lankans are currently facing the critical economic crisis, the research focuses on using low-cost components readily available in the market to construct an IoT device.

This research involved conducting surveys and collecting data from people who are severely affected by the economic crisis. It clearly identified their needs and emphasized the uniqueness of this project in offering a cost-effective solution for managing energy usage during economic hardships. This practical approach to building an energy management system is designed to meet specific needs identified through this research.

The primary objectives of the Smart Energy Management System project are to offer a practical, cost-effective solution to the challenges of electricity usage and the rising costs of electricity in Sri Lanka. This system enables users to set limits on their consumption and optimize electricity usage based on established priority levels. It aids individuals in reducing and monitoring their consumption, ultimately helping them save money. Additionally, the

project discusses the tools required to develop wireless home equipment for detecting and controlling energy usage.

**Methodology**

This section highlights three Smart Energy Management System designs. Selecting option 03 is because of its low infrastructure costs and Blynk Cloud server usage. Unlike the expensive machine learning and Raspberry Pi options, this design has affordable components like NodeMCU, ZMPT101B Voltage Sensor, ACS712-30A Current Sensor, and Arduino Pro. It offers scalability, a user-friendly Blynk Cloud mobile app, and real-time energy monitoring for efficient cost management.
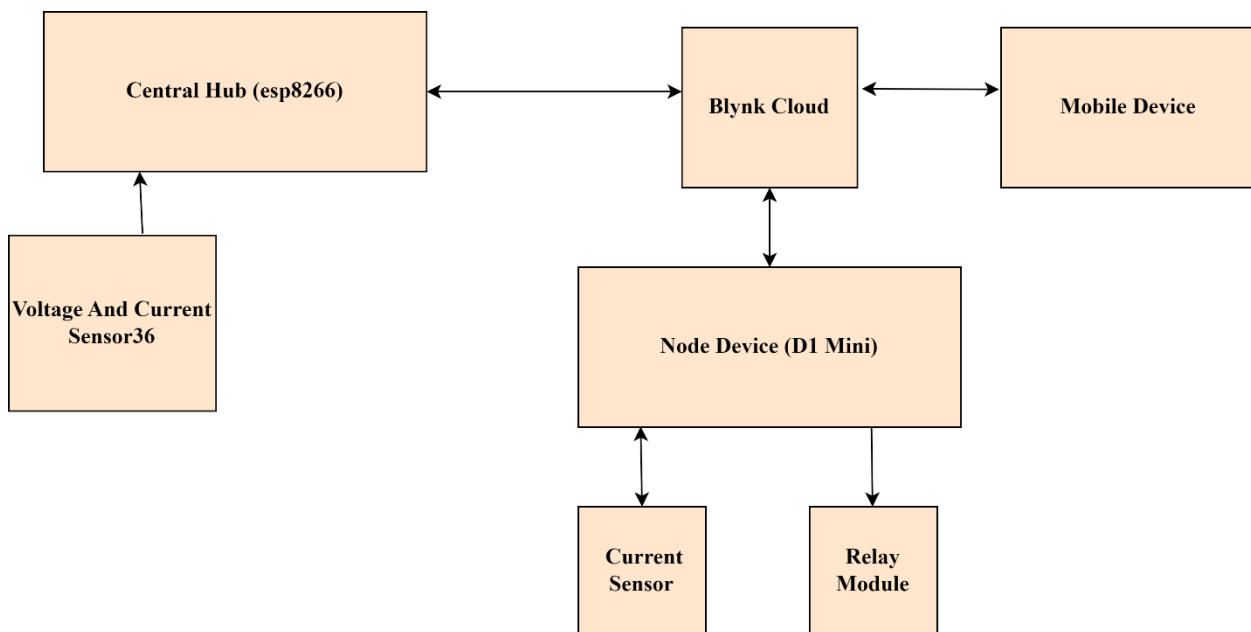


*Figure 1:Conceptual Design*

Conceptual Design No. 03 can consider as is the best and most logical solution for the Smart Energy Management System, according to the user survey and other factors.
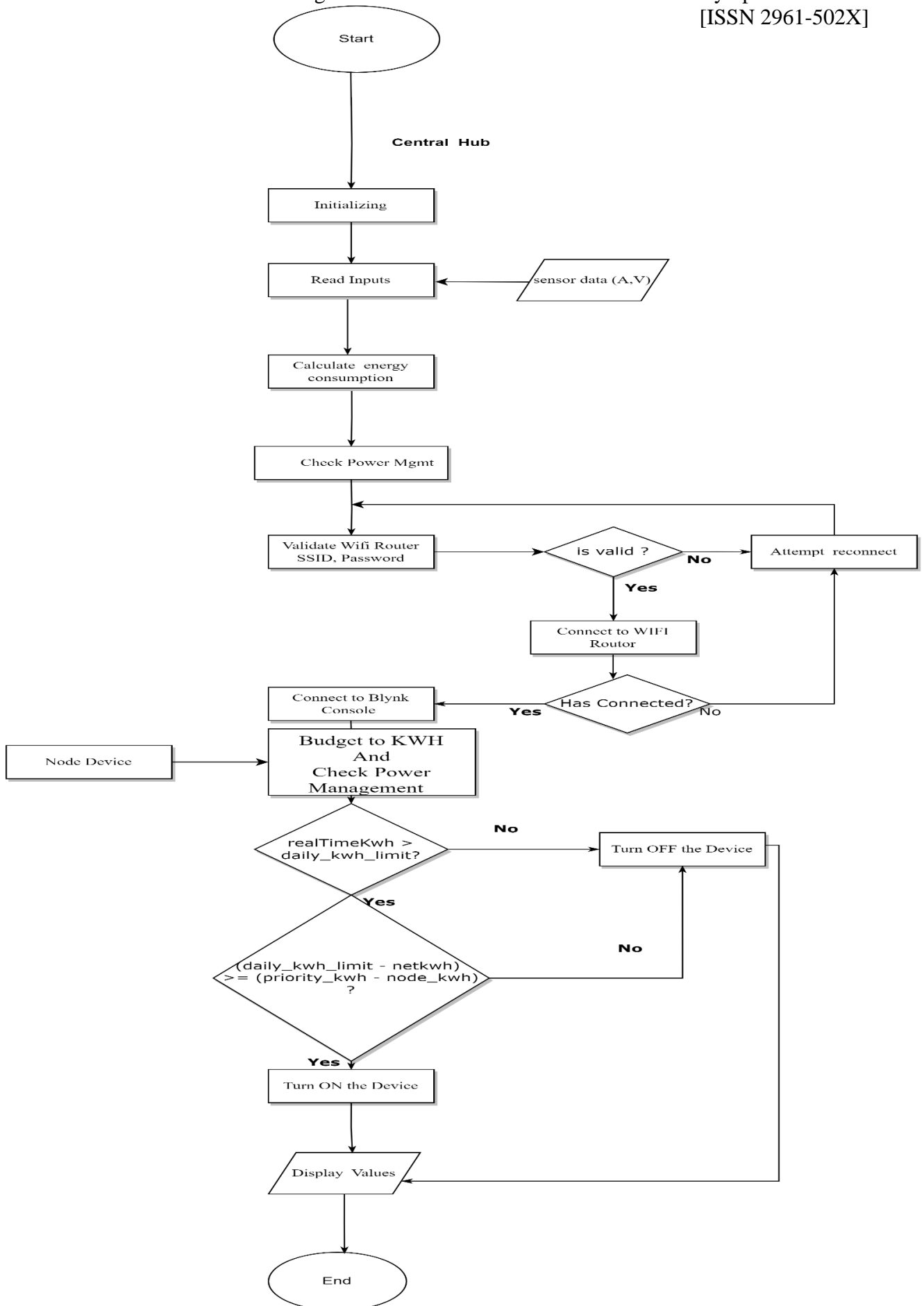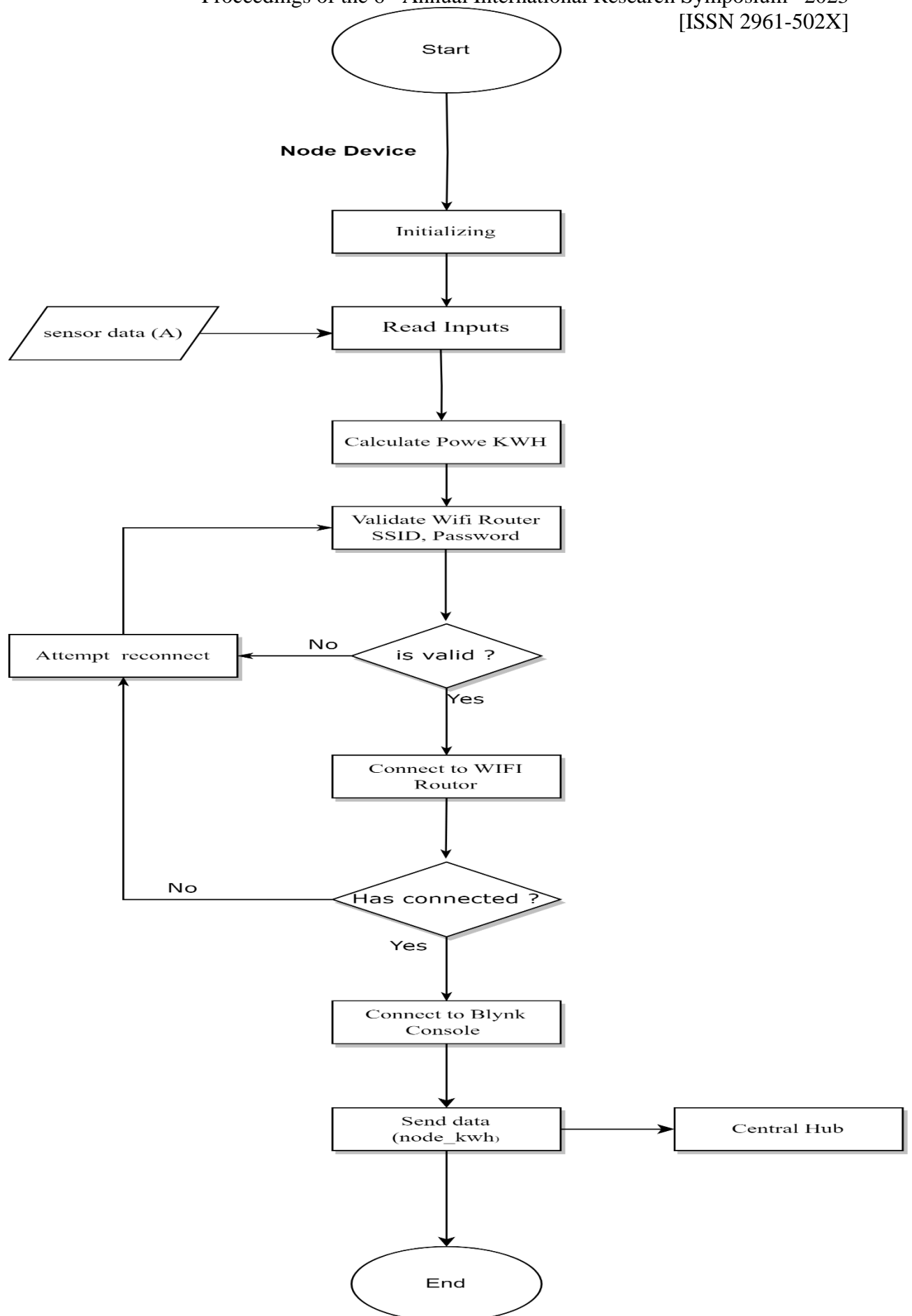
*Figure 2: Central Hub*

*Figure 3: Node Device*

*Design and Implementation*

As the Central Hub and the Node Device are the two main parts of (TAŞTAN, 2019) IoT design.
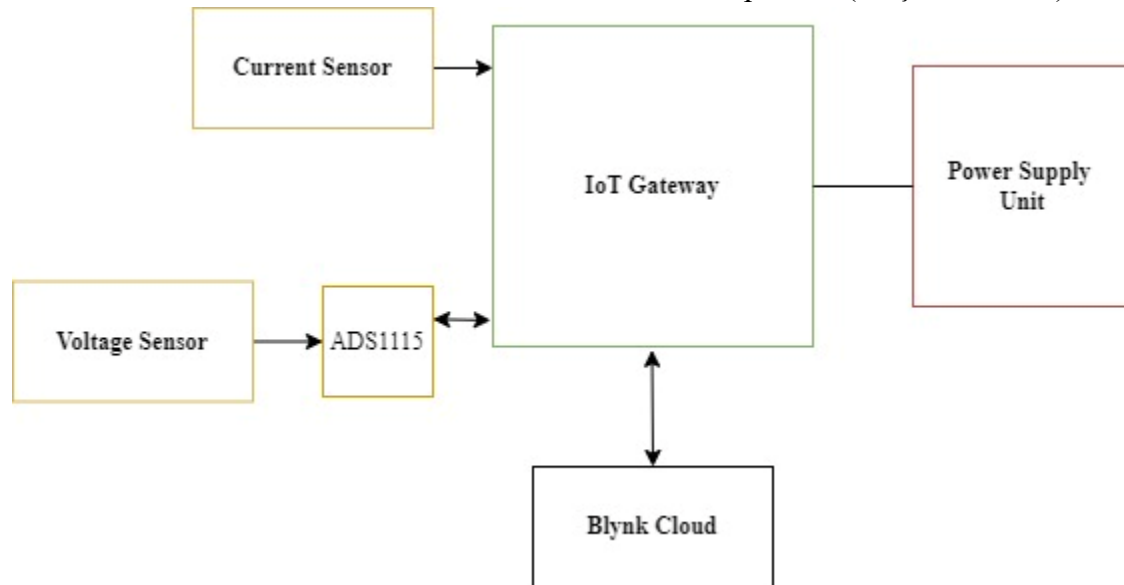


*Figure 4: Central Hub*

The Central Hub is essential for supporting communication between the Blynk Cloud and the Node Device which connects the two devices. Secondary devices are controlled and monitored by the Node Device. This setup enables real-time data access and budget input via mobile devices as well as data logging, storage and direct user communication with IoT devices.
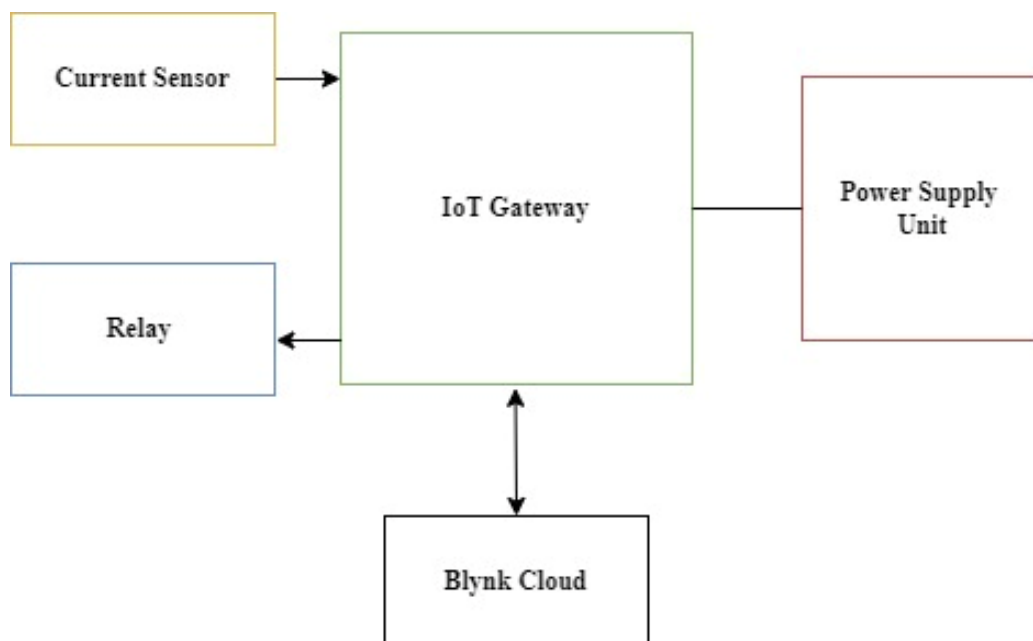


*Figure 5: Node Device*

*Interface Implementation*

With the help of "Blynk IoT" software the Blynk Cloud interface and NodeMCU combine to simplify IoT device management. It allows for monitoring and budget changes based on historical consumption data and it has DataStream and virtual pins for data sharing. It additionally displays real-time energy use and cost.

## Results and Discussion

*Interaction with Interface*

In the test cases presented shows the Itsme management interface's response and its corresponding display on the Blynk cloud interface. The data from the system is represented across multiple windows as presented in the figures provided below.
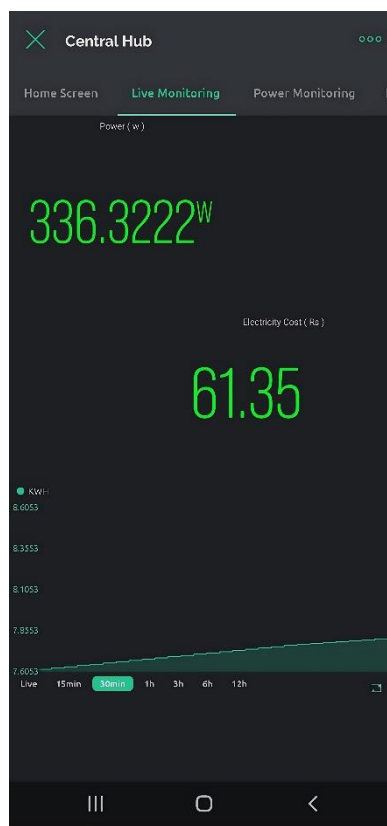


*Figure 6: Home Screen*       *Figure7: Monitoring*       *Figure 8: Power Monitoring*

To get a simple navigation with clear picture of your energy usage swipe right on the screen to view real-time data from the energy management system. This data shows current power use total cost and consumption patterns over a period of 30 minutes, an hour, 12 hours, and a day.
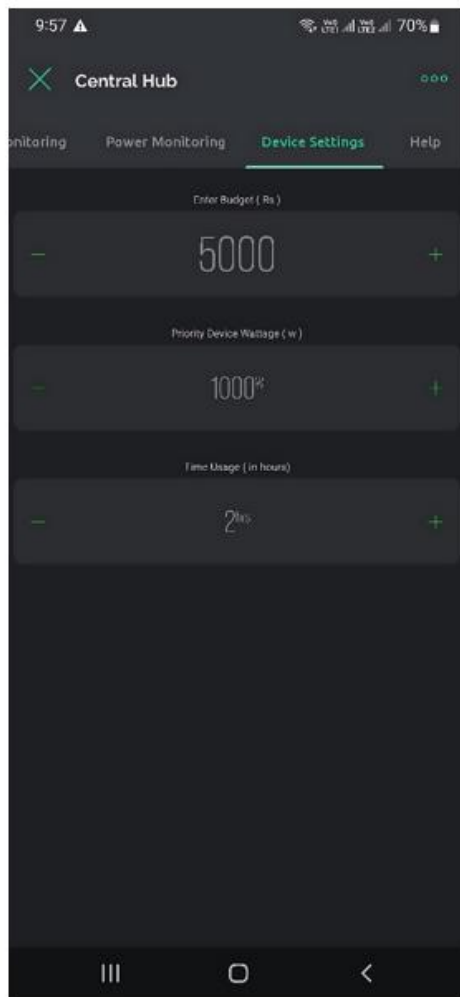
*Figure 9:Settings*



*Figure 10: Help*

## User Requirement with Cost-Saving Analysis

A user without energy management devices is shown using Figure 11. The weekly appliance usage and priority are shown in Figure 12 for Managing Bills with significant devices presented in yellow. The table uses green, blue, and orange to denote non-essential appliances showing ways to reduce electricity use. These are divided into three phases, showing that good management needs only three node devices.

*Figure 11: Without - IOT device using Bill.*

| Device | Wattage | Time Usage In Hours | | | | | | | KWH |
|---|---|---|---|---|---|---|---|---|---|
| | | Monday | Tuesday | Wednesday | Thursday | Friday | Saturday | Sunday | |
| Store Room Bulb | 11 | 2 | 2 | 2 | 2 | 2 | 4 | 4 | 0.198 |
| Living Room Bulbs | 11 | 2 | 2 | 2 | 2 | 2 | 4 | 4 | 0.198 |
| Porch Bulb | 11 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 0.308 |
| Outside Bulbs | 11 | 2 | 2 | 2 | 2 | 2 | 3 | 4 | 0.187 |
| Bedroom Bulbs | 11 | 2 | 2 | 2 | 2 | 2 | 4 | 4 | 0.198 |
| Coconut Scraper | 150 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.525 |
| Blenders | 400 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.7 |
| Laptop | 60 | 4 | 4 | 4 | 4 | 4 | 2 | 4 | 1.56 |
| Bathroom Bulb | 10 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 4 | 4 | 0.205 |
| Kitchen Bulbs | 11 | 2 | 2 | 2 | 2 | 2 | 3 | 3 | 0.176 |
| Cloth Iron | 1000 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0 | 1.8 |
| Washing Machine | 320 | 0 | 0 | 0.55 | 0 | 0.55 | 0 | 1 | 0.672 |
| Refrigerator | | 0.75714 | 0.75714286 | 0.7571429 | 0.757143 | 0.7571 | 0.75714 | 0.75714 | 0.0053 |
| Hot watter Shower | 1500 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 10.5 |
| Microwave oven | 2500 | 1 | 1 | 1 | 1 | 1 | 1.5 | 1.5 | 20 |
| AC | 3000 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 4 | 6 | 52.5 |
| Desktop PC | 700 | 1 | 1 | 1 | 1 | 1 | 1.5 | 2 | 5.95 |
| Exhaust Fan | 50 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 0.45 |
| LED TV | 60 | 1 | 1 | 1 | 1 | 1 | 2 | 4 | 0.66 |

*Figure 12: User Requirements for Managing Bills*

Node Device D3
Node Device D2
Node Device D1
Priority Device

Table 1 Node Device Manufacturing Cost

| Node Device | |
|---|---|
| Device | Cost LKR |
| WeMos D1 Min | 1000 |
| SCT-013- 030 | 2200 |
| JQC3f(T73) | 420 |
| 230 to 5v Dc | 150 |
| Total | 3770 |

Table 2 Central Hub Manufacturing Cost

| Central Hub | |
|---|---|
| Device | Cost LKR |
| ESP8266MOD | 1000 |
| SCT-013-030 | 2200 |
| ZMPT10B (230V AC) | 680 |
| ADS1115 | 650 |
| 230 to 5v Dc | 150 |
| Cloud | 1500 |
| Total | 6180 |

Table 1 and 3 shows that import restrictions increased IoT device development costs. Though component prices rose buying in bulk reduced costs by up to 45% balancing the increased cost of smaller purchases.

Table 3 Non-Priority Device energy usage

|  | Device Phase | Unit limit |
|---|---|---|
| Non-Priority Device | D1 | 4.35 |
|  | D2 | 238.24 |
|  | D3 | 30.5 |
|  | Total | 273.096 |

Table 4 Total Manufacturer Cost for this system

| Device | Cost in LKR |
|---|---|
| Three Node Device | 11310 |
| Central Hub | 6180 |
| Total project cost | 17490 |

Table 5 energy saving analysis.

| Usage condition | Unit per month | Bill per month |
|---|---|---|
| With IOT Device | 387.16 | 29,282.00 |
| Without IOT Device | 560 | 45,480.00 |
| Total Saving | 172.83 | 16,198 |

Tables 3 and 4 show the kWh usage and costs for building an IoT device and the final table highlights potential savings from managing non-priority appliances. This IoT system helps users maintain an electricity budget of Rs 29,000.00. It is by efficiently managing power consumption. Data indicates current usage without the IoT device separating both essential and non-essential appliances. The initial cost of the system is expected to be recovered in 1.5 months, potentially reducing to 1 month with bulk purchases. Calculations are based on assumptions like a refrigerator using 21 kWh in 4 weeks demonstrating the potential savings with this smart energy management system.

***Current Accuracy Calibration***

The SCT013-050 current sensor used in the energy management IoT device was evaluated against the Zoyi Zt-QB4 clamp (Lin, et al., 2021) Table 06 shows minor differences in most scenarios except for a significant discrepancy in scenario D indicating a possible measurement error.

Table 6 Clamp Vs Current Sensor Reading

| Scenario | Clamp Reading (V) | Sensor Reading (V) | Error (%) |
|----------|-------------------|--------------------|-----------|
| F | 231.2 | 230 | -1.2 |
| G | 229.1 | 227.8 | -1.3 |
| H | 230.1 | 230 | -0.1 |
| I | 234 | 233.6 | -0.4 |
| J | 235.6 | 234.4 | -1.2 |

## *Voltage Accuracy Calibration*

Inaccurate voltage readings were caused by calculation problems with the ZMPT101B sensor module (Khalid, et al., 2017)requiring the use of the Zoyi Zt-QB4 clamp for correction. Improved measuring techniques increased accuracy even small reading mistakes might have a big impact on the outcome.

## *Appliance Testing*

The user interface lights up when a non-priority appliance turns on, as Figure 01. Important parameters include a 2-hour duration a 1000W appliance and a budget of Rs 5000. The Blynk app allows for both data entry and device connectivity shown Figure 13.

Table 7 Clamp Vs Voltage Sensor Reading

| Scenario | Clamp Reading (A) | Sensor Reading (A) |
|----------|-------------------|--------------------|
| A | 4.10 | 4.15 |
| B | 2.56 | 2.49 |
| C | 3.01 | 3.01 |
| D | 6.85 | 6.01 |
| E | 5.85 | 5.04 |
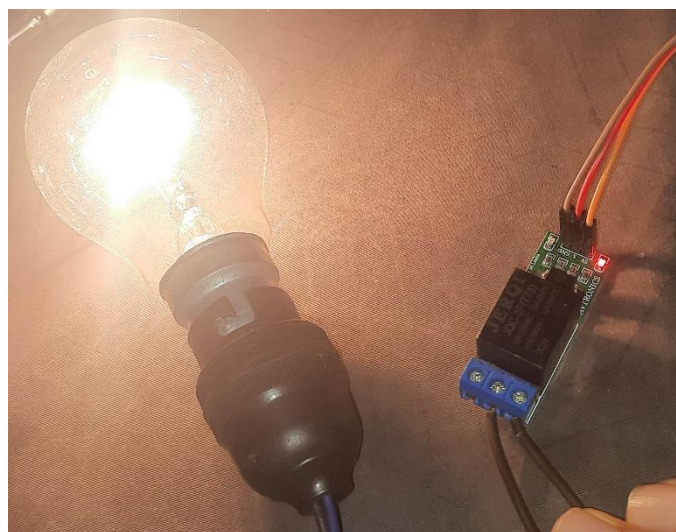


*Figure 13: Turn-on the appliance*

Figure 15 shows program verification with appliance activation via the algorithm and detailed outputs on a serial monitor. When the daily limit exceeded a signal from the central hub through the Blynk cloud turns off non-priority devices shown Figure 14.
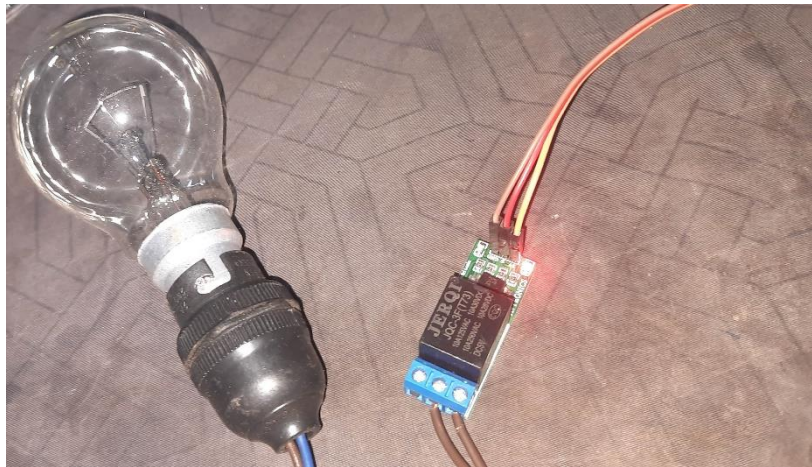


*Figure 14: turn-off the appliance*

This section shows user settings from the Blynk cloud Figure 16 including images for program verification for device settings window and central hub output Figure 15.



*Figure 15: Serial monitor output*
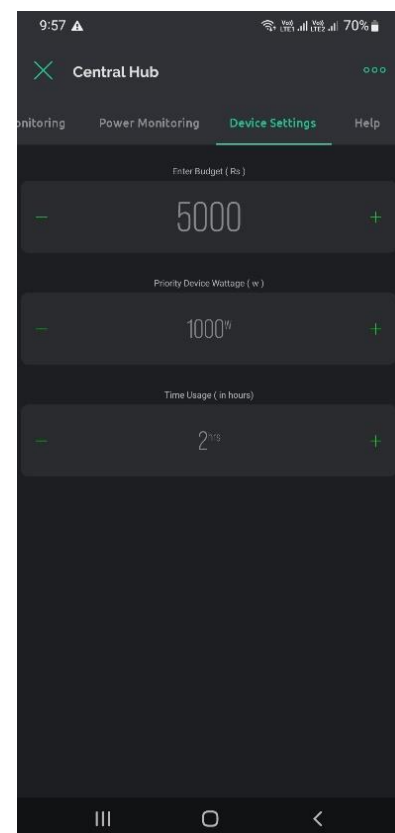


*Figure 16: Device settings*

**Conclusion**

The project successfully addressed the problem of increasing the electricity cost in Sri Lanka due to the high inflation by the development of IoT device to regulate the electricity usage in households. The project described what are the required tools and equipment. The designed system was completed by a minimum and reasonable cost by allowing to use the system by the vulnerable people in Sri Lanka. It includes the budget configuration real-time data monitoring and a mobile interface. In response to Sri Lanka's economic crisis, this research focuses on preparing an affordable IoT device for energy management using low-cost materials and addressing the needs of cost management. As a conclusion this system will play a significant role because it brings real-time expense monitoring in local households.

**Recommendations for Further Development**

For the future development of this IoT device, several further developments are recommended:
01. The scope of the device should be enhanced to handle multiple priority devices by allowing users to customize the device as they need.
02. The low-quality components of the device used due to high inflation in Sri Lanka need to be replaced with higher quality hardware items.
03. The existing relay module need to be replaced with a solid-state relay for more practical future iterations of the device.
04. Integrate the software with AI can get more advantages such as analyzing the power consumption patterns, usage of chatbots, identifying the appliance malfunctions and recommendations to do energy-saving replacements.
05. Add more languages which use in Sri Lanka as Sinhala and Tamil in addition to English.

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# LOW-COST AND PORTABLE VENTILATOR WITH PATIENT'S HEALTH MONITORING SYSTEM

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## Abstract

Due to the current economic crisis in Sri Lanka, medical equipment must be used to its maximum lifetime, and the scarcity of equipment and trained individuals in rural areas has skyrocketed. One such device that has been affected by this is the emergency ventilator, according to (Fernando, et al., 2012) only 18 ICUs (intensive care units) have 1:1 or more bed to ventilator ratio in Sri Lanka. Therefore, as an initiative, a portable and low-cost ventilator prototype that can overcome problems such as the scarcity of trained healthcare personnel via remote monitoring capabilities has developed while maximizing its efficiency and fulfilling the goal of reinforcing the healthcare sector in Sri Lanka in these rough times.

**Keywords:** Bag Valve Mask (BVM), Pulse Width Module (PWM), Tidal Volume, Heart Rate (HR), Oxygen Saturation (SpO2).

## Introduction

Ventilator machines are one of the most important biomedical devices that are used in critical care as a life-saving respiratory support. In Sri Lanka, these devices are in short supply as observed in the previous COVID-19 pandemic in smaller healthcare facilities and rural areas. To address this, there is a strong emphasis on developing affordable, low-cost, portable, and locally manufactured ventilators. This approach is not only to increase accessibility but also to solve the pressing issue of ventilator shortages in healthcare facilities, underscoring the vulnerability of the healthcare system during respiratory emergencies and the limited availability of healthcare personnel by integrating a remote monitoring system into the device. The current economic crisis is taking a toll on the healthcare sector of Sri Lanka, where there is a timely need to address these challenges through research, conceptualization, design, implementation, and testing of affordable and locally manufactured medical equipment. This prototype is an initiative for a greater cause.

## Methodology

This project comprises a mechanical ventilator prototype with a remote monitoring system. The central control unit, represented by an Arduino Uno, serves as the system's brain, processing sensor data and ensuring optimal performance. The SMPS power supply provides the necessary power for the system. A crucial element, the robotic arm, automates the operation of an AMBU bag, ensuring consistent and controlled airflow to the patient. The implementation of NEMA 23 stepper motors enhances precision and control, ensuring a smooth and steady rotation of the motor shaft. The user interface is designed with user-friendliness in mind,

incorporating push-button controls and input sensors for precise adjustments and monitoring of ventilation parameters.
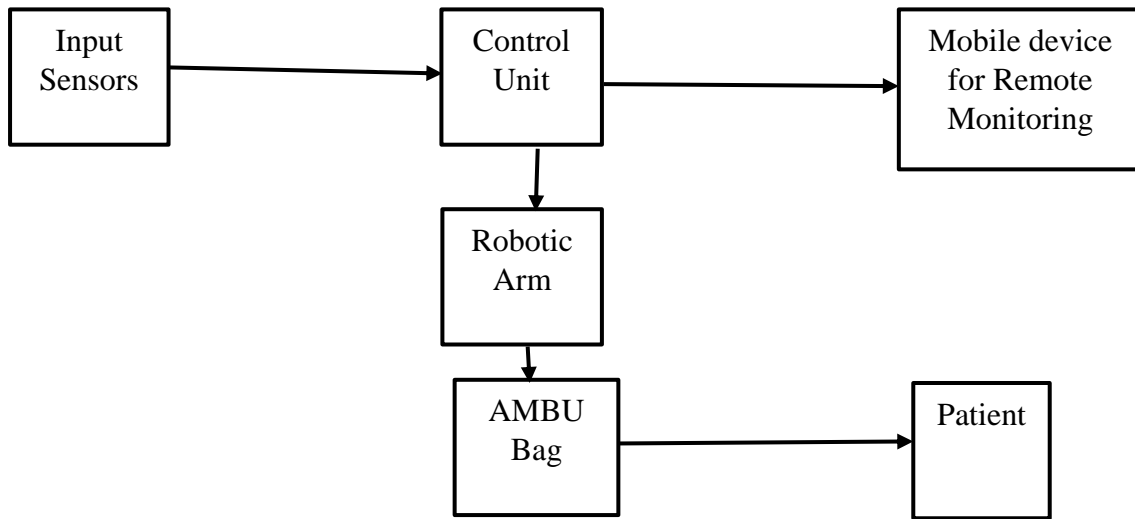


Additionally, the inclusion of an ESP32 enables remote monitoring through a dedicated mobile application, empowering healthcare professionals to monitor and adjust settings from a distance. The system also integrates data storage and safety features, highlighting a commitment to patient safety and data-driven healthcare practices.
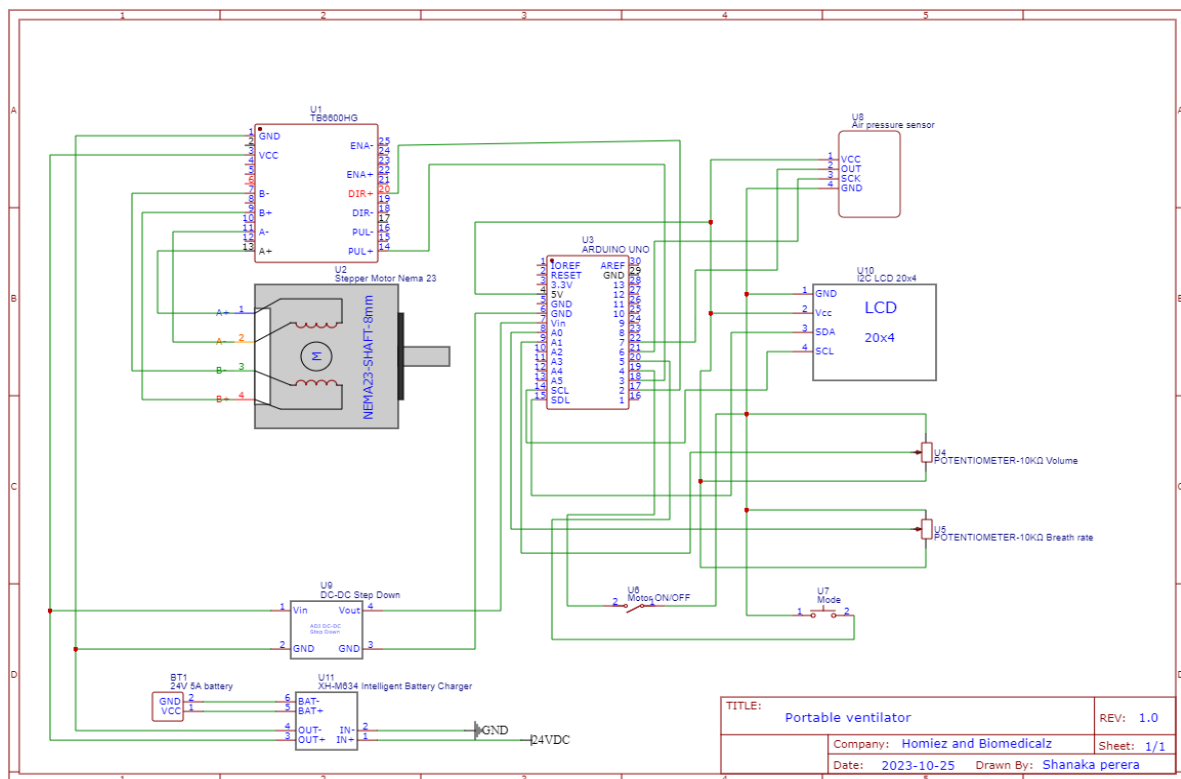


*Figure 1 : Schematic diagram for ventilator mechanical system*

This schematic diagram illustrates the complex mechanical system of the ventilator, delineating crucial components and their interconnections. Precision-engineered valves, sensors, and actuators orchestrate the airflow, showcasing the device's life-saving functionality.
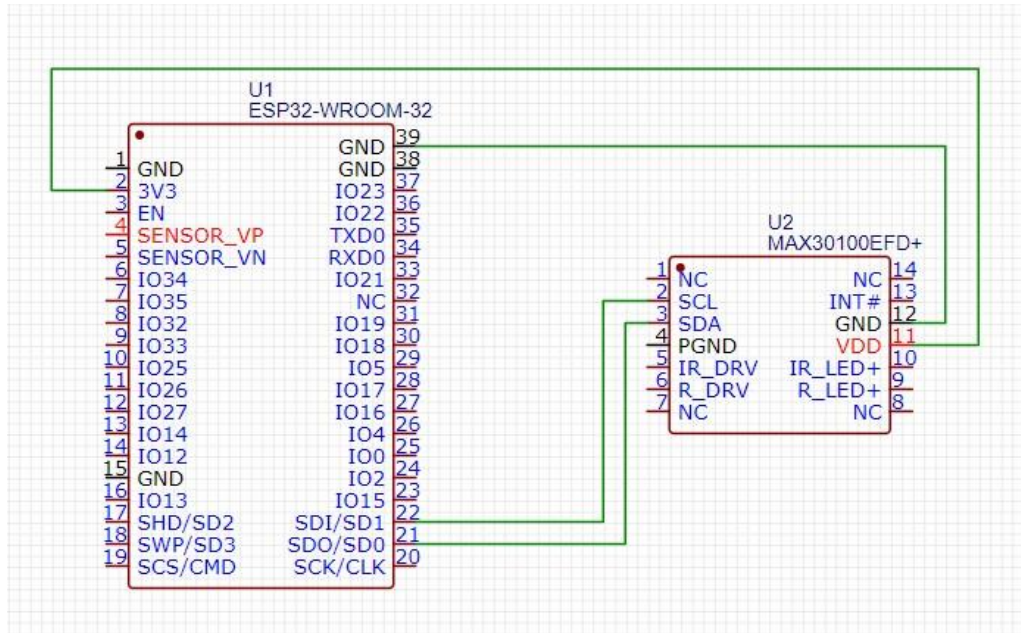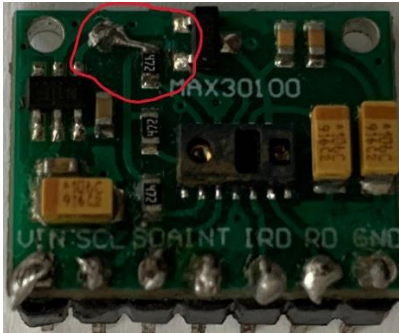


*Figure 2 : Schematic diagram for remote monitoring system*

The sensor and the ESP32 microcontroller communicate using I2C protocol, therefore the serial clock (SCL) and serial data (SDA) pins of the sensor are connected to the SD0 and SD1 of ESP32 and ground and voltage pins are connected respectively.

| Before the modification |  |
|---|---|
| After the modification |  |
| The modification |  |

MAX30100 sensor does not function properly when it's plugged into a high logic level microcontroller such as ESP32, therefore a modification has to be made as follows,

An incision in the line marked with red color must be made and two ends marked with the blue color line must be connected as shown in the modification row.

*Mechanical ventilator system*
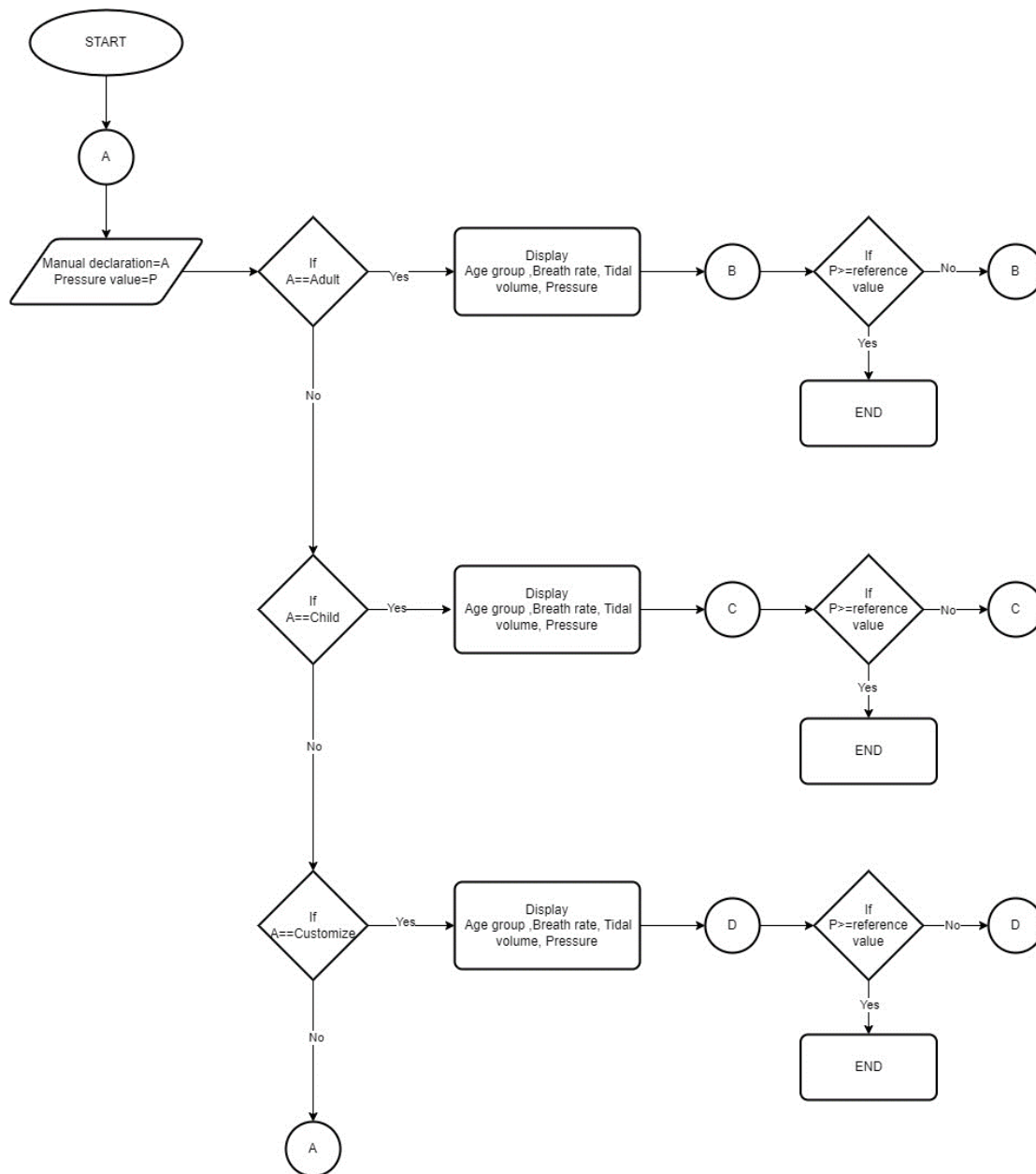


The system categorizes individuals as "Adult," "Child," or "Customize" based on age, denoted as "A." For adults, it displays age, breath rate, tidal volume, and pressure (P). If the pressure exceeds a specified reference, the motor halts. Similarly, for children, the system provides the same parameters, halting if pressure surpasses the limit. In the "Customize" setting for other age groups, the process repeats. This comprehensive approach ensures the system's safe and effective operation across diverse age ranges, prioritizing user well-being by automatically halting the motor when pressure exceeds predefined limits.

*Remote monitoring system*
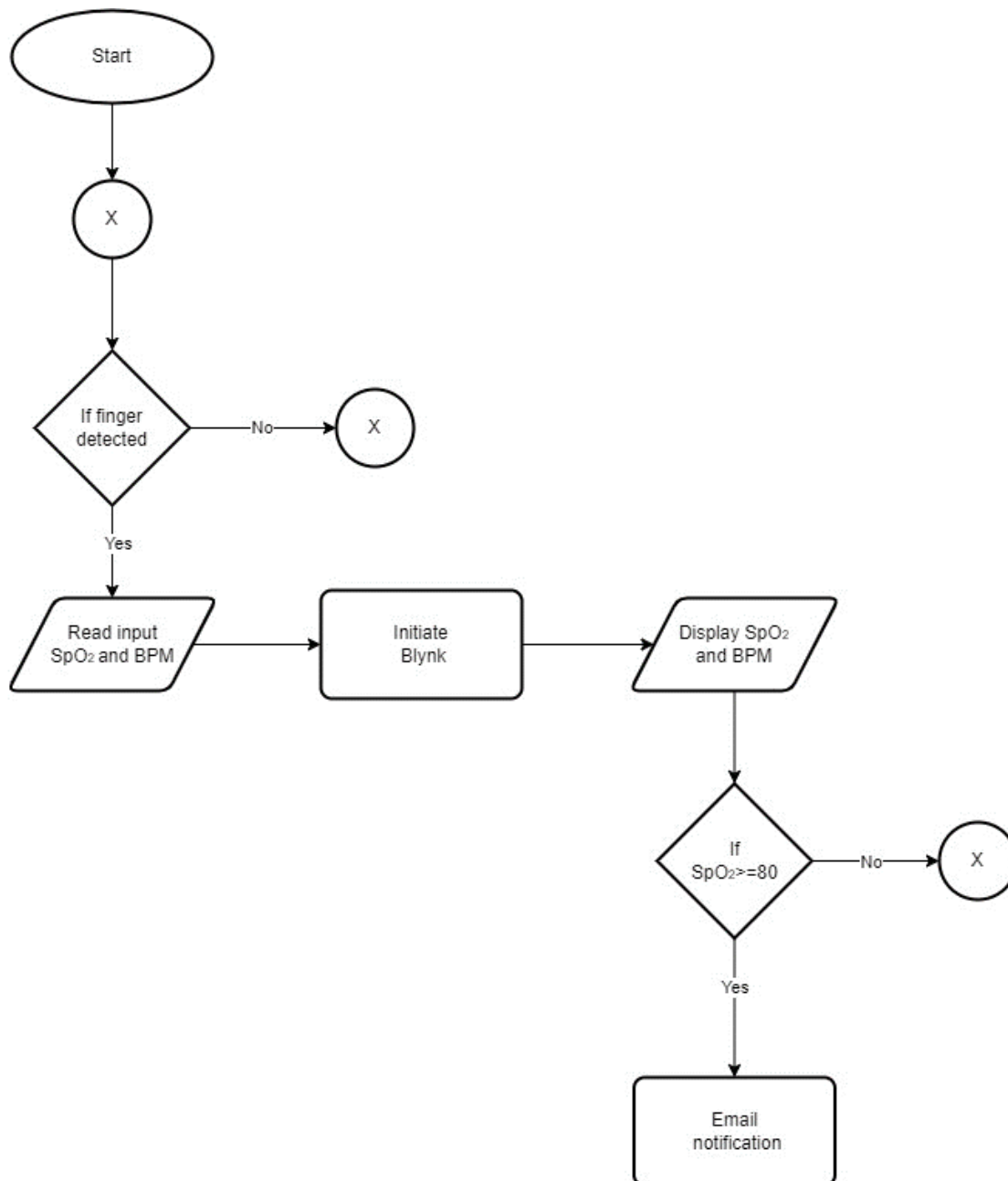


The system begins by detecting a finger and reading oxygen saturation (SpO2) and breaths per minute (BPM). If no finger is detected, the process restarts. It then initiates Blynk, an IoT platform, displaying sensor data on a smart device. If SpO2 surpasses 80, an email alert is sent to a designated recipient for immediate attention.

**Results and Discussion**

The study aims to cultivate a ventilator prototype with integrated remote monitoring, highlighting consistent tidal volume delivery and low voltage utilization.

Figure 6: Voltage consumption by the stepper motor over the time
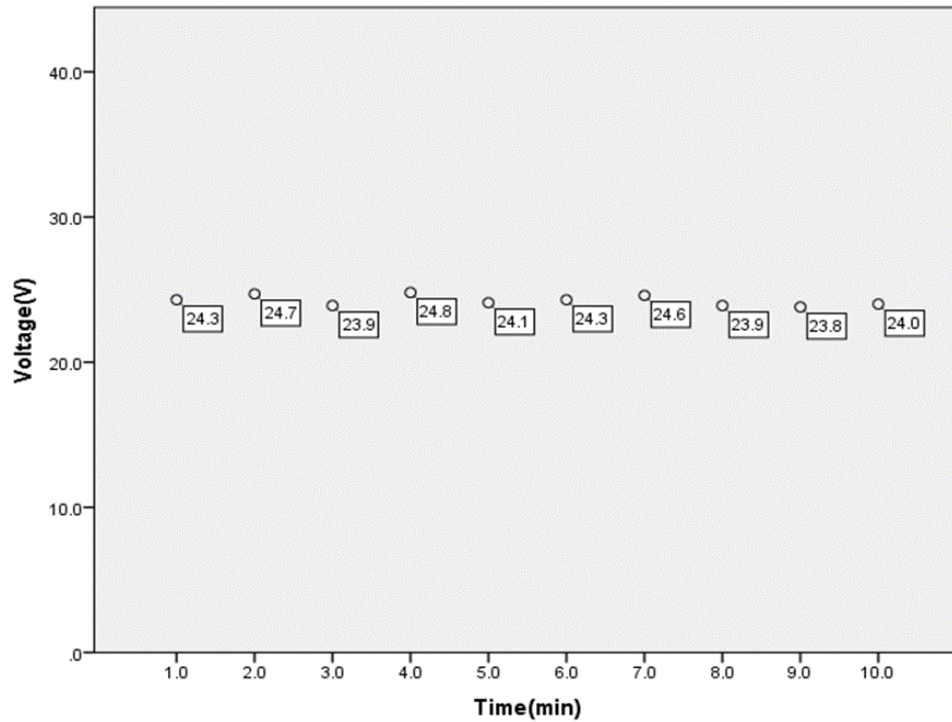
This study analyzed the input voltage of a NEMA 23 stepper motor through one- minute interval tests utilizing a multimeter. The resulting graph showcased minimal fluctuations, suggesting a steady operational condition with virtually no voltage fluctuations.
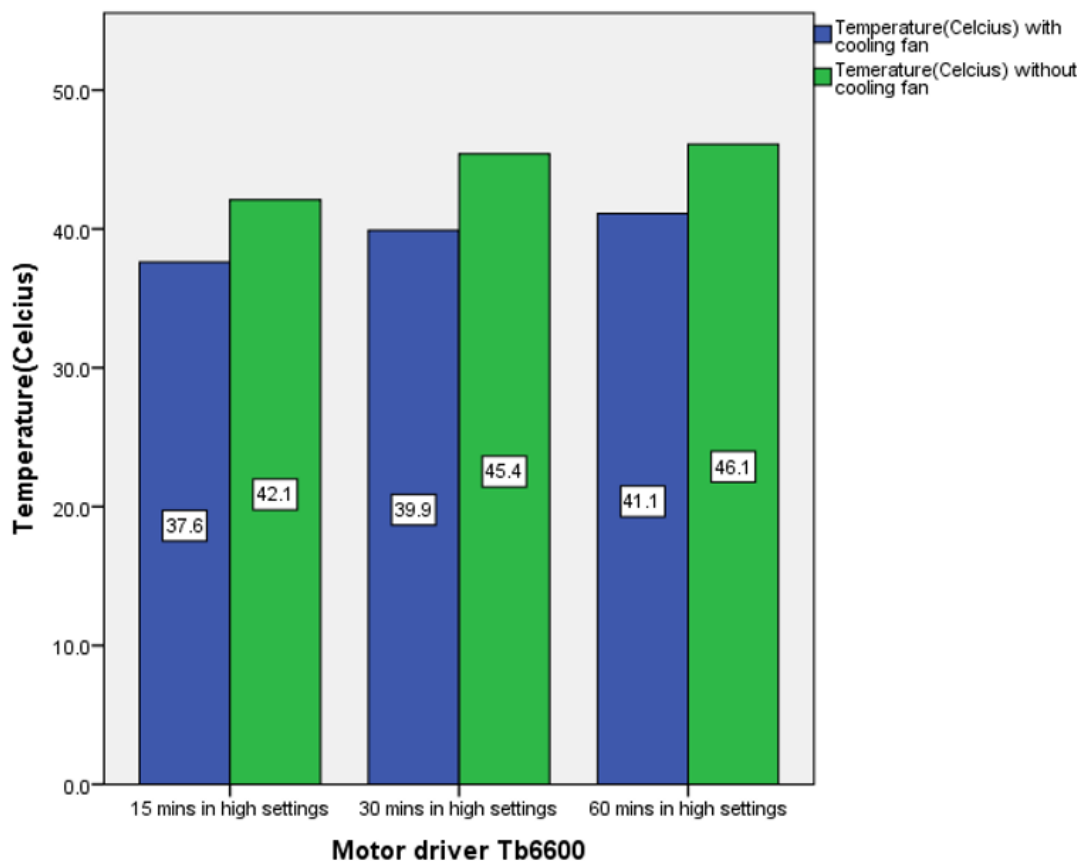


*Figure 3 : Temperature of the motor driver Tb6600*

Temperature measurements using a thermometer validated observations that the TB6600 motor driver exhibits elevated temperatures without cooling fans. Conversely, introducing cooling fans significantly reduces the TB6600 temperature. These experiments, conducted separately during different time periods, underscore the critical role of cooling mechanisms in optimizing the operational temperature and overall performance of the TB6600 motor driver. Precise temperature measurements further emphasize the importance of implementing effective cooling strategies for efficient thermal management in motor driver applications. Additionally, it shows that NEMA 23 operates efficiently without overheating when the TB6600 driver is in a cool environment.

Table 1 : Comparison of parameters between commercial models and prototype (Ding, et al., 2023), (Haque, et al., 2022)

| Parameters | Model no 1 | Model no 2 | Prototype |
|---|---|---|---|
| Tidal volume | 300ml,350ml,400ml | Normal condition- 529.47+/- 5.34ml COPD condition- 525+/-6.35ml ARDS condition- 521.53+/-4.81ml | Child-600-900ml Adult-800-1000ml Custom-600-1000ml |
| Battery back-up | 5.6h | - | 2.5h -3h |
| Portability | portable | Portable | portable |
| Remote monitoring | - | - | yes |
| Ventilator modes | 1. Pressure Regulated Volume Control (PRVC) mode. 2. Pressure Control Ventilation (PCV) mode. 3. Synchronous Intermittent Mandatory Ventilation (SIMV) mode. | 1. Volume controlled intermittent positive pressure ventilation (V-IPPV) mode 2. Pressure controlled intermittent positive pressure ventilation (P-IPPV) mode. | 1. Pressure Regulated Volume Control (PRVC) mode. 2. Pressure Control Ventilation (PCV) mode. |
| Low cost | yes | yes | yes |

| Input voltage | 12.6 V | 24V | 24 V |
|---|---|---|---|

The study used the MAX30100 sensor for pulse oximetry and heart rate monitoring (Krishnakumar, 2022), integrated with an ESP32 board. The obtained data is processed and presented graphically using BlynkIoT. This allows medical professionals to monitor SpO2 levels and heart rate, assisting adjustments to tidal volume. The NEMA 23 stepper motor, addressed by (Petsiuk, et al., 2020), functions smoothly with micro-stepping, contributing precise control. With a holding torque of 1.9Nm, proficiency, low noise, and minimal heat production, this motor is appropriate for accurate tidal volume delivery in portable ventilators. The prototype shares characteristics with prevailing ventilators.

Table 2 : Cost Analysis for the Portable ventilator Project

| Item | Price (Rs) |
|---|---|
| Nema23 stepper motor | 6000.00 |
| Arduino UNO | 1500.00 |
| TB660 stepper motor driver | 1950.00 |
| LCD 20x4 with I2C module | 950.00 |
| 3D printed arms | 2500.00 |
| Shaft and bearing | 400.00 |
| Power supply | 2000.00 |
| ESP32 | 500.00 |
| Pulse oximeter sensor | 600.00 |
| Temperature sensor | 400.00 |
| Battery charging module | 1000.00 |
| Ambu bag | 6000.00 |
| Miscellaneous | 2000.00 |
| **Total cost** | **25800.00** |

The project ensures cost-effectiveness with a budget under LKR 30000, and the utility of recycled wood in the prototype's framework aligns with the modern trend of evading plastic as a raw material, reflecting an eco-friendly approach.
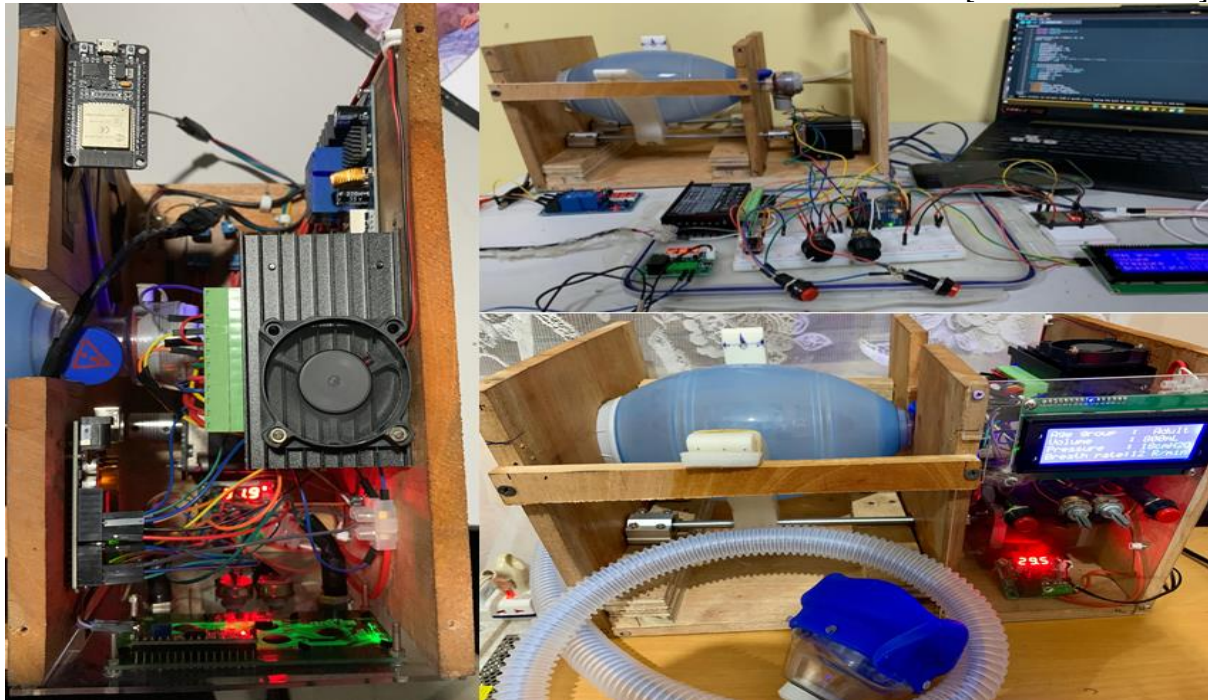
*Figure 4 : Prototype of portable ventilator with health monitoring system*

**Conclusion and Recommendations**

The development and testing of the low-cost portable ventilator prototype, featuring a remote health monitoring system and enhanced durability of the AMBU bag, mark a significant advancement in accessible healthcare solutions. In tandem with this, innovative features could further revolutionize the field. An Artificial Intelligence (AI) integrated CPR system could automate AMBU bag operations during CPR, reducing the need for two trained individuals. To cater to infants, a replaceable AMBU bag with adjustable settings could address the requirement for low tidal volume. Substituting the Blynk application with a locally developed application and an advanced notification system enhances privacy and reduces costs. Additionally, increasing battery life with a higher ampere-hour battery and utilizing multilayered PCBs for a compact design contribute to the prototype's efficiency. These advancements collectively position the ventilator prototype as a comprehensive, cutting-edge solution for affordable and accessible healthcare, especially in resource-constrained conditions. While further upgrading and testing are required to assure its safety and efficacy, this low-cost portable ventilator prototype, with its additional features, places a strong basis for evolving the field of affordable medical devices, potentially saving uncountable lives in the process.

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# UNDERSTANDING CARDIAC HEALTH IN MARATHON RUNNERS: UTILIZING ADVANCED WEARABLE TECHNOLOGY FOR REALTIME DETETION OF HEART ABNORMALITIES

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## Abstract

This research delves into monitoring heart irregularities and cardiac failure among marathon runners using advanced wearable tech. Examining the impact of prolonged strenuous exercise on cardiovascular health is crucial given the rising marathon participation. Employing wearable devices for real-time tracking during races allows precise data collection on heart rate variability and rhythm irregularities. The methodology involves participant enrollment, wearable device usage, and post-marathon evaluations to identify trends and risk factors. This study aims to fill knowledge gaps, offering insights into preventive measures and training strategies for better cardiovascular health in endurance athletes, while assessing the effectiveness of wearable tech in detecting heart issues.

**Keywords:** Biomedical wearable, Cardiac monitoring, Heart rate monitoring, Remote patient monitoring, Wearable technology

## Introduction

The relentless pursuit of human excellence in endurance sports, exemplified by the exponential growth in marathon participation, necessitates a paradigm shift in our understanding of the physiological impact on athletes. In this era of technological innovation, harnessing the power of advanced wearable technology becomes imperative to unravel the intricacies of cardiovascular dynamics during marathon running. This research embarks on a pioneering journey into the realms of engineering and biomechanics to delve deeper into the intricacies of cardiac health among marathon runners, leveraging state-of-the-art wearable devices for real-time detection of heart abnormalities. The surge in marathon participation globally underscores the need for a comprehensive exploration of the biomechanical intricacies and engineering challenges posed by prolonged strenuous exercise. Marathon runners, akin to high-performance machines, push the limits of human endurance, demanding a nuanced understanding of the intricate interplay between the cardiovascular system and the mechanical stresses imposed during each stride. This research endeavors to bridge the gap between sports science and engineering, unraveling the biomechanical intricacies that underpin the cardiovascular responses of athletes engaged in endurance activities. Biomedical wearable technology emerges as a beacon of innovation in this pursuit, with its capability to seamlessly integrate into the fabric of athletic performance. This research extends beyond the traditional scope of cardiovascular health, delving into the engineering marvels encapsulated within

wearable devices. These sophisticated devices, equipped with cutting-edge sensors and communication interfaces, afford a real-time window into the intricate biomechanics of the human body. The focus shifts from mere cardiac monitoring to a holistic exploration of the mechanical stresses, strain distribution, and biofeedback mechanisms that define the endurance athlete's journey. In this advanced exploration, the methodology transcends conventional literature reviews, delving into the engineering nuances of wearable technology. The synthesis of data involves not only the analysis of heart rate variability but extends to biomechanical data streams, encompassing gait analysis, joint kinetics, and muscle activation patterns. The wearable devices employed in this study become not just cardiovascular monitors but integral components of a biomechanical engineering framework, unraveling the mysteries of how the human body responds to the rigors of marathon running. As we venture into the engineering intricacies, it becomes pivotal to redefine the objectives of our research. Beyond the detection of heart abnormalities, our goals encompass the development of advanced algorithms for real-time biomechanical feedback, forging a symbiotic relationship between athletes and wearable devices. This research aims to create a blueprint for the next generation of wearable technology that not only identifies cardiac risks but also optimizes athletic performance by providing real-time biomechanical insights. The backdrop of our investigation delves into the profound risks and rewards associated with marathon running. The cardiovascular demands are juxtaposed against the potential for musculoskeletal injuries, prompting an engineering-centric exploration of how wearable devices can serve as preemptive tools, identifying not only cardiac irregularities but also biomechanical stressors that may lead to injuries. In this amalgamation of sports science and engineering, our research envisions wearable technology not merely as observers but as active participants in the athlete's journey. The implications extend beyond athlete safety to the realm of personalized training regimens, where biomechanical insights guide the optimization of training protocols tailored to individual responses. As we embark on this advanced exploration, the ultimate objective is to redefine the landscape of wearable technology in the context of endurance sports. Our contribution lies not just in empirical insights into cardiovascular dynamics but in laying the foundation for a new era where wearable devices seamlessly integrate with the biomechanical fabric of athletic performance, transcending traditional boundaries and propelling the understanding of human endurance to unprecedented heights.

### *Background*

According to Allison G. Yow in Sudden Cardiac Death, "sudden cardiac death is the leading cause of nontraumatic cause of death among young athletes" (Yow, et al., 2022). Matthew A. Nystoriak in Cardiovascular Effects and Benefits of Exercise has stated that "Frequent exercise is robustly associated with a decrease in cardiovascular mortality as well as the risk of developing cardiovascular disease. Physically active individuals have lower blood pressure, higher insulin sensitivity, and a more favorable plasma lipoprotein profile" (Bhatnagar, 2018). According to the article, The Impact of Excessive endurance exercise on the heart by Andrea K.Y. Lee, "The effects of long-term endurance exercise are still unclear; however, a growing body of data suggests such exercise may be harmful" (James H. O'Keefe, 2012). Long-term endurance athletes have been observed to experience functional impairment in the right

ventricle (RV) both during and after activity, as well as the occurrence of RV arrhythmias, left atrial dilation, atrial fibrillation (AF), atrial flutter, and coronary artery calcification. The same article stated that, "In preparation for these events, endurance athletes may train for several hours per day, often exceeding 300 MET hours (metabolic equivalent task hours) per week— 20 to 30 times more than the amount of exercise recommended for mortality benefit" (O'Keefe, 2012). Long-term endurance training might lead to adverse consequences, including myocardial fibrosis and atrial enlargement. However, while acknowledging these risks, it's crucial to note that moderate exercise remains highly beneficial for heart health. In the journal The cardiovascular system after exercise, Steven A. Romero stated that "some of these changes during recovery from exercise may provide insight into when the cardiovascular system has recovered from prior training and is physiologically ready for additional training stress" (Steven A. Romero, 2017). Marathon running induces transient alterations in cardiac function. According to the article Myocardial injury and ventricular dysfunction related to training levels among nonelite participants in the Boston marathon by Tomas G Neilan, "multiple studies have individually documented cardiac dysfunction and biochemical evidence of cardiac injury after endurance sports." (Tomas G. Neilan, 2006). Research indicates myocardial injury and arrhythmias during and post-races, highlighting potential cardiac stress. Anna Maria Kaleta-Duss and the crew was the first to analyze changes in novel biomarkers reflecting cardiac injury and overload in the group of male amateur runners and assessed at baseline, immediately post-marathon and two weeks after the marathon. According to the journal Myocardial Injury and Overload among Amateur Marathoners as Indicated by Changes in Concentrations of Cardiovascular Biomarkers by them, "it found as that, completing a marathon by an amateur led to an acute, significant cardiac volume and pressure overload, as indicated by significant increases in BNP, NT-proANP and GDF-15 levels." (Anna Maria Kaleta-Duss, 2020). Some cases have reported cardiac arrest. The "Sudden Cardiac Death and Endurance ET" in the journal Potential Adverse Cardiovascular Effects from Excessive Endurance Exercise by James H. O'Keefe stated about the sudden cardiac deaths of marathoners in the US over the past 35 years. (James H. O'Keefe, 2012). Despite the infrequency of such events, understanding the cardiovascular strain imposed by endurance running is crucial for participant safety and medical preparedness. Research on heart abnormalities in marathon runners aims to address the risks linked to endurance events. A study by T D Noakes says, "Physicians should not assume that "physically fit" marathon runners cannot have serious, life-threatening cardiac disease" (Noakes, 1987). This statement becomes true according to the journal Cardiovascular Damage Resulting from Chronic Excessive Endurance Exercise by James H. O'Keefe, "However, continuous running such as is required for training and participating in a marathon may be detrimental to cardiovascular health" (O'Keefe, 2012). The undetected heart conditions among athletes highlight the need for proactive monitoring. In 2011, Domenico Corrado stated that, "The primary purpose of preparticipation screening is to identify the cohort of athletes affected by unsuspected cardiovascular diseases and to prevent SCD during sports by appropriate interventions." in the article Strategies for the prevention of sudden cardiac death during sports. (Domenico Corrado, 2011). Early detection strategies are pivotal in averting adverse cardiac events during intense exertion, ensuring athlete safety.

Recent advancements in wearable technology have significantly enhanced the capability to monitor an athlete's physiological responses during exercise. In the journal Cardiac Risks Associated With Marathon Running, Sharlene M. Day has stated that, "n the Twin Cities and Marine Corps marathons, successful defibrillations were achieved within 5 minutes of collapse among 4 runners, with manually operated defibrillators and rapid response teams that included physicians, paramedics, and emergency medical technicians" (Siegel, 2023) (Sharlene M. Day, 2012). There are not just defibrillators, but many other medical devices to monitor athletes' movements and health parameters. According to a study done by Hans-Georg Predel, it says that "In addition, the clinical value of further diagnostic tools, such as cardiac biomarkers, echocardiography, and/or advanced imaging techniques remains to be clarified." (Predel, 2014). These devices, embedded with sophisticated sensors, offer real-time insights into heart rate variability, ECG patterns, and other vital metrics. Such continuous monitoring enables a comprehensive assessment of an athlete's cardiovascular health, facilitating early detection of abnormalities and optimizing. While wearable devices present an exciting opportunity for monitoring, their effectiveness in detecting nuanced cardiac changes during marathon running necessitates thorough examination. According to a study done by Selena R. Pasadyn, "The purpose of this study was to measure the accuracy of the HR monitor feature in four watches at six different treadmill speeds" (Selena R. Pasadyn, 2019). Also, the journal Accuracy of wrist-worn wearable devices for determining exercise intensity by Wei-Te Ho stated that, "In the last decade, there has been a surge in the availability of wrist-worn devices and HR monitors in the market" (Wei-Te Ho, 2022). Investigating the limitations, accuracy, and suitability of these tools in endurance events is pivotal for their reliable application in identifying potential cardiac concerns among athletes. "Pertinent caveats, such as signal quality, connectivity issues, battery life limitations, sub-optimal diagnostic accuracy and data security and storage, need to be addressed, in order to enable their full utilization as medical devices" Says Anastasia Xintarakou in the article Remote Cardiac Rhythm Monitoring in the Era of Smart Wearables: Present Assets and Future Perspectives (Anastasia Xintarakou, 2022). A comprehensive understanding of these factors will enhance the efficacy of wearable monitoring systems in safeguarding athlete health.

This comprehensive investigation seeks to amalgamate insights from sports cardiology with advancements in wearable technology. According to an article published by Monika Pobiruchin, "runners use wearable technology such as global positioning system (GPS)-enabled sport watches to track and optimize their training activities, for example, when participating in a road race event." (Monika Pobiruchin, 2017) (Justin E. Trivax, 2010) (Sharlene M. Day, 2012). The study aims to elucidate the relationship between marathon running, cardiovascular health, and the utilization of wearable devices. Another study done by Javier Lluch said that "long-distance runners and examines the differences between genders, regions (the USA and Europe), age, and performance." (Huaiming Wang, 2022) (Javier Lluch, 2023) (Sharlene M. Day, 2012). Its goal is to furnish valuable data guiding preventive strategies, training regimes, and medical interventions, thereby ensuring the safety and health of endurance athletes.
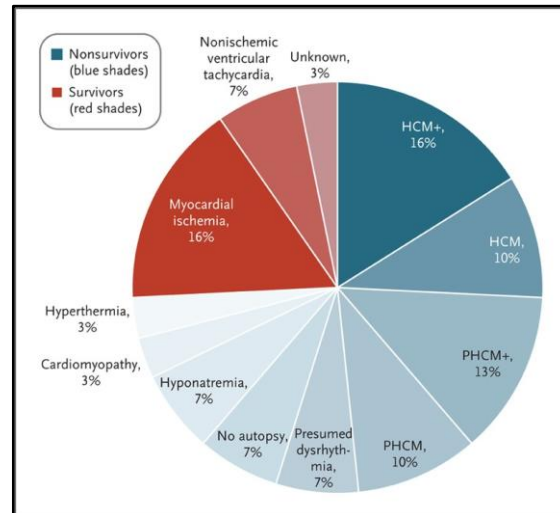
*Figure 1 : Cardiac arrest during long-distance running races*
(Resource: https://www.nejm.org/na101/home/literatum/publisher/mms/journals/content/
nejm/2012/nejm_2012.366.issue-2/nejmoa1106468/production/images/img_medium/
nejmoa1106468_f2.jpeg)

**Methodology**

The research methodology involved an extensive literature review conducted exclusively through online resources, focusing on scholarly articles and research papers. The primary objective was to gather information on marathon runners' cardiovascular health and the integration of wearable technology in monitoring their heart rates on pre-running state and during running with a specific interest in the development of a device equipped with an alert system.

The selection process commenced with the careful identification of reputable online databases and academic platforms renowned for hosting pertinent studies on marathon runners' cardiovascular health and wearable technology. A systematic search strategy, employing relevant keywords such as "marathon running," "cardiovascular health," and "wearable devices," was implemented, complemented by Boolean operators to refine the search results. Stringent inclusion criteria were applied to ensure the relevance of selected studies, emphasizing recent publication dates, specific study designs, and source credibility. Extracted data included study objectives, methodologies, key findings, and conclusions related to heart abnormalities, cardiac risks, and the role of wearable technology in marathon runners.

Thorough analysis focused on identifying patterns, trends, and gaps in the literature, with critical evaluation assessing study strengths and limitations. Emphasis was placed on gathering information related to the creation of a device with an alert system monitoring marathon runners' heart rates. All sources were meticulously documented, adhering to the specified

citation style to ensure accuracy and traceability of referenced literature throughout the review process.
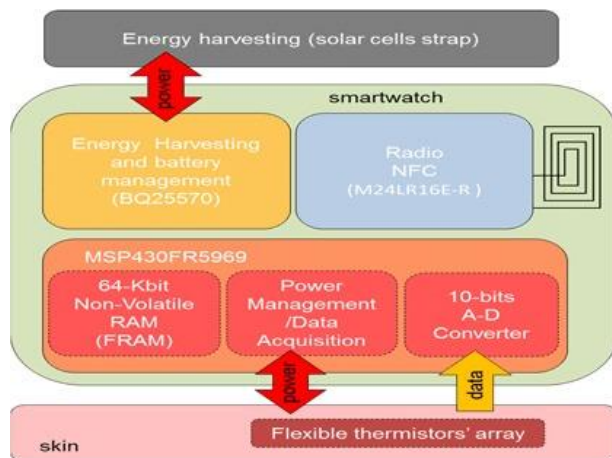


*Figure 2 : Block diagram for the proposed design*
(Resource: https://www.researchgate.net/profile/Michele-Magno/publication/309613732/figure/fig1/AS:429802814480390@1479484384958/A-block-diagram-of-the-wearable-device-which-consists-of-a-smartwatch-of-solar-cells.png)

**Results and Discussion**

Wearable thermoelectric energy harvesting stands as a revolutionary process, seamlessly converting the body's heat into electrical energy. The emphasis on mechanical aspects, crucial for engineering students, involves the intricate design of flexible thermoelectric generators. These generators, a cornerstone in this transformative process, are meticulously crafted to efficiently harness body heat.
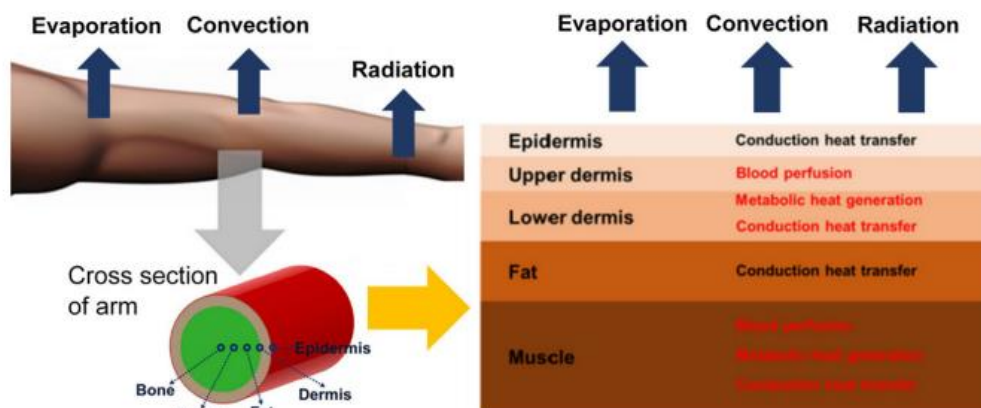


*Figure 3 : Illustration of different aspects of modeling of the human body*
(Resource : https://www.sciencedirect.com/science/article/abs/pii/S0306261919317568)
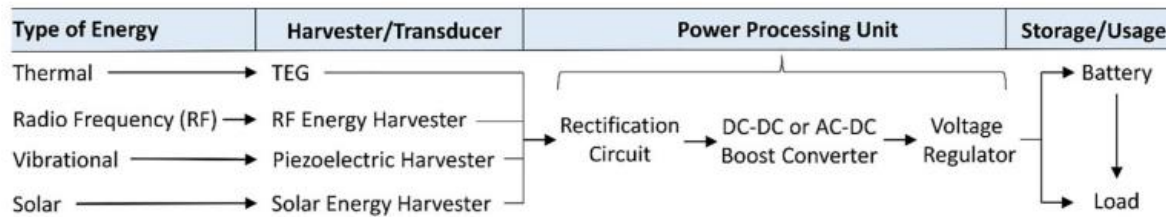
*Figure 4 : Diagram of energy harvesting system components*
(Resource : https://www.sciencedirect.com/science/article/abs/pii/S0306261919317568)

The mechanical design aspect, guided by Nozariasbmarz et al., identifies the upper arm as an optimal site for energy harvesting, emphasizing flexibility for comfort and wearability. Material selection becomes pivotal, with a delicate balance needed between flexibility, durability, and thermal conductivity for compatibility with the human body.
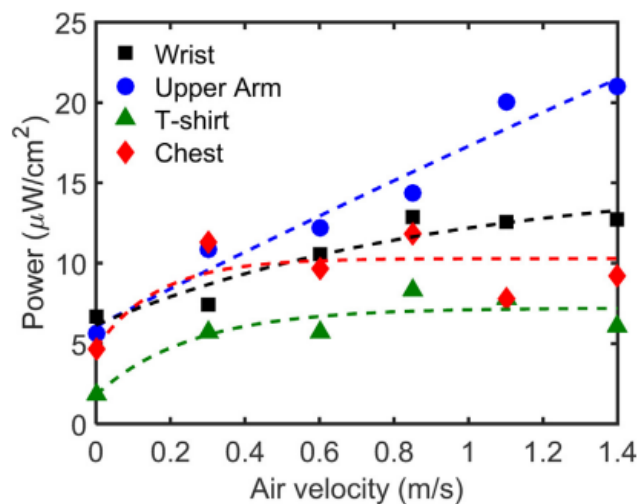


*Figure 5 : The power generated by a bulk TEG at various body locations*
(https://www.sciencedirect.com/science/article/abs/pii/S0306261919317568)

Fabrication techniques, as highlighted by Nozariasbmarz's research, play a crucial role in ensuring the mechanical integrity of wearable thermoelectric generators. Achieving high power density is underscored for effective energy harvesting. Power generation variations, influenced by mechanical properties, are evident in diverse locations such as the upper arm, wrist, chest, and T-shirt.

Integration challenges underscore the need for seamless blending of wearable thermoelectric generators into clothing, addressing mechanical stability and user comfort. Achieving optimal mechanical efficiency involves collaboration between mechanical engineers and material scientists, considering thermal conductivity and flexibility.

Shifting focus to a comprehensive marathon event analysis, wearable devices equipped with advanced sensors provide critical insights into cardiovascular dynamics and energy harvesting. Irregular heart rate patterns and diverse abnormalities, identified during different marathon phases, highlight the physiological challenges of endurance racing.

Correlation analyses establish connections between physical exertion, cardiovascular stress, and abnormal heart rates. Real-time monitoring during marathons is crucial for preemptive detection of potential cardiac risks, enhancing participant safety. These findings contribute to athlete safety, inform training methodologies, and drive advancements in wearable technology. The holistic approach integrates insights from cardiovascular dynamics with the groundbreaking work of Tabaie et al. on thermoelectric generators, placing the upper arm at the forefront for the development of wearable electronic devices designed for strenuous activities like running marathons.

**Conclusion**

This research, utilizing wearable devices, highlights the critical role of real-time data in understanding marathon runners' cardiovascular dynamics. It identified patterns of heart abnormalities, emphasizing the strain of prolonged exercise. Insights offer safety considerations for athletes, advocating proactive wearable tech use for early cardiac risk detection. Correlation analyses during marathons pave the way for enhanced device accuracy and stressor identification. This study deepens the link between endurance exercise and heart health, advocating real-time monitoring and interventions for runner well-being.

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# ENHANCING WIRELESS COMMUNICATION NETWORKS FOR FUTURE CONNECTIVITY

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**Abstract**

The way information is transmitted and accessed has changed significantly as a consequence of the growing popularity of wireless communication networks. The number of connected devices is growing rapidly, and people's desire for fast, dependable, and secure communication is growing. Therefore, improving existing wireless communication networks is essential for addressing future requirements. This analyses the opportunities and challenges which wireless communication networks currently face. In the same time, it also suggests creative solutions and improvements in technology that will improve network performance, increase connection, and assuage concerns regarding security. This study focuses into the most recent developments in wireless communication technologies in a bid to help the creation of strong and long-lasting network infrastructures that are capable of supporting the growing demands of the digital era.

**Keywords:** Connectivity, Future Technology, Network Enhancement, Wireless Communication

## Introduction

In modern society wireless communication has become a vital part of connecting people, devices and machines. With the improvement of 5G and ongoing research into 6G, the demand for faster, reliable and efficient wireless networks is ever-increasing. (Anon., 2023) This research proposal purpose to occupy the challenges and opportunities in wireless communication, focusing on improving network performance and reliability with the development of new technologies to enhance the future of connectivity among population.

The significance of the background in the research on "Enhancing Wireless Communication Networks for Future Connectivity" lies in its function as a fundamental framework that expresses the urgent need for wireless communication innovations. The research proposal aims to address the challenges and opportunities in wireless communication by developing innovative technologies. The program involves experiments to evaluate theoretical concepts and assess the practicality of proposed solutions. It includes developing and testing novel security protocols, encryption methods, dynamic spectrum allocation methods, and cognitive radio to optimize spectrum usage and mitigate interference. The proposal aligns with data analysis, technology evaluation, and literature review, introducing novel protocols, techniques, and network architectures to ensure data security, improve network performance, and meet future interaction demands. Simulation and testing phases measure the efficacy of suggested

solutions, focusing on data transmission speeds, scalability, and network reliability. The research findings provide a comprehensive overview of recommendations for implementing enhancements in real wireless communication networks.

| Performances | 5G | WIFI 6/WIFI 6E |
|---|---|---|
| Spectrum Range | Low Band, Mid Band, High Band | Mid Band |
| Spectrum Type | Licensed & unlicensed | Unlicensed |
| Data Rate MAX (theoretical) | 20 000 Mbps | 9600 Mbps |
| Reliability | 99,999% | Low |
| RAN latency | 1 ms | 2-6 ms |
| Location accuracy | < 1m | 3 to 5m |
| Device Density (Devices/km²) | 1 000 000 | Low (X00 per AP) |
| Network slicing | Y | N |
| Mobility Km/h | 500 | Unknown (range 300m) |
| Security | Simcard | WPA3 |

*Figure 1 : performance analysis*

According to the data analysis of fire cell above is the comparison of performance analysis. (Anon., 2023)

As we reach the fifth generation (5G) and beyond, the need for connectivity extends beyond supporting more quickly downloads or smoother video streaming. It additionally supports mission-critical applications, enables real-time communication in healthcare, powers smart infrastructure, and promotes innovation across various sectors. The research project looks at how advances in communication protocols, network architecture, and spectrum utilization can help lay the groundwork for the next wave of technological innovation.

This synopsis offers an in-depth look of the challenges that modern wireless communication networks face, including performance-influencing factors, security flaws, and scalability limitations. Additionally, it assesses cutting-edge technologies with a focus on mesh networks, 5G, and Wi-Fi 6, describing their advantages, disadvantages, and potential for improving user experience and network connectivity. Not only that but also proposed enhancement strategies, protocols, and network architectures to maximize efficiency and performance are presented in the summary. Experimental proof is employed for confirming the solutions, which show the extent to which they are able to improve scalability, security robustness, reliability, and data transmission speeds of network. Improved network coverage, lowered latency, higher data transfer rates, and improved data security constitute some of the performance improvement measurements.

On the other hand, increased data rates through improved spectral efficiency. Insights into the application of emerging technologies for future networks as well.
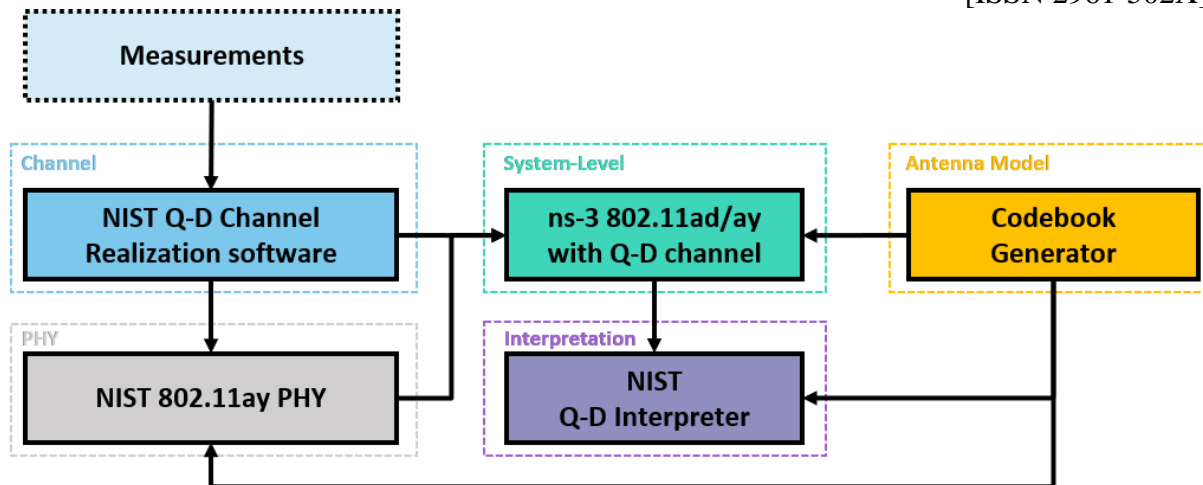
*Figure 2  future wireless connectivity*

**Methodology**

We will conduct a multi faced research programmer to full fill alleged objectives. As the very first we implement simultaneous experiment to evaluate theoretical searching and asses the practicability of proposed solutions.as well as we develop and teat novel security protocols and encryption methods to secure wireless communication from vulnerabilities and cyber-attacks .as the next step we investigate dynamic spectrum allocation methods. Likewise, cognitive radio to optimize spectrum usage and low down the interference. In the same time for the development of the proposal to enhance wireless communication networks that takes into consideration what learned from the data analysis, related to technology evaluation, and literature review. Propose novel protocols, techniques, and network architectures that ensure data security, improve network performance, and satisfy the requirements of future interaction. for the Simulation and Testing In order to assess suggested solutions and verify their efficacy for improving wireless communication network performance, making utilize of simulation tools and testing environments. Measure the effects of the suggested modifications on data transmission speeds, scalability, and reliability of networks via experiments. At last but not least Offer an overview of the main research findings and recommendations for implementing the suggested enhancements into real wireless communication networks. Discuss concerning how the research findings could influence the way networks are developed going forward and make suggestions for future research and advancement.

**Results**

While acknowledging the various issues that modern wireless communication networks face, this research explores into a thorough assessment of factors influencing performance, discovering security vulnerabilities, and overcoming scalability constraints. A comprehensive approach is taken, including a focus on cutting-edge technologies such as mesh networks, 5G, and Wi-Fi 6 in order to investigate their potential impact on user experience and total network connectivity.

The research looked at mesh networks, 5G, and Wi-Fi 6 technologies potential methods to increase wireless connectivity. Mesh networks provide resilience and flexibility, whereas 5G

provides ultra-low latency, high data speeds, and increasing device density. They nevertheless confront obstacles like as infrastructure requirements and security issues. To enhance efficiency and performance, the research offers enhancement methodologies, new protocols, and topologies for networks. (Sachdeva, 2023) Collaboration with specialists in the subject helps in the refinement of protocols and architectures. Experiment validation indicates that the solutions are practical while offering tangible benefits in a variety of network contexts. Metrics for performance improvement quantify changes and provide a practical view on the real-world impact of intended improvements. This method combines theoretical frameworks with practical industry expertise to provide actionable wireless communication network strategies.

**Discussion**

The research explores the evolving landscape of wireless communication networks, focusing on performance influencing factors, security flaws, scalability limitations, cutting-edge technologies, enhancement strategies, experimental validation, performance improvement metrics, sustainability considerations, and collaboration. Professionals can contribute insights on signal interference, bandwidth constraints, security flaws, and scalable architectures. They can also discuss the implementation of mesh networks, 5G, and Wi-Fi, and their challenges. The research also includes discussions on performance improvement metrics, sustainability considerations, and collaboration between researchers and industry practitioners. The research also highlights the importance of sustainability in minimizing the carbon footprint of wireless networks. By engaging with industry professionals, the research aims to improve network performance and security.

The discussion serves as an opportunity for integrating theoretical frameworks with practical industry expertise, encouraging a better understanding of the difficulties and opportunities in wireless communication networks. Professionals contribute a wealth of experience that can bridge the gap between research and real-world application, paving the way for a more connected, secure, and efficient future.
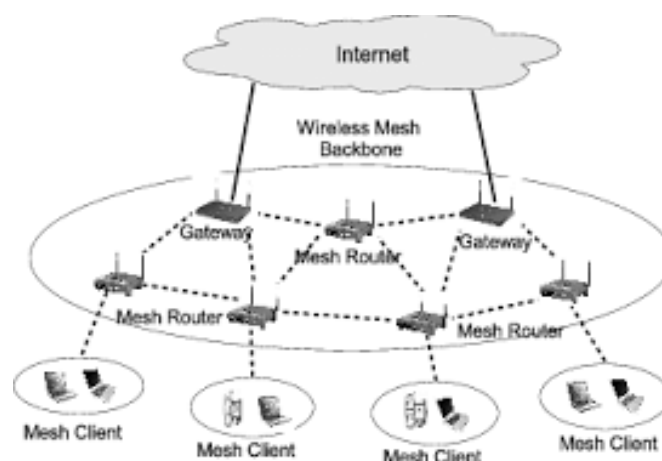


*Figure 3 wireless mesh network*

**Conclusion**

Boosting wireless networks for future connectivity has been the focus of research that has produced important insights into the opportunities, problems, and possible solutions in the field. The present research provides an in-depth comprehension of the complexities and demands associated with current wireless communication networks through an extensive review of the literature, data analysis, and technology evaluation. The research highlighted the significance it has become to have dependable and efficient network infrastructures so as to cope with the growing requirements of the digital era. Furthermore, this demonstrated an opportunity to increase security of data, reducing delay, promoting data transfer rates, and optimizing network performance through putting out new methods, protocols, and network architectures. The results of this study show how ideally suited modern technologies are to solving current problems while improving user experience and connectivity in overall. Some of these technologies include 5G, Wi-Fi 6, and mesh networks.

The potential of the proposed approaches to significantly enhance the scalability, efficiency, and reliability of wireless communication networks was validated by testing and simulations. The performance metrics which have been observed to have enhanced highlight the real-world benefits that come from implementing the suggested improvements in real-world scenarios. With the aim to promote a more combined, successful, secure digital ecosystem, it is recommended that participants in the wireless communication sector give the greatest attention to implementing the suggested strategies and technologies. The study also highlights the necessity of ongoing R&D projects to handle novel issues and take benefit of technological achievements that will enhance wireless communication networks even more.

In the final analysis, this work grows wireless communication networks and defines the foundations for a stronger and more adaptable network structure which is capable of handling foreseeable shifts in connectivity demands.

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# SMART BIN SYSTEM

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## Abstract

This research, which specifically addresses Sri Lanka, focuses on the economic feasibility and challenges of implementing smart waste management systems into practice in developing countries. The literature study looks into how technology-driven waste management solutions might be used to meet the distinct environmental and socioeconomic dynamics that are common in developing countries. Through the experiences of Sri Lankan cities and organizations, this abstract explores how smart waste management technology might be adapted while taking community involvement, economic viability, and infrastructure constraints into consideration. In the same way, the obstacles and economic viability of bringing smart waste management systems into practice in nations that are developing are the primary concerns of this study, which focuses on Sri Lanka distinctively. Investigating how technology-driven waste management solutions could be applied to address the unique environmental and socioeconomic conditions prevalent in developing nations is focused on, as well as this points out the methods to adapt smart waste management while keeping infrastructure restrictions, economic feasibility, and community involvement in mind, using the experiences of Sri Lankan cities and organizations.

**Keywords:** Economic Feasibility, Environmental Sustainability, Smart Waste Management, Waste Collection Efficiency

## Introduction

The integration of smart technology and automation has become an exciting approach to the persistent issues with sustainable garbage disposal and segregation in the constantly shifting waste management landscape. The development of an automated waste management system driven by a moveable chain connected with an image sensor is the primary aim of this undertaking. The objective of the system is to use image recognition technology to completely transform the way that waste is thrown away of. As Sri Lanka developing a more urbanized country, the increasing garbage management problem is becoming pressing problem that requires creative solutions that reduce the burden on the country's limited infrastructure. (Udayangi, n.d.) Even though there is a system in place for collecting garbage properly, the process is manual and requires human work.

The hierarchy of Sri Lanka's solid waste management is represented in the figure. As we believe that the waste management system ought to be implemented at the provincial level. (Nilanthi Jayathilake, , 2020)
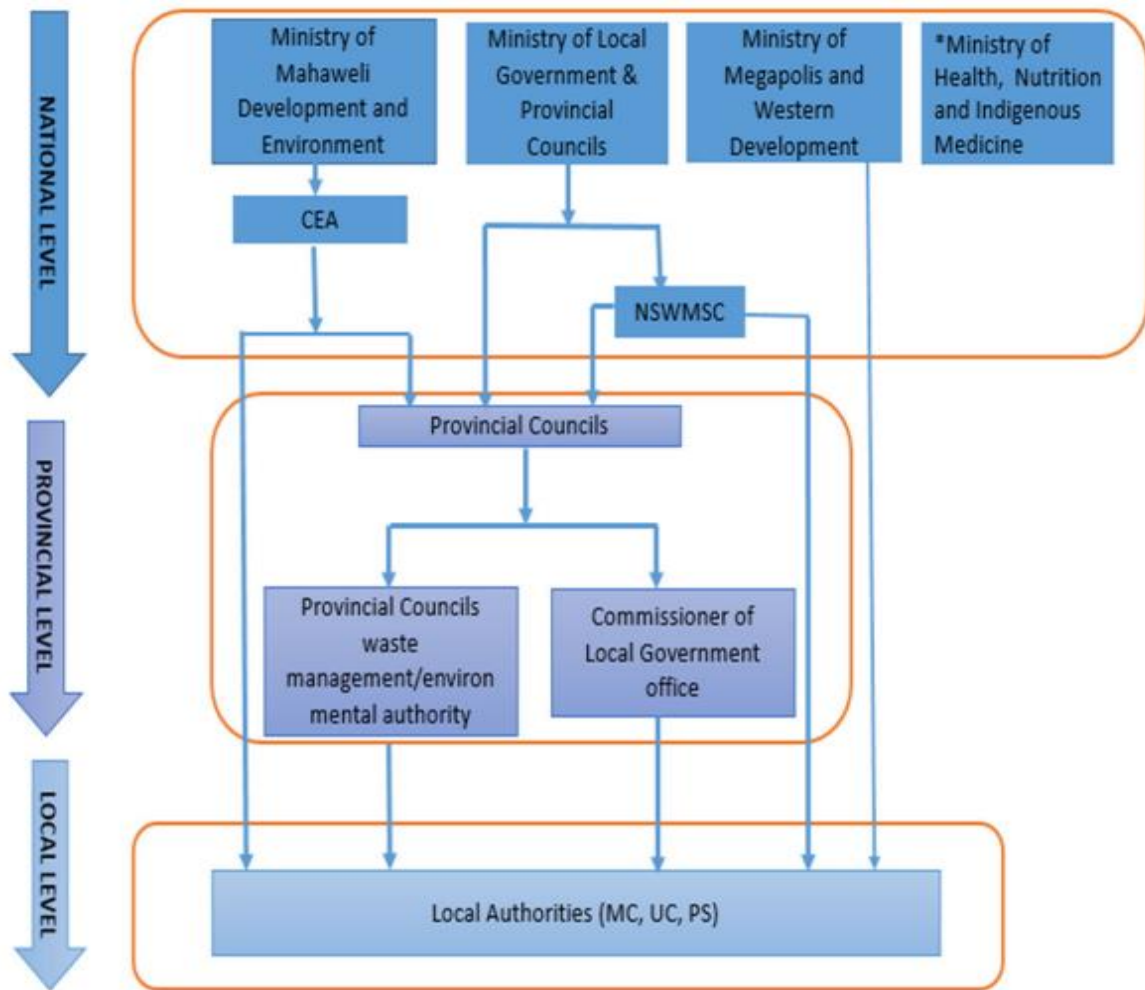
*Figure 1-Hierarchy of SWM system*

However, like other countries have found that the solution to many of the problems facing, it essential as we think to implement such system in Sri Lanka is to create an automated method for sorting those waste. Additionally, the burden on conventional waste disposal techniques has increased due to rapid urbanization and shifting consumption patterns, which has resulted in landfill overflow, environmental damage, and weakened public health. (Abdul Majeed Aslam Saja 1ORCID, 2021).

The proposed automated strategy provides an indication of opportunity for a more efficient and sustainable approach to trash management in this situation. The garbage accumulation is represented province-wise in the above image (figure 02) which gathered data from the survey on solid waste management in democratic socialist republic of Sri Lankan 2020. (Nilanthi Jayathilake, 2020)

As previously stated, we may be able separate that disposal and utilize them appropriately in a short while. The 5r concept (recycle, reuse, reduce, repurpose, and recycle). Under this research, waste materials are able to be dynamically categorized into multiple groups, such as cardboard, plastics, glass, and others. In a comparable manner enhance the waste disposal chain's mobility to ensure adaptability to Sri Lanka's dynamic urban surroundings, enabling widespread use in densely populated places with different waste disposal methods. Similarly,

enhance the waste disposal chain's mobility to ensure adaptability to Sri Lanka's dynamic urban surroundings, enabling broad implementation in highly populated places with diverse waste disposal practices. In the same way, reduce the amount of manual work required for garbage collection by utilizing automation. This will increase efficiency, protect operating costs, and lower any potential health risks related to manual waste processing.

| Data Collection Survey on Solid Waste Management in Democratic Socialist Republic of Sri Lanka | Japan International Cooperation Agency (JICA) Kokusai Kogyo Co., Ltd. |
|---|---|

Table 1-2: Thirty three (33) local authorities as survey candidates selected at the stakeholder meetings.

| No | Province | Local authority | | Waste collection amount (ton/day) | No | Province | Local authority | | Waste collection amount (ton/day) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Northern | Karachchi | PS | 6 | 18 | Uva | Badulla | MC | 28 |
| 2 | Northern | Vadamarachchi (South-West) | PS | 5 | 19 | Western | Gampaha | MC | 17 |
| 3 | North-Central | Hingurakgoda | PS | 10 | 20 | Western | Negombo | MC | 68 |
| 4 | Uva | Kataragama | PS | 8 | 21 | Western | Katunayake Seeduwa | UC | 35 |
| 5 | Southern | Hambantota | MC | 8 | 22 | Western | Kotikawatta Mulleriyawa | PS | 38 |
| 6 | Eastern | Kinniya | PS | 6 | 23 | Western | Moratuwa | MC | 85 |
| 7 | Western | Kalutara | PS | 8 | 24 | Western | Kesbewa | UC | 54 |
| 8 | North-central | Thamankaduwa | PS | 10 | 25 | Western | Kolonnawa | UC | 30 |
| 9 | Northern | Jaffna | MC | 69 | 26 | Western | Maharagama | UC | 82 |
| 10 | North-Central | Anuradhapura | MC | 25 | 27 | Western | Kaduwela | MC | 85 |
| 11 | Eastern | Trincomalee | UC | 26 | 28 | Western | Kalutara | UC | 20 |
| 12 | Eastern | Batticaloa | MC | 60 | 29 | Western | Beruwela | UC | 14 |
| 13 | North-Western | Chilaw | UC | 18 | 30 | Western | Colombo | MC | 775 |
| 14 | North-Western | Kurunegala | MC | 48 | 31 | Western | Dehiwela Mt. Lavinia | MC | 170 |
| 15 | Central | Nuwara Eliya | MC | 21 | 32 | Western | Sri Jayawardenapura Kote | MC | 100 |
| 16 | Sabaragamuwa | Kegalle | UC | 15 | 33 | Central | Kandy | MC | 130 |
| 17 | Sabaragamuwa | Rathnapura | MC | 32 | | | | | |

*Figure 2 -The garbage accumulation province vise*

**Methodology**

Accomplishing research, data collection, and the creation and testing of the suggested automated waste management system are all included in this multifaceted methodology to fully satisfy the objectives. Fundamentally with an in-depth examination of the current state of research on pollution of the environment, waste management techniques, and the difficulties involved in gathering and sorting waste and thereafter Analyze the many approaches and technologies used worldwide for the separation of trash, emphasizing automated systems and Conversely , investigate case studies from various cities in Sri Lanka as well as abroad that have successfully implemented automated waste management systems. Through doing so, we can identify best practices, challenges faced, and insights acquired from these case studies. Examine academic papers, articles, and reports to comprehend how improper disposal of waste affects the environment. On the other side, develop and distribute surveys and Google Forms

to collect information about the opinions, attitudes, and experiences of the general people about Sri Lanka's present waste management procedures.

## Results

This innovative automated trash management system that has the potential to completely transform conventional disposal methods has surfaced in the search for more environmentally friendly and efficient waste management solutions. A carefully designed system utilizing state-of-the-art technology to expedite garbage collection, classification, and segregation—with a special focus on handling the particular issues encountered in urban environments—is at the core of this invention.

This consists

- Movable Chain Conveyor and Image Recognition
- Rotating Plate with Segregation Bins
- Fill-Level Monitoring and Alarm System
- Load sensors



**1. Movable Chain Conveyor**

The system utilizes a movable chain conveyor to transport garbage efficiently and seamlessly through the waste management process.

**2. Rotating Plate with Segregation Bins**

A rotating plate with segregation bins ensures the proper classification and segregation of waste materials, optimizing recycling and disposal processes.

**3. Fill-Level Monitoring and Alarm System**

The system incorporates a fill-level monitoring and alarm system to track and manage waste levels, ensuring timely collection and preventing overflow or underutilization of waste containers.

**4. Load Sensors**

Load sensors are employed to accurately measure and manage the weight of garbage, optimizing collection routes and resource allocation.

*Figure 3 -Part of invented system*

Basically, this innovative method employs a mobile chain conveyor together with a modern image sensor to start a transformational process as soon as waste is added to the system. Real-time pictures of the eliminated waste are captured by the image sensor, and a computer-based recognition system that has been instructed to recognize patterns in the images analyzes them thoroughly using the mahlab software. With the aid of powerful machine learning algorithms, this waste recognition system efficiently sorts the waste and directs it into bins designed specifically for glass, plastics, cardboard, and general debris on a motorized revolving plate. The component that contributes to the effectiveness of the system is the dynamic sorting mechanism that the revolving plate organizes. The rotating plate automatically centers itself

around the bin that corresponds to the waste category as it is recognized, allowing for accurate sorting without a lot of manual work.

Moreover, but significantly A further level of sophistication is added by the fill-level
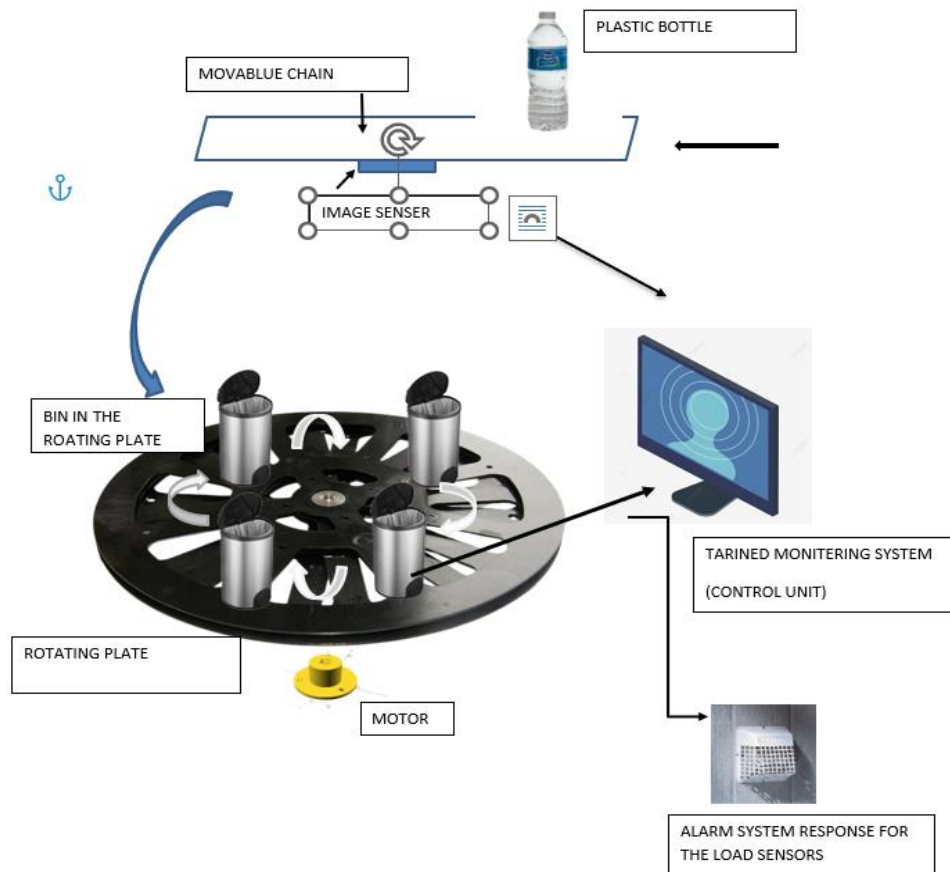


*Figure 4 - Major parts of automated system*

monitoring sensors installed in each bin in the system. These sensors monitor the filled levels of the separated garbage on a continuous basis, acting as watchful guardians. An integrated alarm system sounds a timely signal to waste management authorities when a bin gets close to its designated capacity. This proactive strategy ensures the timely departure of garbage, reduces concerns about the environment, and reduces the chance of overflow.
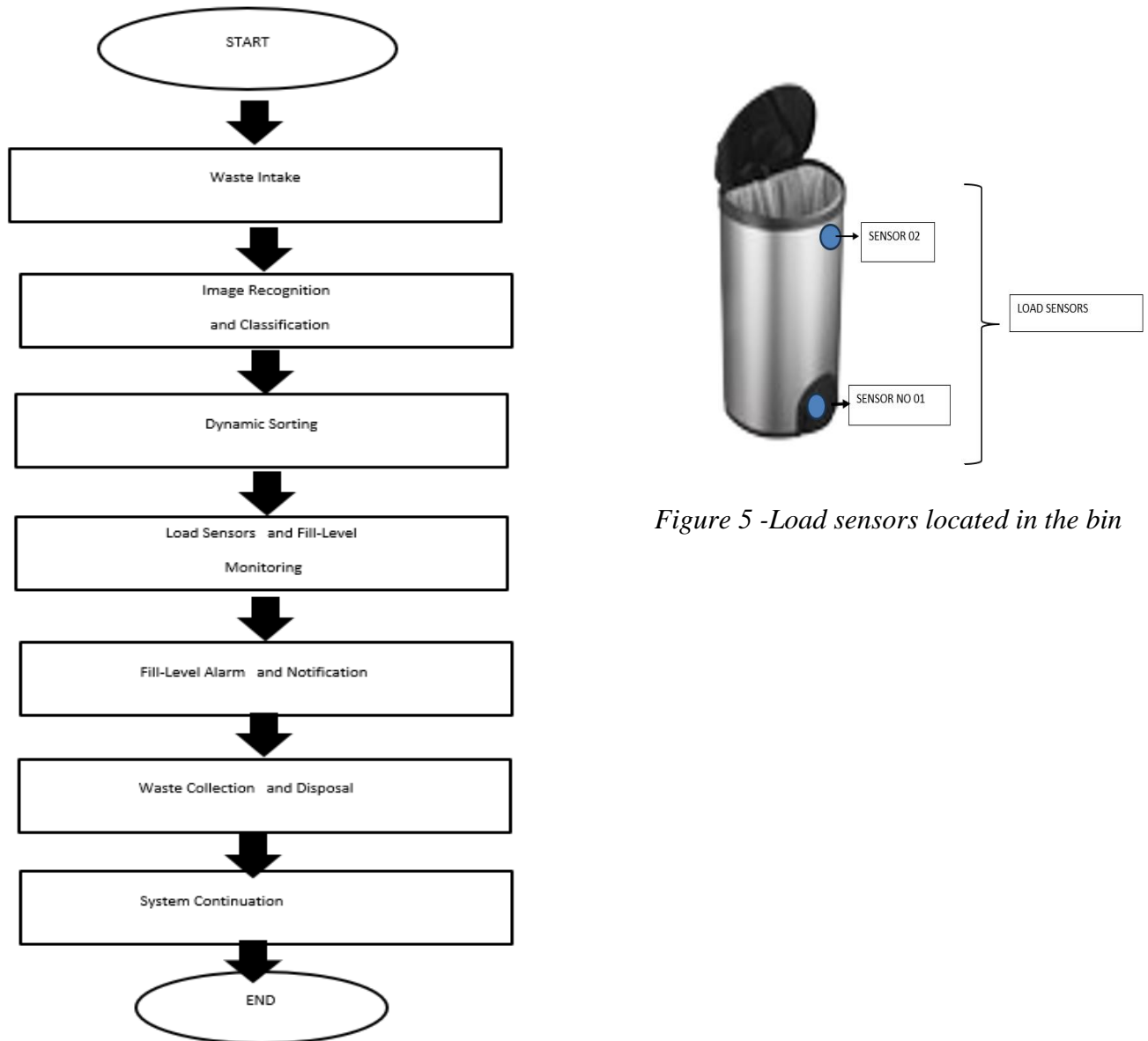
Figure 5 -Load sensors located in the bin



Figure 6 -Flow chart of the algorithm

## Discussion

With the potential of revolutionary improvements in efficiency, environmental sustainability, and adaptability, the automated waste management system that is being envisioned is an outstanding instance of innovation in the area of urban trash disposal. Firstly, the system's effectiveness and capacity for resource optimization indicate an evolution from typical labor-intensive methods. Combining a spinning plate with segregated bins and image recognition speeds up waste collection and has the potential to be a cost-effective solution, especially for governments with limited resources. In the same way, the conversation around this technology heavily emphasizes sustainability and environmental effect. The automated technology supports accurate sorting and recycling procedures, which is in keeping with international sustainability targets. This is an innovative take regarding how waste is going to be dealt of in the future. Through thoughtful discussion, continuous investigation, and cooperative

initiatives, the possible advantages of this technical advance might be utilized to facilitate the development of a more environmentally friendly and enduring metropolitan environment.

**Conclusion**

The development of automated waste management systems offers a viable approach to resolving the complex issues surrounding the disposal of trash in urban settings, with a particular emphasis on Sri Lanka. The system's capacity to proactively avert environmental threats, enhance resource use, and sort waste materials dynamically. The successful transition of this unique system from concept to practical implementation will largely depend on the cooperative efforts of scholars, legislators, tech developers, and communities especially the government. Continuous technological improvement, feasibility studies, community outreach, pilot projects, cooperative collaborations, environmental impact assessments, regulatory frameworks, and public-private partnerships are all needed for the automated waste management system. It is essential to devote resources on research and development to solve problems like sensor dependability and image recognition accuracy. Evaluating the system's economic viability requires conducting extensive feasibility studies and cost-benefit evaluations. Successful integration requires putting a high priority on community outreach and education initiatives, starting small-scale trial programs, and developing cooperative partnerships. Assessments of the environmental impact are also essential for making decisions in the future, could be obtained as recommendations. The effective conversion of this unique system from concept to reality is going to depend on the cooperative efforts of researchers, politicians, tech developers, and communities as well.

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# INTELLIGENT POWER CONTROLLING AND ELECTRICAL SAFEGUARD SYSTEM FOR DOMESTIC POWER DISTRIBUTION PANELS

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**Abstract**

This research project introduces an advanced smart home system meticulously designed to augment safety, efficiency, and sustainability within apartment living. The core innovation seamlessly integrates pivotal features, encompassing power protection, intelligent power conservation, gas leakage and fire protection, and RFID-based security. Employing non-intrusive sensors, the power protection feature vigilantly monitors real-time power consumption, promptly responding to overvoltage, undervoltage, or overload scenarios to safeguard electronic devices through immediate power cutoffs. Additionally, the system incorporates an intelligent power-saving mechanism activated by occupancy sensors, facilitating an automatic power-saving mode upon occupants' departure. Furthermore, the integration of RFID-based security fortifies access control. At the same time, robust fire and gas leakage protection mechanisms ensure timely detection and response to potential hazards, thereby providing an additional layer of safety. Rooted in a comprehensive literature review, the project utilizes the ESP-32 microcontroller for hardware implementation, offering a scalable and adaptable platform for Internet of Things (IoT) deployment. Rigorous real-world testing has validated the system's performance, with subsequent analyses elucidating strengths and areas for optimization. The resulting smart home system presents a user-friendly interface, cost-effectiveness, and scalability, establishing a noteworthy benchmark for safety, efficiency, and sustainable living in contemporary residential environments.

**Keywords:** Electrical Protection, Power Monitoring, Smart home

**Introduction**

Contemporary apartment living faces critical challenges in power management systems, with existing power panels offering only basic over-current protection. This leads to frequent disruptions, failures, and voltage fluctuations impacting household appliances (Zhou et al., 2016). Despite protective devices available in the market, economic feasibility hinders their widespread use in apartments, highlighting the need for a cost-effective solution (Zhou et al., 2016). Simultaneously, traditional physical door keys dominate apartment security, prompting concerns (Ali et al., 2017). Integrating in-room power control with door lock security is essential, necessitating an alternative solution (Ali et al., 2017).

Fire safety in buildings, especially when electrical circuits are involved, poses significant risks (Eko Pramunanto et al., 2019). Gas leakages in Sri Lanka compound this threat, with electricity-based fires contributing to 56.7% of accidents (Gunasekera and A.A.P. de Alwis, 2008). Recent cases underscore the need for proactive measures to prevent disasters.

Traditional fire extinguishers are often ineffective in gas leaks or electrical-based fires, emphasizing the urgency to develop innovative safety solutions (Gunasekera and A.A.P. de Alwis, 2008).

| Effect category | Number of accidents | % |
| --- | --- | --- |
| Fire | 34 | 56.7 |
| Explosion | 6 | 10.0 |
| Emission | 7 | 11.6 |
| Release | 6 | 10.0 |
| Fire/explosion | 3 | 5.0 |
| Emission/explosion | 2 | 3.3 |
| Emission/release | 1 | 1.7 |
| Fire/release | 1 | 1.7 |

*Figure 1 - Analysis data for industrial accidents in Sri Lanka*
(Gunasekera and A.A.P. de Alwis, 2008)

Furthermore, there is a lack of awareness among apartment dwellers regarding home appliance electrical consumption. Studies indicate the need for increased attention to powering down devices when leaving, reducing wasted energy and electricity costs. While the market offers various power meters, their inability to identify wasteful consumption necessitates a more nuanced solution. Analyzing power consumption details can empower consumers to adopt more sustainable practices and reduce costs.

This project explores integrated solutions addressing challenges in power management, security, fire safety, and consumer awareness to enhance efficiency, safety, and sustainability in apartment living. Through interdisciplinary research and innovative technologies, we aim to contribute to developing a comprehensive framework aligned with the evolving needs of modern apartment dwellers.

**Methodology**

An extensive literature review identified the optimal design from a few viable options. The operational process is elucidated in the subsequent flow chart.
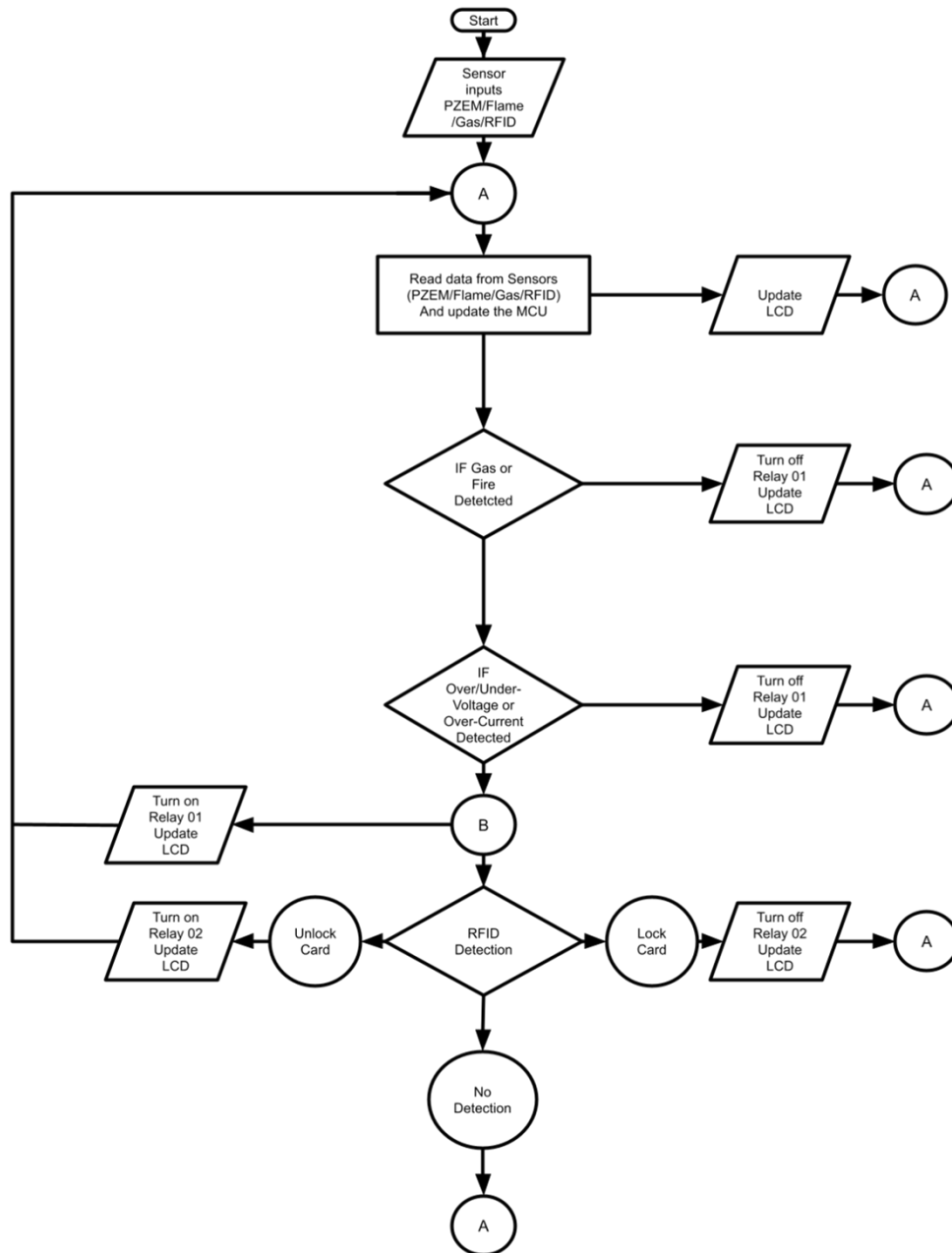
*Figure 2 - Flow chart of control system*

**Design and Implementation**

*System Components:*

ESP32 Microcontroller unit (Figure 3)

The central processing unit manages and controls the entire system, as shown in Figure 3. This MCU has Higher processing power than 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 by Figure 9
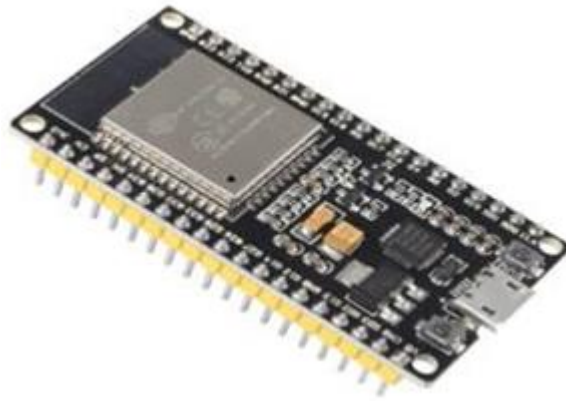
*Figure 3 - Microcontroller unit of the project (ESP32)*

PZEM-004T Voltage and Current Sensor Module. (Figure 4)
This Module can measure voltage and current parameters in real time and is able to program to provide wattage and kWh values. (Ravi Kishore Kodali and Sahu, 2016). Sensor data is transmitted to the ESP32 MCU for real-time analysis and the MCU calculates and continuously updates root mean square (RMS) values for voltage, current, wattage, and total energy consumption.



*Figure 4 - Voltage and current sensor*

Liquid Crystal Display (LCD) Panel with I2C Module (Figure 5)
The LCD module is used to display real-time information, including voltage, current, wattage, and kWh values. also, this module is programmed to Indicate the state of the main power supply (ON/OFF) and the detection of fire, smoke, or gas.
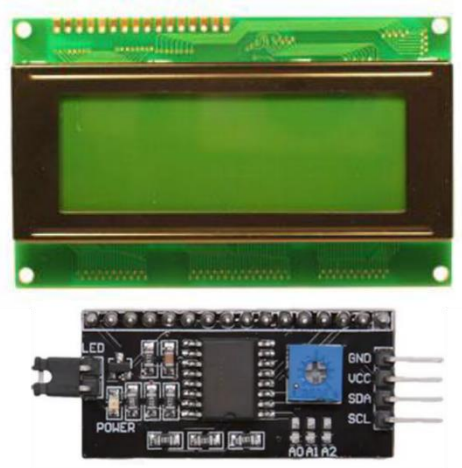
*Figure 5 - LCD module with I2C unit*

RFID-Based Security Module (Figure 6)

A radio field-based module is used for this (Ravi, 2013). Controls the door access to the smart home through RFID-based intelligent cards. The Unlock-Card is used for the unlock function, and the Lock-Card is for the Locking function (or a single card can be used as both lock and unlock functions but needs to be manipulated inside the code). Interfaces with relay module 02 to manage power supply to "Controlled circuits".



*Figure 6 - RFID based security module*

5V Relay Control Module (Figure 7)

Manages the switching of AC outputs for both security and power management functions.
Relay module 01 controls the main power supply based on fire, smoke, or gas detection.
Relay module 02 controls the power supply to "Controlled circuits" based on the presence of the Unlock-Card or Lock-Card.

*Figure 7 - 5 volt operated 4-channel relay module*

Fire and Gas detection sensors (Figure 8)

An infrared wave sensing IR sensor detects fires and is sensitive to the wavelength range 760nm-1100 nm in light radiation. (Huseynov et al., 2007) The MQ-02 Sensor is used as the Gas leakage detection sensor, and this sensor is also susceptible to LP-Gas, (Junaidy Budi Sanger, Sitanayah and Ahmad, 2021) which is used in domestic gas cylinders. If either of these sensors gets triggered by detection, the MCU will recognize that, and a signal will send to shut down the incoming power supply.
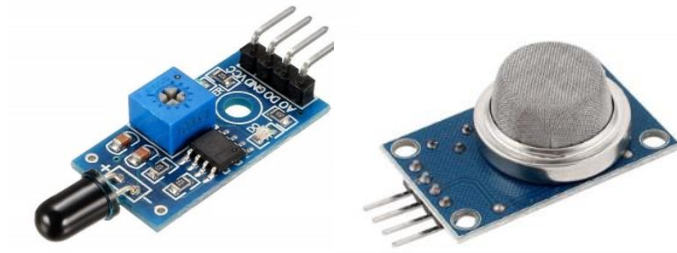


*Figure 8 - Fire and Gas detection module*

*Prototype Implementation*
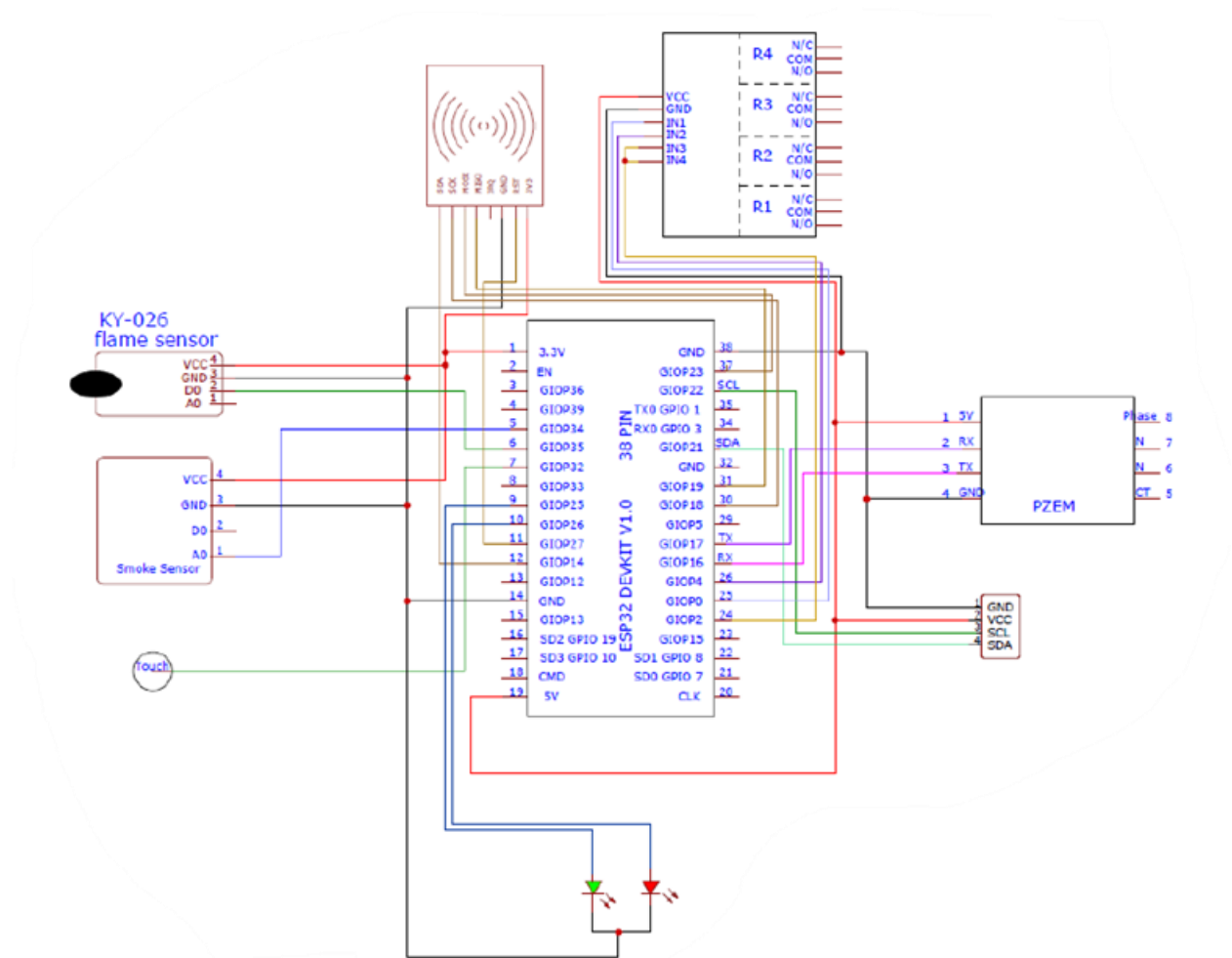


*Figure 9 - Wiring diagram of the design*

The system actively monitors potential environmental hazards, including flames, gas leakage, or smoke. In the absence of any detection, Relay Module 01 remains in the normally closed position, allowing the current to pass through the main switch to the Residual Current Circuit Breaker (RCCB).

Upon detecting flame, gas leakage, or smoke, Relay Module 01 is energized. This action breaks the current flow to both Controlled and Uncontrolled circuits. Simultaneously, the system indicates the type of detection on the LCD panel. Additionally, an audible alert is triggered through the Buzzer (Alarm) to draw immediate attention.

The PZEM-004T is programmed to identify overvoltage, undervoltage, and over-current situations. In the event of any detection, the system initiates a predefined waiting period and subsequently turns off the power supply through Relay 01.

Considering the RFID-Based Access Control, the system releases the lock when an Unlock-Card is detected, allowing the current flow to the "Controlled circuits" through Relay 02. Upon detecting a Lock-Card, the system locks the door, blocking the current flow to "Controlled circuits" to prevent unnecessary power consumption. Simultaneously, LED indicators display

a Green light for Unlocked status and a Red light for Locked status. An audible alert from the Buzzer further signifies the status change.

"Controlled Circuit" encompasses appliances like TVs, radios, electric irons, and fans. Power to these circuits is managed based on RFID detection, ensuring efficient power consumption. "Uncontrolled circuits" include refrigerators, washing machines, and CCTV cameras that remain active 24/7, irrespective of RFID detection status.

The system continuously displays crucial information on the LCD panel, including Voltage (V), Current (A), Wattage (W), KWh (units consumed), and the status of the Main Power System (MPS). Gas or smoke and fire alerts are also prominently displayed for real-time monitoring.

**Results and discussions**

1. Voltage Measurements

A professional multimeter was employed to verify the accuracy of voltage readings. The system's voltage readings were compared against the multimeter readings. The results indicated a consistent match, confirming the system's precision in measuring voltage.



*Figure 10 - Voltage Measurement of the system*

2. Smoke and Fire Scenarios

The system's response to simulated smoke and fire situations was evaluated to assess its performance in emergencies. The system responded to both artificial smoke and fire scenarios appropriately. This showcases its capability to handle unforeseen circumstances and prioritize user safety.



*Figure 11 - Smoke Detection (SMK: DET) and Flame Detection (FLM DET)*

3. Security System Functionality

The security system's role in energy conservation was examined. The system effectively executed its duty by cutting off the "Controlled circuit" to save energy when the user was not In the house. Upon the user's return, the system seamlessly reactivated, ensuring energy efficiency and user convenience. All the testing outcomes affirm the system's reliability and
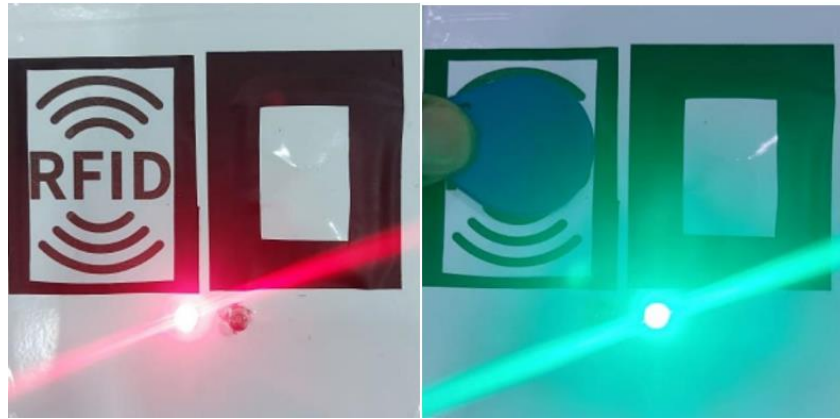


*Figure 12 - Security system lock (Red LED) and Unlock (Green LED) state*

adherence to specified performance criteria. The accuracy of voltage measurements and successful responses to artificial smoke and fire situations underscores the system's robustness. Additionally, the integration of the security system for energy conservation further enhances the system's practicality and user-friendly features.

**Conclusion and recommendations**

*Conclusion*

Examining apartment power panels reveals safety and energy efficiency issues, primarily due to inadequate protection against fluctuations, posing electrical hazards and system failures. The absence of mechanisms to cut off power during emergencies increases risks to life and property, while the lack of control over in-room panels by door systems exposes residents to electrical safety vulnerabilities (Zhou et al., 2016; Ali et al., 2017; Eko Pramunanto et al., 2019; Gunasekera and A.A.P. de Alwis, 2008).

To address these challenges, deploying advanced power panels is imperative, offering comprehensive protection and integrating a monitoring system for enhanced safety and reduced energy costs. This technology ensures efficient power consumption, minimizes associated costs, and empowers residents to make informed decisions through usage pattern analysis (Zhou et al., 2016).

Implementing advanced power panels, fortified with comprehensive protection and monitoring, is crucial for overcoming existing challenges in apartment buildings. This strategic move guarantees safety, efficiency, and sustainability in power consumption, substantially reducing energy costs (Zhou et al., 2016).

A meticulous project evaluation affirms achieving objectives, advancing safety, efficiency, and sustainability in apartment power consumption. The research identifies critical issues and provides tangible solutions, paving the way for future advancements in power panel technology

and residential energy management (Zhou et al., 2016; Ali et al., 2017; Eko Pramunanto et al., 2019; Gunasekera and A.A.P. de Alwis, 2008). Further development involves exploring avenues to enhance and extend the proposed system's capabilities, representing potential expansion, refinement, and innovation areas.

## *Recommendations*

The research findings present valuable insights, leading to several critical recommendations for advancing and implementing power monitoring systems. First, extending the existing single-phase monitoring system to a 3-phase setup is proposed, particularly beneficial in industrial contexts where 3-phase power systems are prevalent. Additionally, integrating advanced sensors, such as temperature and humidity sensors, is recommended to enhance hazard detection capabilities and contribute to a more comprehensive monitoring approach. Establishing a framework for continuous optimization, conducting further research on energy consumption patterns, and collaborating with industry stakeholders for standardization are suggested to address evolving challenges and enhance system efficiency. User education and awareness campaigns are advised to promote effective system utilization and energy savings. Furthermore, exploring the integration of renewable energy sources and enhancing security protocols, including encryption and authentication measures, are essential for sustainability and protection against potential cyber threats. Collectively, these recommendations aim to guide future endeavors, fostering continuous improvement, innovation, and widespread adoption of efficient and secure power management systems.

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# A PROTOTYPE OF THE ARDUINO-BASED, LOW-COST SEIZURE DETECTING AND ALERTING DEVICE

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## Abstract

Seizure and epilepsy are non-communicable brain diseases which affect people of all age groups. The patients who encounter seizure may face complications such as, aspiration pneumonia due to inhaling food or saliva into the lungs, injuries from fall, drowning, self-inflicted bite, operating machines or driving during seizure and in severe cases permanent brain damage. These complications can be mitigated by detecting seizure before it occurs, where the patient will be able to discontinue his/her activities and find a safer environment or consume the prescribed medication. For this purpose, a seizure detecting and alerting low-cost device based on Arduino has been designed. This device detects seizure before it occurs by analysing the rapid changes in heart rate, body temperature and sweat level through various sensors and alerts the patient for a possibility of seizure and also alerts the caregiver by sending an SMS.

**Keywords:** Seizure, Arduino, Alert-system, Sensors

## Introduction

Seizure is an abnormal, uncontrolled electrical activity of the brain which could cause changes in movement, feelings, behaviour and consciousness (Huff and Murr, 2023). Epilepsy, which is caused by two or more unprovoked seizures, is one of the most common neurological diseases in the world, as almost 50 million people around the world are diagnosed with epilepsy and per year around 5 million people are diagnosed. As per World Health Organization, about 80% of people with epilepsy are from countries with low income, mainly due to increased endemic conditions like neurocysticercosis or malaria, injuries related to birth and road traffic, inadequate medical infrastructure and health programmes for preventing. Three quarters of middle-class income families of low-income countries do not get the proper treatment. In high income earning countries 49 out of 100,000 people are diagnosed per year. The people with epilepsy have three times higher risk of premature death than general population. People who are epileptic undergo discrimination and stigma in many parts of the world (WHO, 2022).

Seizure can be both predictable and unpredictable and sometimes the person will be aware or will not be aware of any occurrence of seizure. Nevertheless, seizure can be hazardous if the patient is in a precarious environment, driving a vehicle, operating a machine, swimming, pregnant and various others which could lead to calamitous situation. Most of the existing devices in the market that are used by seizure patients focus on detecting seizure when it occurs. The main purpose of these devices is limited to alerting the user and people surrounding the patient that the patient is suffering from a seizure. Therefore, this device is designed to detect

seizure before it occurs and alert the patient and caregiver. This could assist the patients who are suffering from seizures to do their day-to-day activities independently and without any risk.

*Objectives*

Design a system to measure the patient's heart rate, body temperature, and sweat level time to time.

Develop an automated system to make the patient aware of the above-mentioned measures by displaying them in the LCD display worn by the patient.

Analyse the above-mentioned readings and develop a device to alert the patient and the caregiver of the patient when there is a risk of seizure.

**Methodology**

This device consists of heart rate sensor, temperature sensor, galvanic skin response sensor and the 3- axis accelerometer receives and send the data to the processing unit, Arduino Uno to process and the result will be displayed on the LCD screen, which will be worn by the patient; therefore, the patient will know his/her readings time to time. During emergency situations, such as when there is a rapid increase in the heart rate, body temperature and sweat levels or when seizure movements are detected, the buzzer in the device alerts the patient and the surrounding people as well as the GSM module sends an SMS to the caregiver's mobile phone to alert them. The block diagram and schematic diagram of the device is given below.
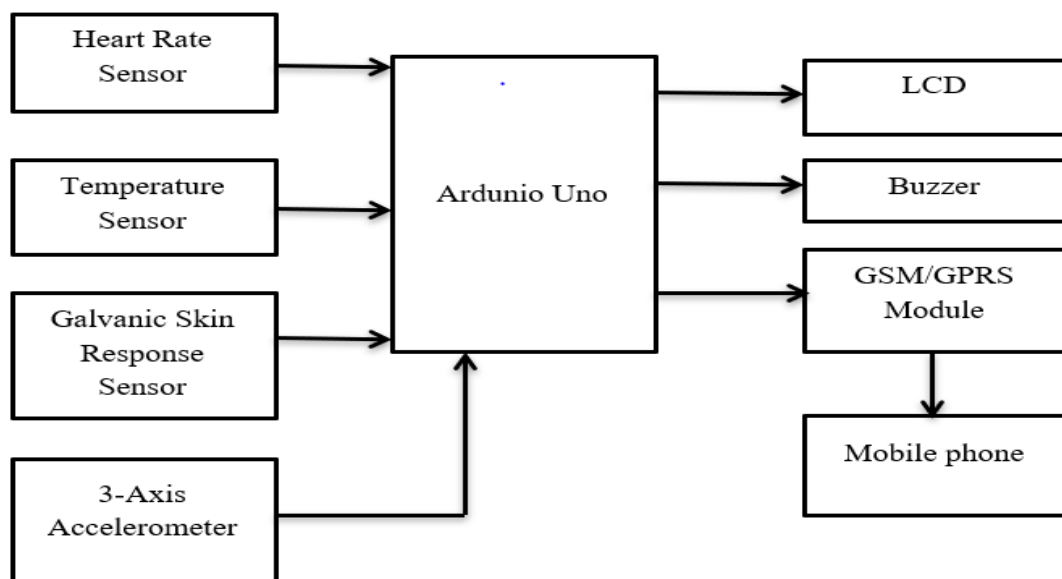


*Figure I Block diagram of the perfect design.*
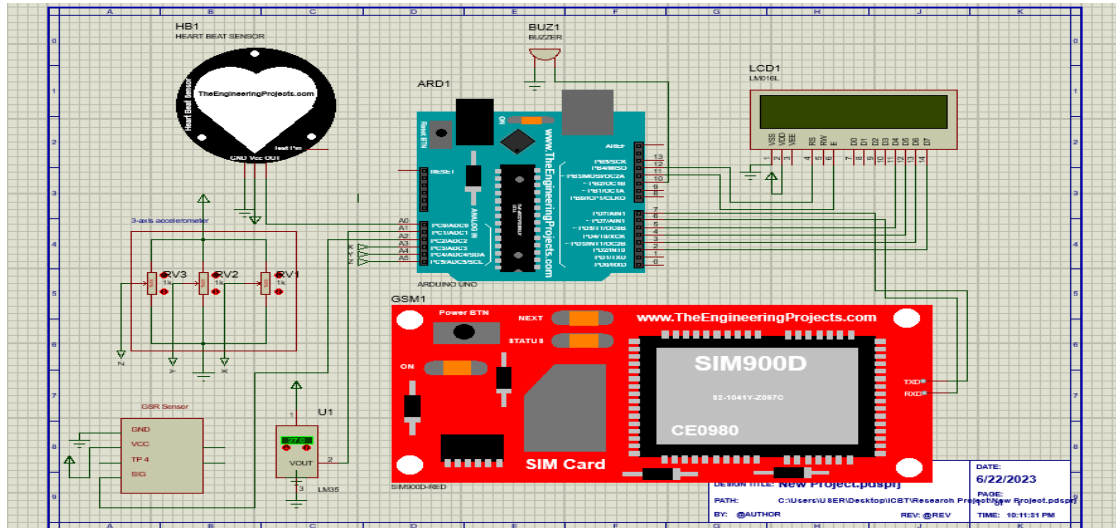
*Figure II Schematic diagram of the circuit design of the device*

The optimum design shown above in figure 2 will be implemented by connecting the heart rate sensor, temperature sensor, GSR sensor and the accelerometer to the Arduino uno to obtain the inputs. The output will be displayed on the LCD screen. The buzzer will also be used as output when the possible seizure is predicted or when the patient gets seizure. The Arduino codes will be uploaded to the Arduino uno board to predict or detect seizure by setting values, such as heart rate 90 BPM or more, body temperature 40ºC or more and GSR 515 or more. For the alarm to get activated all these three readings should be equal to or more than the above-mentioned values.

The device was tested on ten random individuals to find any correlation between their age and the readings obtained from the device. The test results obtained from the individuals are shown in table 1 below. Then the device was tested on three individuals selected from the ten individuals, and measured their heart rate, temperature and skin conductance using the device during various activities, such as at rest, during work or studies and after a walk or workout, to find whether there is any correlation between the work done and the readings obtained from the device.

**Results**

The results obtained showed a correlation between the heart rate, body temperature, skin conductance and the activities, which could be observed in figure 3, 4 and 5.

Table 1 Test result of 10 random individuals

| Individual | Age | Heart Rate (BPM) | Temperature ('C) | GSR | Did the device alert |
|---|---|---|---|---|---|
| A | 25 | 77 | 35 | 436 | No |
| B | 30 | 88 | 33 | 485 | No |
| C | 74 | 95 | 34 | 492 | No |
| D | 63 | 98 | 33 | 485 | No |
| E | 59 | 76 | 30 | 507 | No |
| F | 24 | 74 | 32 | 494 | No |
| G | 37 | 66 | 30 | 435 | No |
| H | 65 | 133 | 52 | 521 | Yes |
| I | 28 | 70 | 31 | 492 | No |
| J | 54 | 63 | 96 | 427 | No |

Table 2 Test result of 3 individuals while performing various activities.

| Activities | | C | E | I |
|---|---|---|---|---|
| At rest | Heart Rate (BPM) | 60 | 73 | 67 |
| | Temperature ('C) | 32 | 29 | 30 |
| | GSR | 519 | 507 | 485 |
| Did the device alert | | No | No | No |
| After a walk/workout | Heart Rate (BPM) | 74 | 85 | 107 |
| | Temperature ('C) | 35 | 36 | 38 |
| | GSR | 550 | 536 | 547 |
| Did the device alert | | No | No | No |
| During work/studying | Heart Rate (BPM) | 66 | 80 | 81 |
| | Temperature ('C) | 34 | 33 | 36 |
| | GSR | 545 | 510 | 504 |
| Did the device alert | | No | No | No |



*Figure III The heart rate variation of three individuals during various activities*
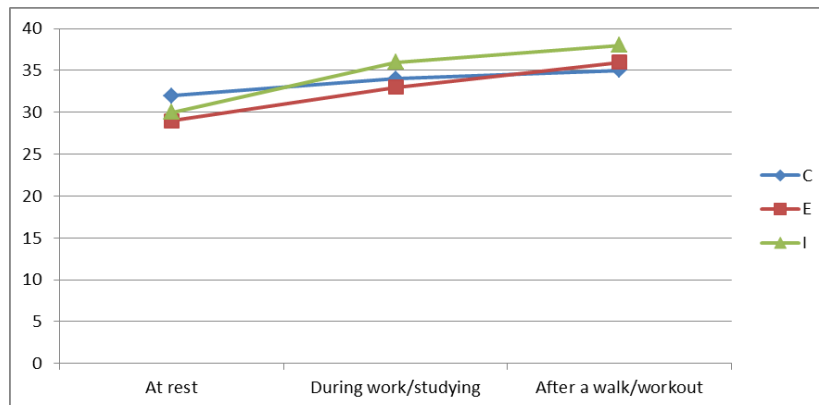
*Figure IV The temperature variation of three individuals during various activities*
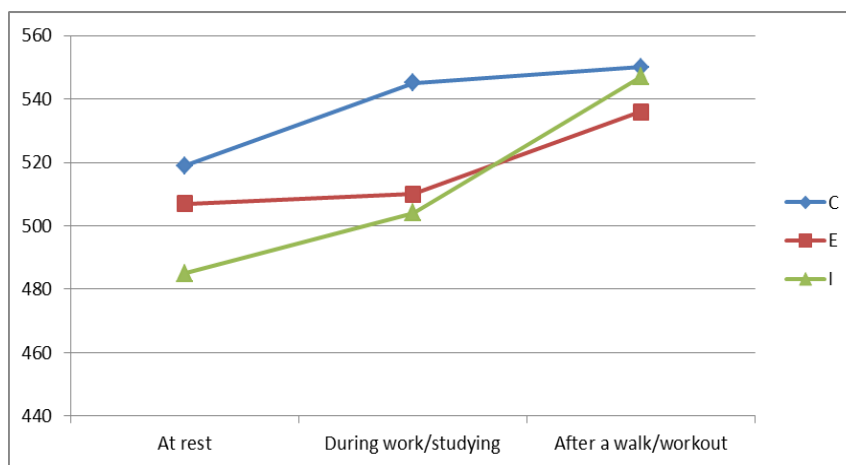


*Figure V The skin conductance variation of three individuals during various activities*

**Discussion**

From the results obtained from Table 1, it was notified that the heart rate, body temperature and GSR do not depend on age. These could depend on the person's health condition, but there is no correlation noticed between the age and the above-mentioned readings.

Table 2 shows the heart rate, body temperature and GSR of three individuals during and after various activities, such as at rest, during working or studying and after workout or walking. From the results obtained above, it was observed that the heart rate, body temperature and GSR vary according to the intensity of the work done. Also, it was observed in all three individuals, that the heart rate, body temperature and the GSR were less when they are at rest, when compared to the same measures taken after workout or walking. From this, it's concluded that the heart rate, body temperature and the GSR varies with the activities of the person.

It can be observed from the above figures 23, 24 and 25 that heart rate, body temperature and the skin conductance can vary in-line with the activity performed. When the individuals are at rest, a relatively less heart rate, body temperature and skin conductance were observed due to the relaxing. During the studies or work, a relatively higher heart rate, body temperature and skin conductance were observed due to the stress of the activity and after the workout/walking

shows even higher values of heart rate, body temperature and skin conductance, because of the intensity of the activity was higher than the other two activities.

The main drawback with this device is that due to the structure of this device, the parameters cannot be observed while doing the workout, where the heart rates, body temperature and GSR could be very high. This could be rectified by enclosing the device in a proper manner, without disturbing the connections and locating the sensors in contact with the skin to obtain the readings.

**Conclusions and Recommendations**

Seizure is a non-communicable disease which occurs due to sudden and uncontrolled electrical activity between the brain cells. It causes temporary abnormalities in movements and muscle tone, such as twitching, stiffness or limpness. Seizure symptoms can vary and can cause a loss of consciousness or sudden changes in awareness, and in some cases fatality. Predicting seizures has been a challenge and if predicted earlier it could help in avoiding accidents and hazards by consuming medication before the seizure or discontinuing any activities which could be harmful, such as driving or swimming.

It has been proved in studies that the heart rate usually increases due to the electrical activity during seizure in the brain. In a study conducted on the behaviour of the heart rate during seizure, it is revealed that during the first 10 to 30 seconds of the seizure, the heart rate usually increases (Smith and Lim, 2001). However, during ictal asystole, which is a rare condition associated with the temporal lobe seizure (Ravat et al., 2017), the pulse rate can decrease or even pause temporarily (Ghearing, 2014). In another study conducted on patients with epilepsy to describe the fever that followed a generalized tonic-chronic seizure, it was evident that the body temperature of the patients increased, similar to a vigorous workout (Wachtel et al, 1987). It is also proved that sweating, pallor, piloerection and flushing are the cutaneous manifestations that occur during seizure (Devinsky, 2004). Hence, this device measures the heart rate, body temperature and skin conductance and predicts whether the patient will encounter seizure attack and alerts the user through the buzzer and by displaying "Seizure Detected" on the LCD screen which is attached with the device. This could help the user to detect seizures in advance and do precautionary action to avoid any hazards.

Even though this device is constructed to detect seizure and alert the user and the caregiver to prevent any harmful risks, some developments could be made to obtain a more acceptable result. Since this device is useful for seizure or epilepsy patients, it will be appropriate if the device could be designed in a wearable device, by replacing some of the components to smaller alternatives, in order that could be worn by the patient all the time to predict any seizure attacks in advance and do the needful to avoid any harm. Furthermore, since seizure or epilepsy could also occur in other animals, such as dogs, cats and other pets, this device could be modified according to the specific animal's parameters and could be used to predict seizure by the owners of the pets.

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# FOOTSTEP POWER GENERATION TO OPERATE AND CONTROL THE STREET LIGHTS IN SRI LANKA

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**Abstract**

Electricity is an essential in modern society and the demand for the electric power is increasing day by day. In Sri Lanka, even though there are many primary energy sources, there is a trouble in electricity generation due to the economic crisis in Sri Lanka, which leads to frequent power shortages. Therefore, a temptation to produce energy artificially is a serious topic now. As a result, this project suggests a method to store the dissipated energy from footsteps, to generate electricity and use that power to glow the streetlights. This research represents a prototype of the designed system which can be used in real world scenario. The dissipated energy from the footsteps while people walking or jogging in the pavement was harvested using a Piezoelectric Energy Harvesting tile. The harvested energy was stored in a battery to use to light up a streetlight. The battery powers up the streetlight and can be controlled automatically to switch on during the nighttime and to switch off during the daytime. In order to achieve this, a light intensity sensor was used which operates in high resolution mode. The output power of the designed system was observed as 0.25mW with 10 sensor plates and 100 steps as the prototype is in very small scale. Therefore, a buck boost converter was used in the prototype to boost up the power. The LED was used instead of streetlight and the response of light intensity sensor was observed successfully. Even though the output power of the prototype is less, the increase in the sensor plates and the footsteps would increase the power generation in real scenario as the future development.

**Keywords:** Battery Management System, Energy harvesting, Street Lights, Piezoelectric effect, Power generation

## Introduction

With the evolution of man, the utilization of various energies became a necessity. Due to this, many natural resources were found, and they were categorized as, Renewable resources and Non-Renewable resources. Those energy sources are used in the process of producing electrical power. And electricity is essential at present, therefore the demand for electrical power is increasing day by day. But most of the electricity generating resources are decaying and most of them are polluting the environment. In Sri Lanka, the other conditions that should be considered apart from decaying and pollution; are the economic situation (as Sri Lanka is a developing country), and being an island is also a considerable factor. Thermal power, hydropower and non-conventional renewable sources (wind and solar) are the primary sources that use to generate power in Sri Lanka. But with the economic crisis in Sri Lanka, there's a big trouble in electricity generation which leads to frequent power shortages. The data provided

by Ceylon Electricity Board has proven that streetlights are a big burden which is a public service and costs a lot. There are a lot of walking tracks all over the country and roads that people walk or jog frequently, where a lot of energy is dissipated by the people who walk or jog. So, this project will suggest a method to store the wasted energy as electricity and use that power to glow the streetlights. Three conceptual designs were tested, and the most suitable and reliable method was selected. In this design, the streetlights will switch on automatically during the nighttime and switch off during the daytime.

### *Objectives*

*Main Objective:*

The main objective of the project is to design an energy harvesting system from footsteps using a piezoelectric energy harvesting tile in order to store in a battery and reuse the generated power to power up the street lights.

*Sub Objectives:*

Conduct a literature survey on piezoelectric effect and piezoelectric devices in power generation and propose conceptual designs considering the literature survey.

Analyze the conceptual designs proposed and select the most suitable and convenient method. Design and implement a prototype energy harvesting system using piezoelectric energy harvesting tile and battery to glow the LED instead of street light.

Develop a feature in the designed prototype with automatic switch to control the light using light intensity sensor.

### Methodology

Initially a case study was carried out to identify the problem in deep and performed action-oriented research to provide a convenient solution for the problem. Therefore, the problem identification and a technological review was done according to the following mapping.
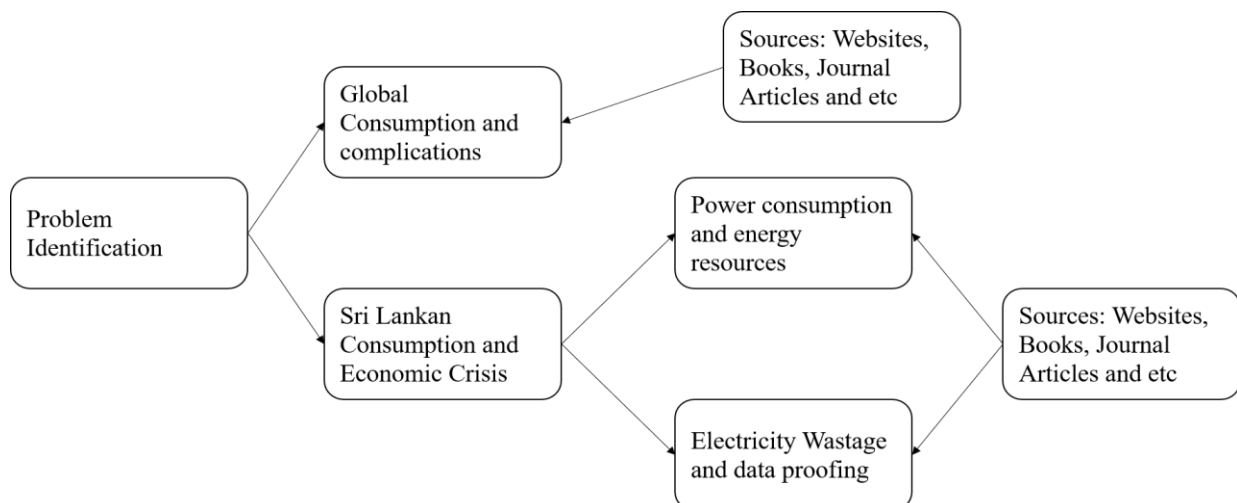


*Figure I Research mapping*
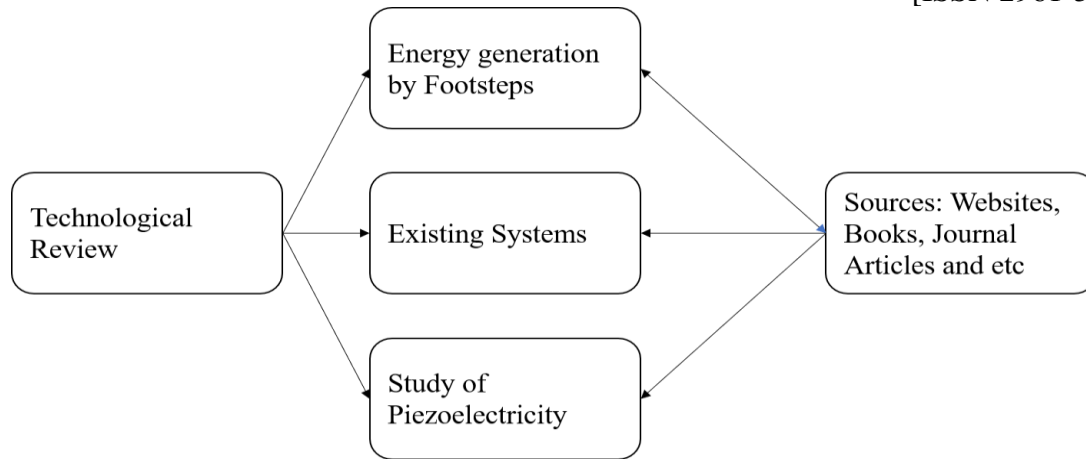
Three conceptual designs were tested, and the most convenient and cost-effective method was selected. The final product of this method was a floor tile. Piezoelectric sensors were used in generating power in this methodology, where the Piezoelectric sensors were placed in between the two plates of the tile. The pressure applied to the top plate will be distributed equally to each Piezoelectric sensor to perform separately. Sensors were arranged parallelly to increase the output current of the system.
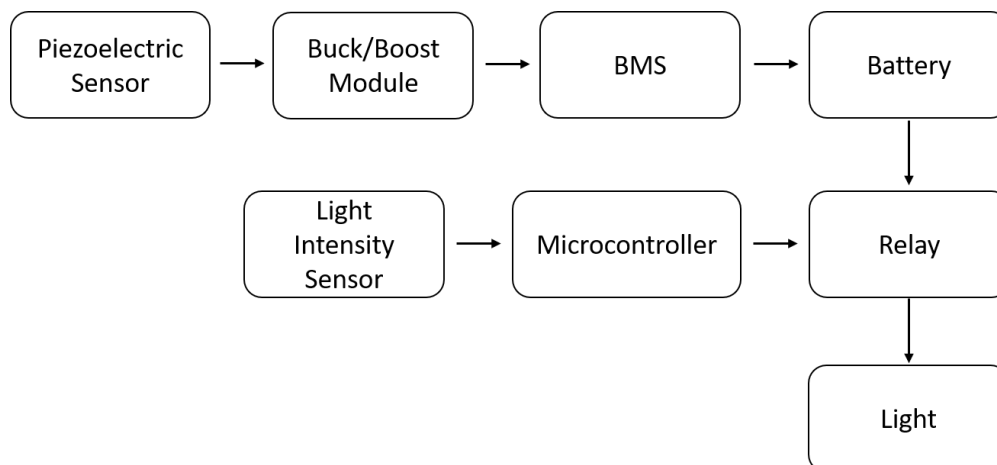


*Figure II Flow chart of the design*

This system harvests the energy dissipated by humans when walking and jogging, using Piezoelectric sensors. The harvested energy will be stored in a battery and used to light up the streetlights. The streetlights are automated to switch on during the nighttime and to switch off during the daytime. For the prototype, ten (10) Piezoelectric sensors were used and connected parallelly in between the two plates of the tile. Each output of the Piezoelectric sensor was connected to a Bridge Rectifier and final positive and negative terminals were connected to the LM2596/LM2577-based Buck/Boost 15W module. Because the output from the energy harvester tile is varying with the force applied to the top plate of the tile. This variation of voltage caused a problem when charging the battery as there is no constant output voltage. The Buck/Boost module gives a constant voltage out after calibrating to a certain voltage with the variation of the input voltage to the module.
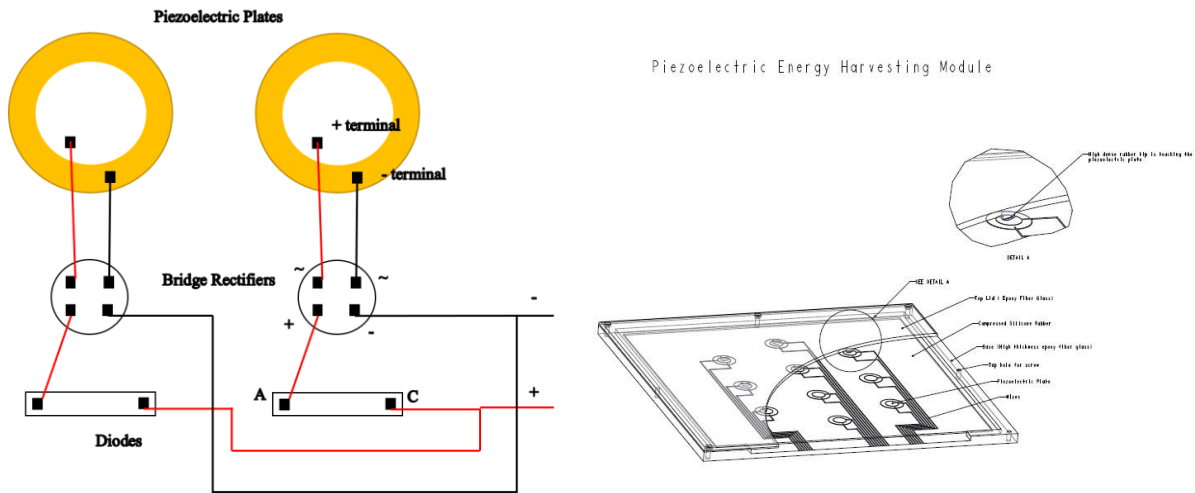
*Figure III Arrangement of Piezoelectric sensors in the tile*

The regulated output of the Buck/Boost module was given to the input terminals of the Battery Management System which the TP4056 Lithium Battery Charger and Protection Module. The B+ and B- outputs of the BMS system were connected to the positive and negative terminals of the 18650 3.7V Li-ion battery to charge the battery and the OUT+ and OUT- terminals were connected to the LED bulb and to the relay module.
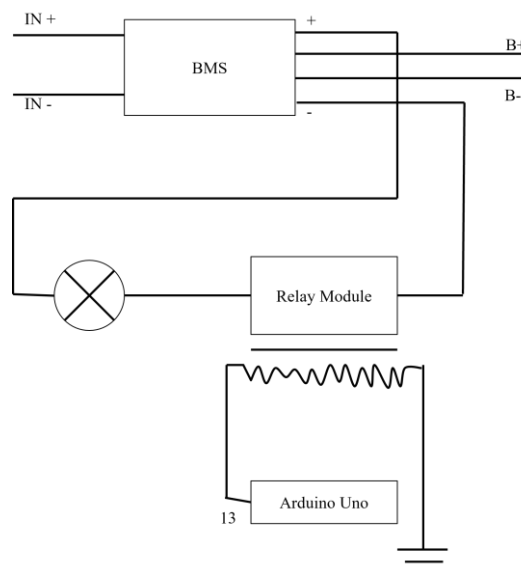


*Figure IV Pin IN and OUT connections of the Battery Management System*

Single channel relay module was used as a switch to the circuit, which operates according to the signal comes from the Arduino Uno board. The relay module operates the battery out to the light bulb with the threshold value of the light intensity from the BH1750 light intensity sensor, where the bulb was switched on, at nighttime and switched off at daytime.
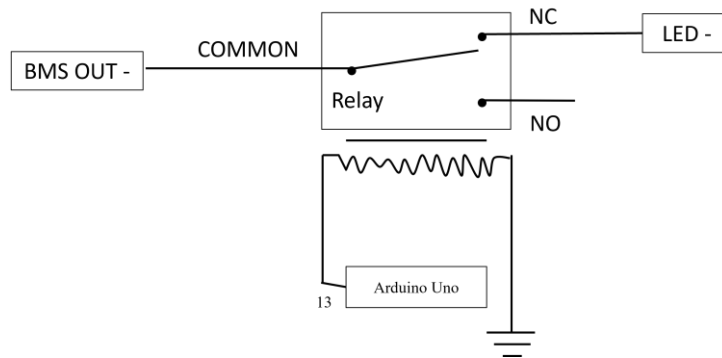
*Figure V Connections of the relay module*

To develop the communication between the sensor and the Arduino board, the SCL and the SDA pins of the BH1750 sensor were connected to the fourth and fifth Analog In pins of the Arduino board. A threshold light intensity value was given to identify the nighttime and the daytime, and it was set to 35 lx. When the sensor out gives lx values below 35lx, the light was switched on and when the lx value is higher than the threshold value, the light was switched off. This Light Intensity sensor will place on the top of the light pole over the light to expose to the natural light. When a pressure applied to the tile, the battery will be charged and during day and nighttime the street will be automatically switched on or off.

The final appearance and details of the tile is shown below in figure vi.
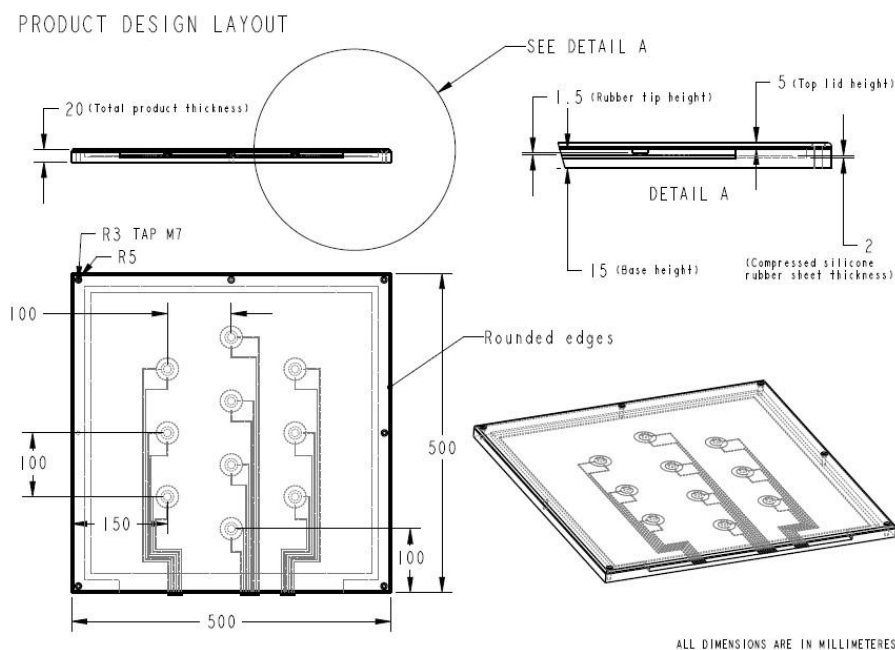


*Figure VI Product design layout*

The following Figure VII. shows the appearance of final system implementation in the real-world scenario.
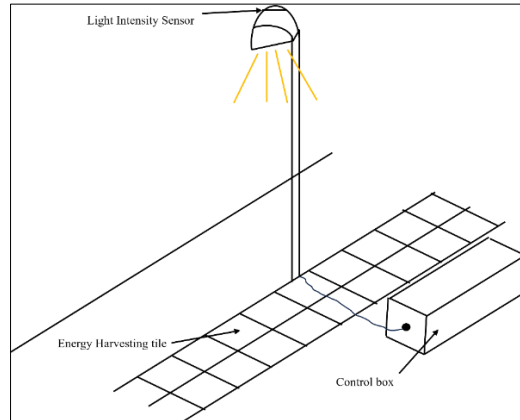
*Figure VII Final appearance of the system*

**Results**

Output voltage range of the Piezo tile (10 sensor plates): 0 – 5V

Output current range of the Piezo tile (10 sensor plates): 0 – 25μA

Table I Output Voltage against the step number

| Step Number | Output Voltage |
|-------------|----------------|
| 1 | 2.4V |
| 5 | 4.2V |
| 10 | 3.6V |
| 25 | 1.7V |
| 40 | 3.2V |
| 50 | 4.2V |
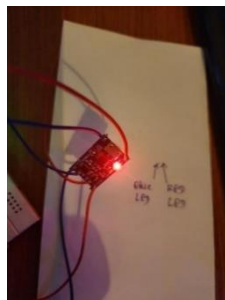


*Figure VIII Battery charging indication*
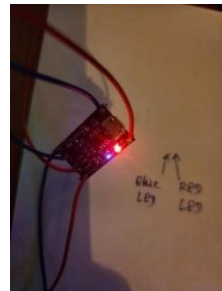


*Figure IX Indication of battery charging completed*
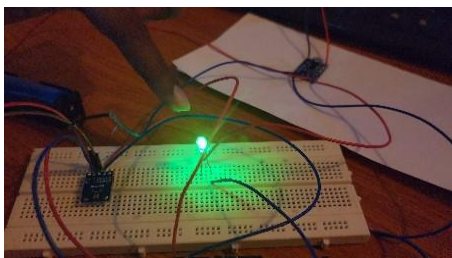


*Figure X Output for warm light condition*
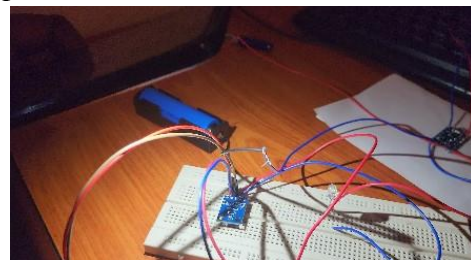


*Figure XI Output for torch light condition*

**Discussion**

In the energy harvester tile, a remarkable power output was given with the parallel arrangement of sensors. The output of energy harvester tile was given to the battery management system through the buck/boost module. The output voltage of the buck/boost module was calibrated for 4V. Then the battery charging was displayed by the red light of the BMS system and charging completion was displayed by the blue light of the BMS system.

The Light Intensity Sensor module was tested for various light situations and the intensity level was recorded from the serial monitoring function of the Arduino, and the signal was communicated through the Arduino Uno microcontroller board to the relay module successfully. The LED light output was tested for warm light condition inside the home and for the torch light keeping one foot distance between the sensor and the light source as shown in above figure x and xi. With the pressure given to the energy harvester tile, the output voltage and current were varied and the variation of the voltage was controlled and set to a calibrated value by the buck/boost module. If the direct output of the energy harvester tile was given to the BMS system, it will occur a problem when charging the battery because of the variation of the voltages. The Arduino microcontroller unit controlled the communication part between the light intensity sensor and the relay module to operate the final light output according to the light condition of the environment.

**Conclusions and Recommendations**

This system was designed to harvest the dissipated energy from people when walking and jogging, using a Piezoelectric energy harvesting tile module. Therefore, a literature survey was conducted for the background study, Piezoelectric effect and modules. Three conceptual designs were proposed by considering the literature survey. First design was to produce a tile module using water pressure. The compressed water pressure was used to operate a turbine. The design was a failure in practical capability of implementation. In second conceptual design, Piezoelectric sensor plates were used and arranged them in series to obtain the output. The third conceptual design was the parallel connection of the conceptual design 2. The selected design was conceptual design 3, because the current output of the parallel connection was comparatively higher than the conceptual design 2.

Before connecting to the circuit all the modules were tested for the operation condition. The Buck/Boost module was calibrated to 4V. Battery management system was checked by giving 5V to the module input and connecting the battery outs to the 18650 Li-ion battery and the charging was checked. BH1750 Light Intensity Sensor was check for different light conditions and accurate output lux levels were recorded using the serial monitoring of the Arduino Interface.

In some cases, the current output of the harvester tile was not enough to operate the buck/boost module. The recommendation to overcome that issue is to use both series and parallel connection for the arrangement of Piezoelectric sensors. The operating conditions of the Piezoelectric plates used in this project was very low. Few plates were removed, and new sensor plates were installed several times due to the damages which were happened when applying the force.

There are so many other Piezoelectric sensors which are having more capability of handling pressure and with more specifications such as, Piezoelectric sheets, Piezoelectric harvester

sensors, etc. For real world practical implementations, those Piezoelectric sensors can be used and when doing the bulk production, the low budget objective can be achieved.

As the future development, the energy harvesting system could be developed in larscale with more sensor plates and in high population area to have more footstep to increase the power generation from the system.

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# THE SMART WALKING STICK FOR VISUALLY IMPAIRED PEOPLE

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**Abstract**

The concept of the smart blind stick project is the idea of assistive devices, that use technological advances to enhance the lives of people with impairments. It is lightweight, cost-effective, securely built, and portable and uses ultrasonic sensors controlled by Arduino UNO to detect obstructions up to a specified distance. A vibration feedback mechanism alerts the user allowing them to avoid obstacles immediately. In addition to obstacle detection, it is also equipped with a GPS module and GSM module, for location detection via a text message. Furthermore, the image processing technique is also used in this project as a future improvement to provide the user with more precise and accurate input about their surroundings. All the objectives of designing the structure, building using components, testing, and analyzing were accomplished at the end. Designed model provide assistance for blind people. GSM and GPS and Ultrasonic Senor provide much accurate results in final model. Many advancements can be made in the future to improve the device.

**Keywords:** GPS-GSM modules, Image processing, Ultrasonic sensor

## Introduction

### Background of the study

Loss of vision has a significant impact on people's lives. It can affect their independence, quality of life, and social life. The leading causes of vision impairment and blindness are uncorrected refractive errors and cataracts.

Approximately 40 million people are suffering from visual impairments worldwide; among them, 15 million have severe visual impairments, and blindness is prevalent among 1.7% of the population of Sri Lanka (WHO, 2022). Being a developing nation with most of the nation considered lower-middle class, blindness has become a significant social and financial constraint, and performing surgeries to treat blindness may not always be a possibility for these patients. Young children with early onset severe vision impairment can experience delayed motor, language, emotional, social, and cognitive development, with lifelong consequences. School-age children with vision impairment can also experience lower levels of educational achievement. Adults with vision impairment often have lower rates of workforce participation and higher rates of depression. Vision impairment can contribute to social isolation, difficulty walking, a higher risk of falls and fractures, and a greater likelihood of early entry into nursing or care homes. Therefore, it is imperative solutions are being sought to address and prevent blindness while also helping people currently suffering from blindness to lead a normal life. This project aims to improve the quality of life for the blind by designing an efficient smart device to replace the conventional white stick.

**Methodology**

After conducting a comprehensive literature survey, the optimal design was chosen from three viable options, and the operational process is elucidated in the accompanying flow charts.
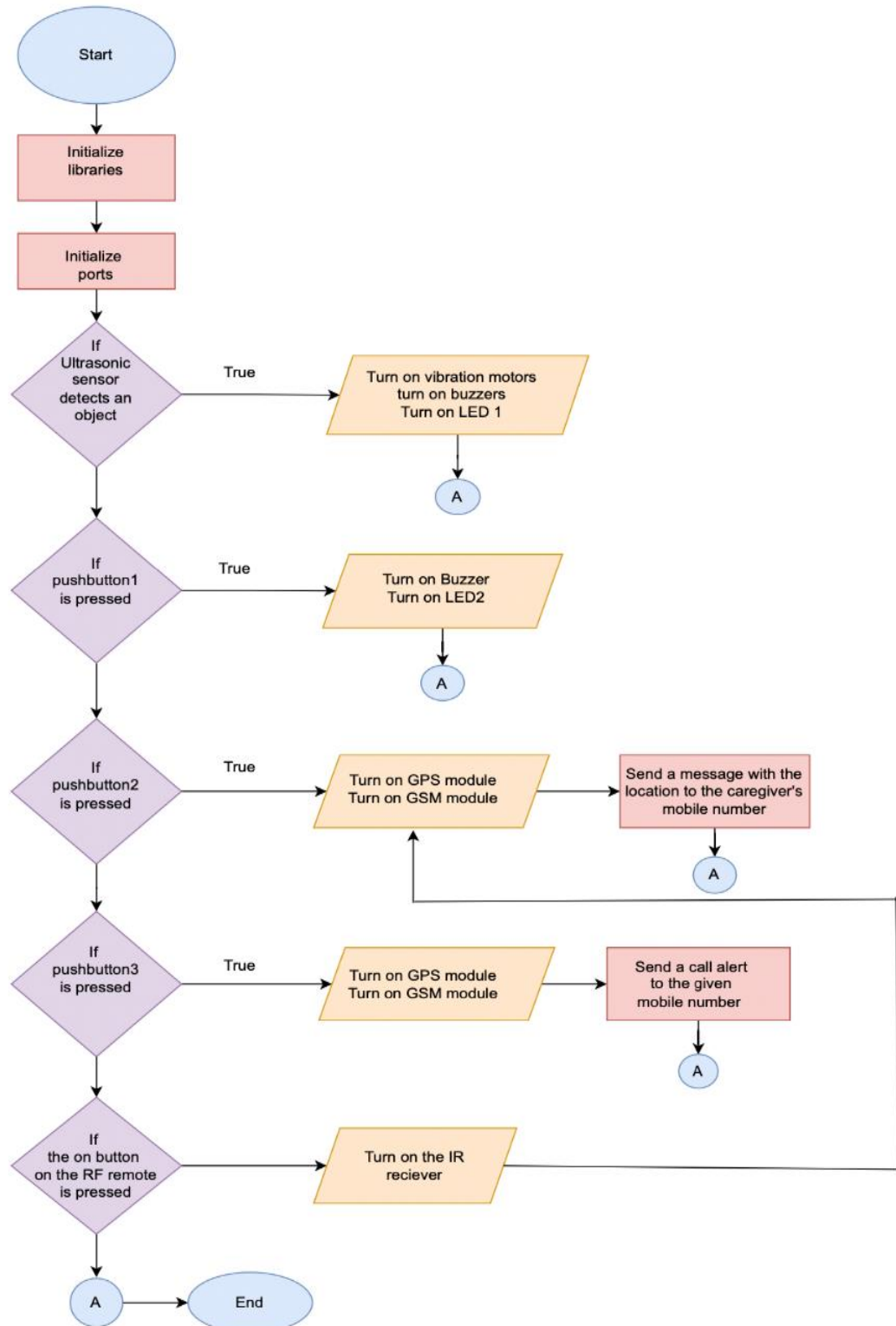


*Figure 1 - Functional Flow chart of main system*
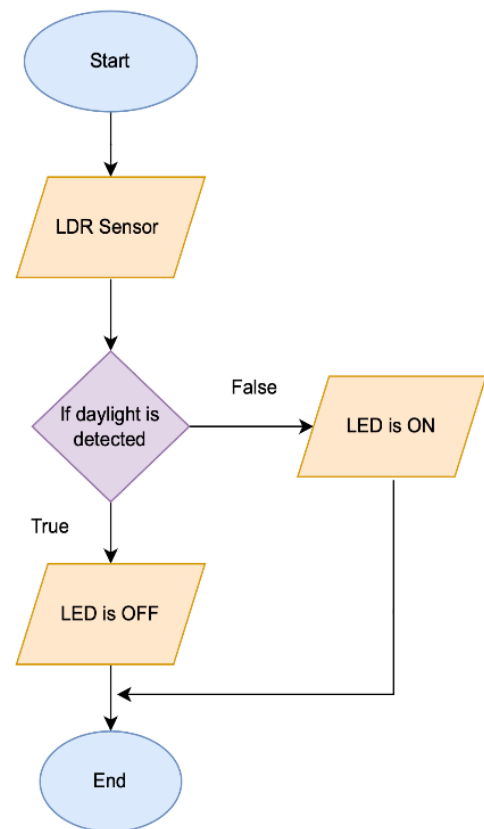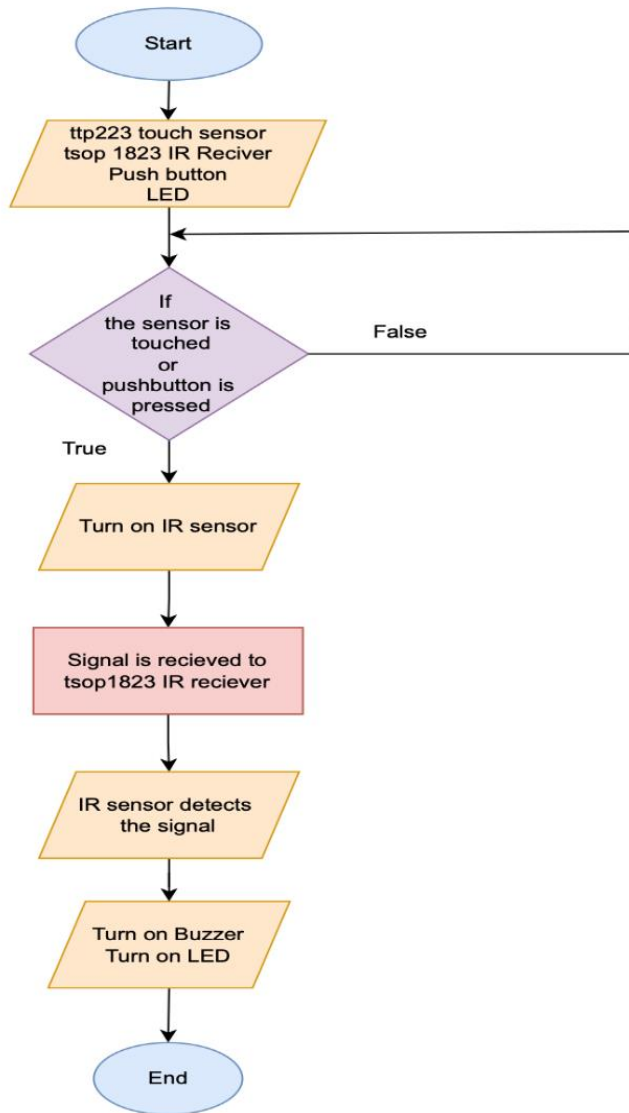
*Figure 2 - Functional Flow chart of wristband    Figure 3 - Functional Flow chart of LDR*

**Design & implementation**

The blind stick prototype, which is powered by rechargeable batteries and an Arduino Nano microcontroller, has ultrasonic sensors, a gyroscope, GSM and GPS modules, and servo motors to assist the sight handicapped. A micro-USB charger or a tiny solar panel is used to charge the device. The Arduino board interfaces with sensors, including an ultrasonic sensor, and uses capabilities such as vibration motors and tiny servo motors to detect obstacles and alter direction. The device's functionality is enhanced by essential components such as a DC-DC buck converter, a relay module for stand activation, an LDR for light indication, and a TSOP1823 IR receiver for physical touch detection.
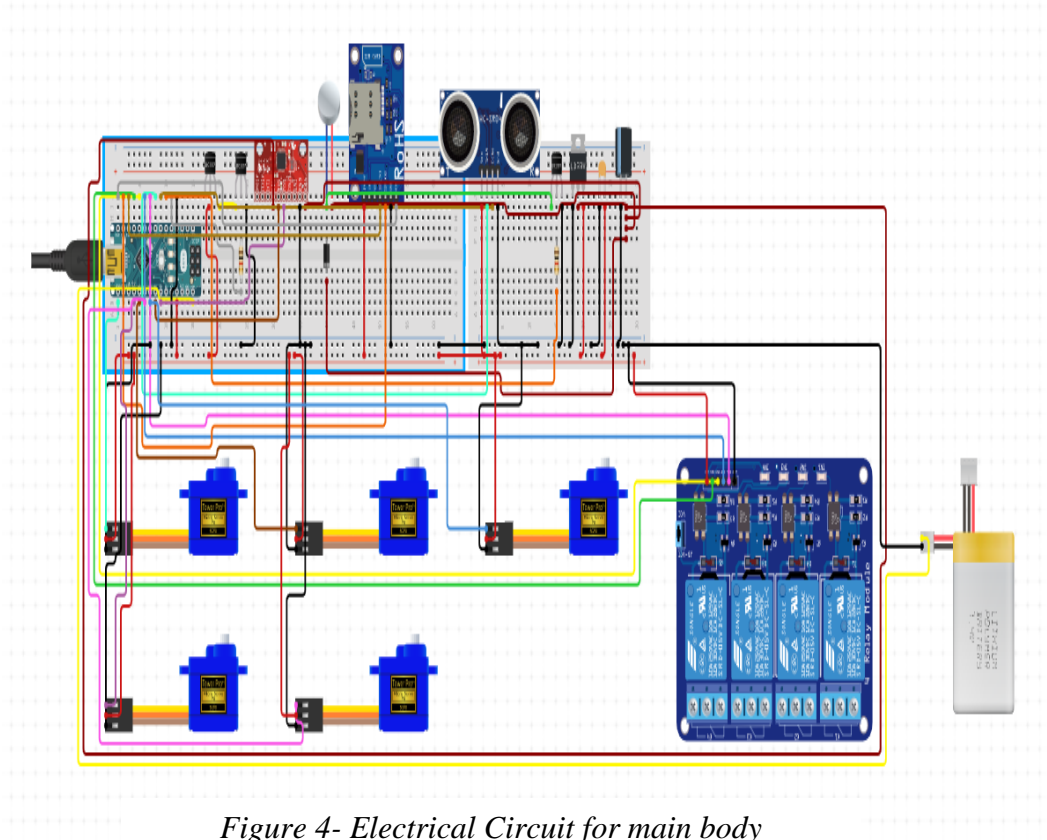
*Figure 4- Electrical Circuit for main body*

The user interface is simple, with pushbuttons, and a 3D model generated in SolidWorks depicts the design process graphically.
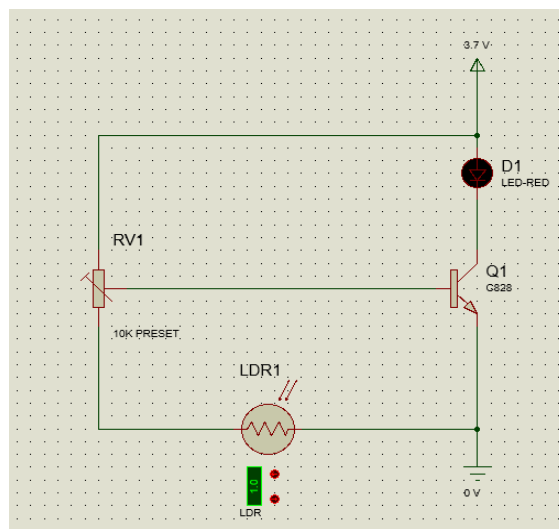


*Figure 5 – Electrical circuit for LDR*
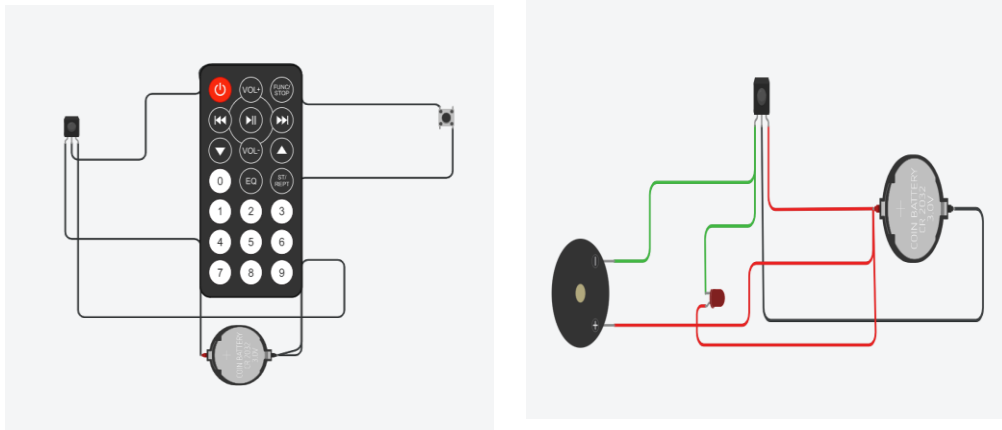
*Figure 6 – Electrical Circuit for wristband*

***Prototype Implementation***

The core circuit of the blind stick prototype is controlled by a switch attached to the Arduino Nano board and fueled by rechargeable batteries and a USB Charging module. The MPU6050 gyroscope, HC-SR04 ultrasonic sensor, Ublox NEO-6M GPS module, and servo motors are all powered by the Nano board. A voltage boost converter increases the power available to the remote-controlled relay module. Arduino pins are strategically coupled to micro servo motors, stand control, and GSM/GPS modules. The stand and LED functionalities are controlled by D7 and D8.
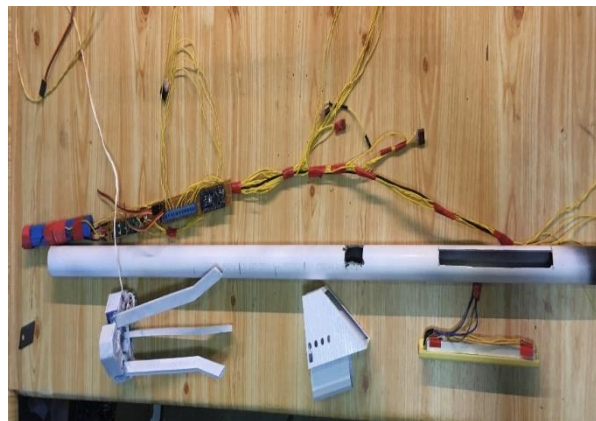


*Figure 7 – Main Body Structure*

The blind stick prototype's external light sensor circuit runs independently, powered by a 3.7V battery. An LDR, a 10K preset button, an LED, and a C828 transistor are all included. The positive terminal of the LED is connected directly to the transistor's collector. The preset button, which controls light detection, connects to the transistor's base. The emitter is grounded, and the positive end of the LDR completes the circuit via the preset button.
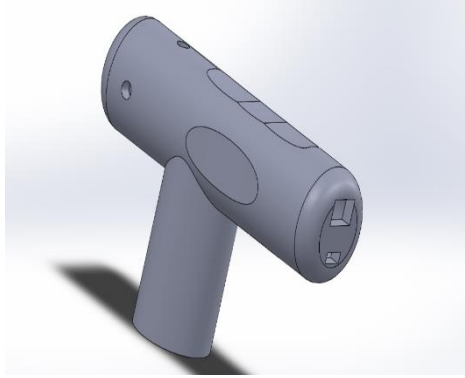
*Figure 8 – Designed 3D handle model*

The 3V battery-powered wristband circuit includes a buzzer, LED, and IR receiver in the stick. Signals from the wristband are detected by the IR receiver. The buzzer, LED, and IR receiver are all connected to the same negative terminal, while their positive terminals are connected to the battery. The negative of the IR receiver is grounded. An IR sensor, a push button, two 3V batteries, and a touch sensor are all included in the bracelet. The positive terminal of the touch sensor is connected to the battery, and the negative terminals of the touch and IR sensors are grounded, completing the circuit.



*Figure 9 – Basic Structure*

### Electrical and Software Implementation
Electrical and software implementation uses open-source software that is compatible with any operating system. The Arduino IDE makes it easy to create, compile, and upload in. ino formatted code to the Arduino board over USB.

**Results and Discussion**

The features included in the Smart Walking Aid prototype were tested against several parameters to ensure optimal functioning. The ultrasonic sensor, configured to detect obstacles at a distance of 30cm away from the smart stick, functioned accordingly, and the physical properties of obstacles did not directly impact the sensor's accuracy.

The combined operation of the GPS and GSM modules that were used to send an emergency message with the user's location coordinates, showed a slight delay in message transmission and this delay resulted due to the time taken to initialize the GPS module. To resolve an issue related to the voltage supply to the GPS module that was initially encountered when interfacing it with the prototype, a DC-DC buck converter was used to provide the module with a regulated voltage of 3.7V. An alternate method of transmitting this emergency message was facilitated with the use of an RF relay module. When tested for its functionality, it could detect RF signals sent from its transmitter within a 100m radius and send the message accordingly.

Tests carried out to determine the operational range of the IR remote control module that was utilized to locate the smart stick, demonstrated that the IR receiver was capable of detecting signals transmitted by its transmitter within a 3m radius. To ensure that the LED connected to the LDR-based circuit lights up only in the dark/night, its functioning was tested under various lighting conditions, and was proven to light up in the dark as required.For the image processing feature, the YOLO model was preferred over the basic neural network-based program due to higher accuracy in object detection and recognition as indicated in the simulations.
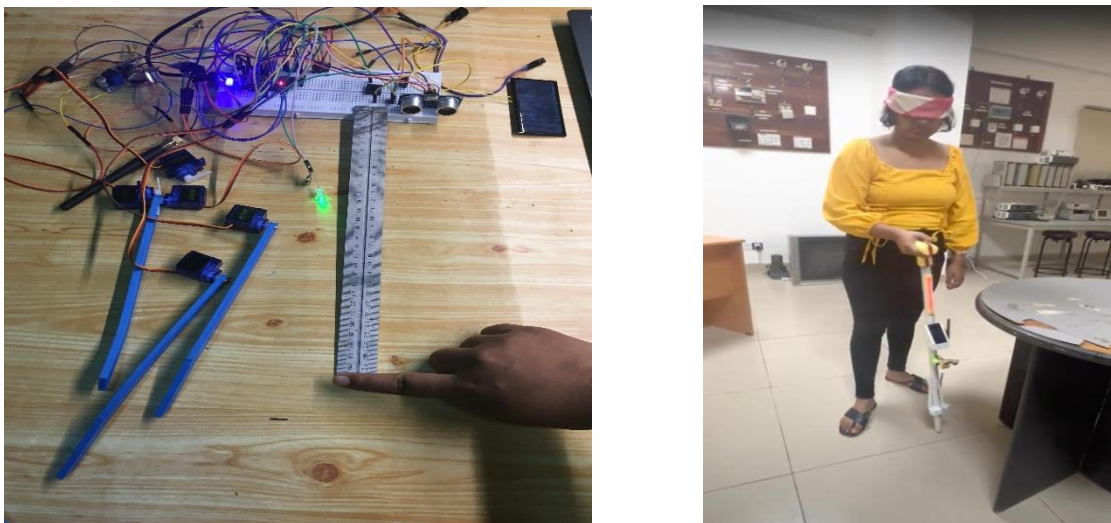


*Figure 10 – Ultrasonic sensor detecting.*

*Figure11 - Outcome from wristband*



*Figure12 - Outcome from stand*

**Conclusion and Recommendations**

This prototype was designed with the main aim of modifying existing smart walking aid solutions by introducing features that were decided after conducting a comprehensive literature survey, to ensure its improved functionality. This prototype can efficiently detect obstacles that are within the ultrasound sensor's detection range and alert the user of such obstacles through vibration modules placed in its handle. The ultrasound sensor was configured with a gyroscope that was used to detect its alignment and alter it accordingly to maintain 0,0 alignment along the horizontal and vertical axes respectively. It is also able to transmit an emergency message with the user's location coordinates to the user's caretaker by means of either a push button or an RF relay module.The designed smart walking aid comes with a wristband, which could be used to sound an alarm from the stick, to help the user to locate it when it gets misplaced. For the purpose of convenience, the smart stick was designed with a retractable tripod stand to keep it erect whenever the user decided not to hold it. This retractable stand could be activated by a push button positioned on the smart stick's handle. In order to overcome the anticipated limitations that would arise when implementing this design, literature studies were thoroughly conducted to provide insight on utilizing appropriate components and various interfacing statergies.

The primary goal of this prototype is to enhance existing smart walking aids by incorporating features identified through an extensive literature survey. The prototype efficiently detects obstacles within the ultrasound sensor's range and alerts the user through vibration modules in the handle. A gyroscope ensures alignment adjustments along the horizontal and vertical axes. It can transmit emergency messages with the user's location coordinates to a caretaker via a push button or an RF relay module. The accompanying wristband serves as an alarm to locate the stick if misplaced. For added convenience, the smart stick features a retractable tripod stand activated by a handle button. Thorough literature studies informed the selection of components and interfacing strategies to address potential implementation challenges.

The main scope of creating a smart walking aid is to provide an effective solution to assist visually impaired people to safely and independently navigate themselves. The integration of enhanced features into newly developed designs suggests an innovative future for the concept of smart walking aids.

High-performing sensors could be used to further improve the functionality of this prototype. For designs that detect obstacles through image processing, enhancing the object identification system and deploying dynamic image recognition algorithms can significantly improve the smart walking aid's functioning.

The stick could be built using superior and light-weight materials such as carbon fiber to prioritize comfort and convenience for the user.

Other advanced features that would positively contribute to the smart walking aid's improvement include, configuring a braille input device to allow the user to enter their destination address and facilitate convenient navigation, implementing the smart walking aid based on IoT (Internet of Things) to enable it to interact with other smart devices and ensure connectivity, and to configure a wireless audio device to the system to provide spoken instructions and feedback to the user.

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# SMART STREET LIGHT SYSTEM DESIGNED USING PIC MICROCONTROLLER & SPECIAL PWM MULTIPLEXING METHOD.

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## Abstract

At present, smart city & smart home technology becomes very popular as well as important field. The main target of smart home, city and relevant IOT related staffs is Energy Conservation. In addition, it may cause to improve the safety, easy to manage. If consider the power demand of the world, its exponential growth, its increasing day by day with high gradient. Typically, still use fossil fuel for electricity generation. Burning fossil fuels and emission has become main reason for global warming and climate changes. So, conservation of electricity is the best option to reduce the above bad impacts. If consider a middle scale city, it consumes tons of energy for lightings. By using this type of smart street light systems, able to reduces the power consumption for street lights with minimum cost. For this project and protype, PIC microcontroller has been used as main microcontroller and Attiny85 as sub microcontroller. IR sensors used for vehicle detection. A special multiplexer has been designed to enhance the number of PWM pins of PIC microcontroller to fulfill this task. Because in PIC 16 and 18 series microcontrollers, there are limited PWM capable pins available.

**Keywords:** PWM (Pulse Width Modulation), MOSFET (Metal Oxide Semiconductor Field Effect Transistors), Schmitt Trigger Inverter. IDE (Integrated Development Environment)

## Introduction

If consider a conventional street light system, after switched on by anyone manually, its light up with its maximum brightness until anyone off it. Its fully manual. It has only on and off states. These conventional methods are very inefficient and involvement of human is needed. So sometimes, because of mistakes lights can be light up in entire day time. So, smart street light systems very useful to reduce large power wastage. (WYZ, 2023) There are many types of lights has been used as street lights from past. As earliest, arc lamps have been used. After the invention of incandescent lights, arc lamps replaced by incandescent lights because of cool white light with better color radiations and long life. Likewise incandescent lights replaced by Sodium lamps then LEDs. Typically for commercial street light, 15 lux intensity is needed. LEDs capable to emit this much of light intensity with minimum power consumption or else efficiency is higher than other lights as well as LEDs have more life typically 50000 to 100000 hours. (Light Bulbs Unlimited, 2020). As smart street light system, there are many functionalities to perform. Such as, Able to detect the ambient light condition and distingue whether its day or night, if it identify as night, need to keep initial brightness of street lights which it enough for pedestrians, if any vehicle is detected, need to boost the light intensity and give good vision to drivers and after vehicle pass it need to reduce the brightness to previous

level. The boosting level as well as initial level (if any vehicle is not detected) is decided by ambient light condition. After sun rise lights should switched off automatically. These are the main functionalities. (admin, 2023)

**Methodology**

To perform above functions, first of all need to clarify all inputs, outputs, sensors that need to detect vehicles and ambient light condition and microcontroller for process. As requirement, need to sense the ambient light condition first. By using LDR able to convert the light variation into voltage variation in voltage divider configuration. For vehicle detection, IR sensors has been used. When going to select a microcontroller need to specially concern about many parameters relevant to this application such as number of GPIOs, PWM pins, output logic level, price and internal peripherals like ADC. The number of require GPIO, PWM pins are depend on number of lights that require to control. For this project, PIC16F877A 8bit microcontroller has been used. But there are only 2 CCP (Capture Comparator PWM) capable pins. If consider PIC 16 & 18 series, the number of PWM pins is limited to 1 to 4. So, need to enhance the number of pins to control more number of street lights. As the solutions there are two methods have been tested.

*Using PWM multiplexer –*

As first method, PWM multiplexer was used to multiplex the number of pins. Because this is the easiest method to enhance the number of PWM pins. There, 16 channel analog MUX has been used. If look at the construction of this multiplexer, for channel selection, there are 4 digital selector pins and one PWM input pin that need to multiplex. By supplying relevant logic states of selector pins, able to select require channel and then pass the PWM signal to selected channel. This is the working mechanism of a MUX. Many troubles were faced after the prototype was developed with general aftermarket PWM analog multiplexer. This type of multiplexers is good for LED decorations and entertainment but not suitable for this type of applications which stability is important. If output is not stable or else output comes with fluctuations, it can be cause to vision of drivers and dangerous accidents as well. (adam-meyer.com, n.d.)
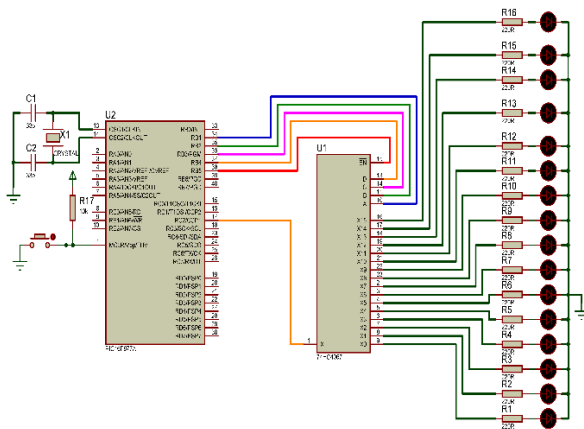


*Figure 1- Circuit Diagram*
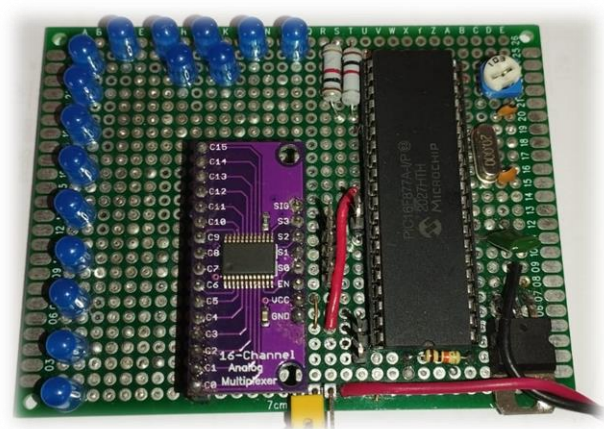


*Figure 2- MUX with PIC16F877A Prototype*
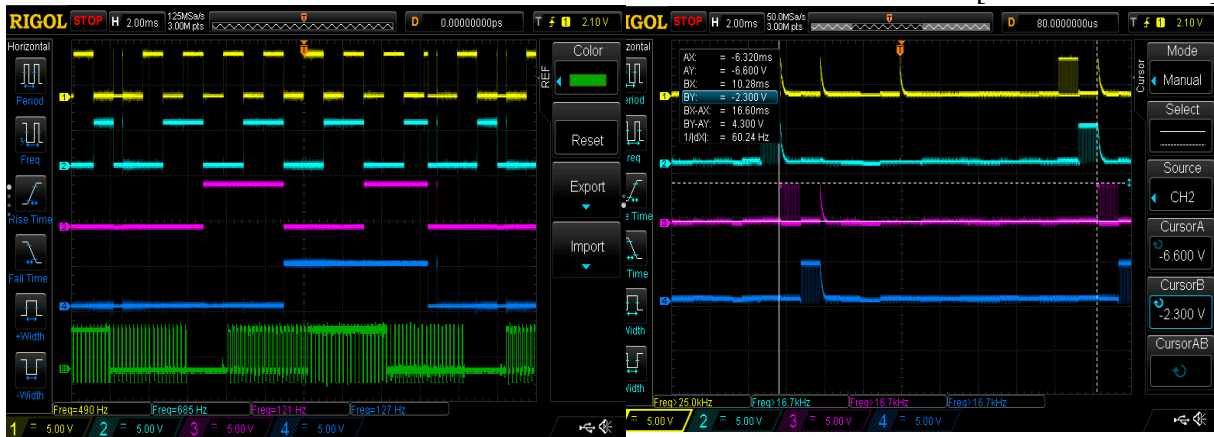
*Figure 3 - Inputs to MUX from PIC16F877A*  *Figure 4 - Output of 4 channels of MUX*

As illustrated in figure 3, these are the five inputs to MUX from PIC microcontroller. First 4 signals for selector pins and last channel is for PWM signal. As shown in figure 4, it's the output channels of first four channels of MUX. There are many important stuffs to note. First concern about the availability and time gap between corresponding two active outputs of a channel. If you closely look at the cursor values its 16ms.It is considerably large time gap respect to availability of relevant PWM signal. The blind time gap is ten times higher than the available time period. So output is out of control. Capacitors were uses to overcome that issue and to achieve smooth variation at the output. But that method wasn't succussed. There was a jitter as well as visible blinking at output and that can be dangerous to drivers. So smooth and steady control of brightness needed.

### Special technique for multiplexing –

As major requirements, outputs should be stable as well as able to easily enhance the number of outputs according to the requirement using single microcontroller. So, there are two common rails was used which is controlled by CCP1 & CCP2 pins of PIC16F877A. Both of these common PWM rails power up by two main power MOSFETs. By using this technique, could reduce the output jitter to considerable level. But when the number of IR sensors are increasing, there was a blinking effect was visible again at output. So, after that another sub microcontroller was used for brightness controlling and keep 16F877A as main microcontroller for vehicle detection. Because 16F877A don't allow to perform both vehicle detection and brightness controlling tasks. Then smooth control and fast response was achieved from system.

If take the big picture of the entire system, as components, MOSFETs, BJTs, Hex inverter, AtTiny85 and PIC16F877A have been utilized. MOSFETs are used to power up the common two PWM rails according to ambient light condition which is manipulated with the aid of AtTiny85 sub microcontroller. PIC16F877A is used to vehicle detection according to IR sensor readings and switch between two main PWM rails and manipulate relevant street light according to above conditions using BJTs. The Schmitt trigger hex inverter used to reduce to GPIO pin consumption of PIC16F877A and its useful to control more streetlights using single main microcontroller and reduce the overall budget of entire system.

*Design and Implementation -*
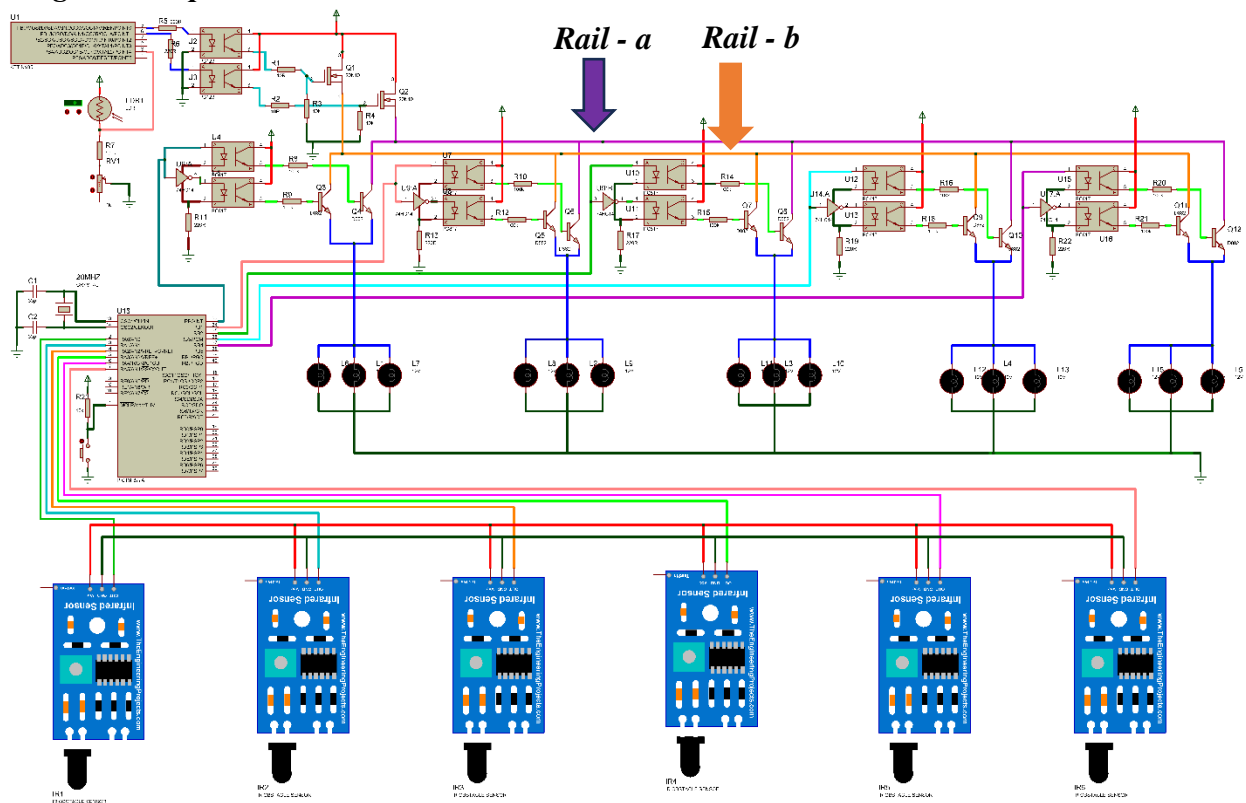


*Figure 5 - Full Schematic Diagram*

This prototype is designed exclusively for control five 12V lights. By using higher spec components with greater current & voltage handling capabilities, able to handle high power lights as well. As a solution for enhancing the number of lights, it can increase up to 15 streetlights. Because there are 33 GPIO pins available. If 15 pins use for sensors, rest of pins can be used for BJT controlling or else light handling.

*Schematic Diagram Explanation -*

According to above schematic diagram, there are two common rails as Rail-a and Rail-b. The Rail-a is powered by Q1 and Rail-2 is powered by Q2 Enhancement mode N- Channel MOSFECTs. These two MOSFETs driven by two separate PWM signals which is changing the duty cycle according to the environment light condition. If rail a is considered, it is the common rail which varies the duty cycle from (0 – 10) %. It is not exceeding the 10% because 10% brightness is good enough for pedestrians.  If any vehicle is not detected, the intensity of the lights is decided by rail-a according to ambient intensity.  If rail-b is considered, its duty cycle is changed from (0 - 100) % because drivers need a good vision to see the pedestrians and other stuffs. The rail-b is also controlled according to ambient light condition. So, both rails response to present light condition to save power.  All other NPN BJTs used to switch the relevant rails according to sensor inputs. As BJTs, D882 has been used for switching between rail a and b. For each output, there are pair of transistors used with complementary relationship.
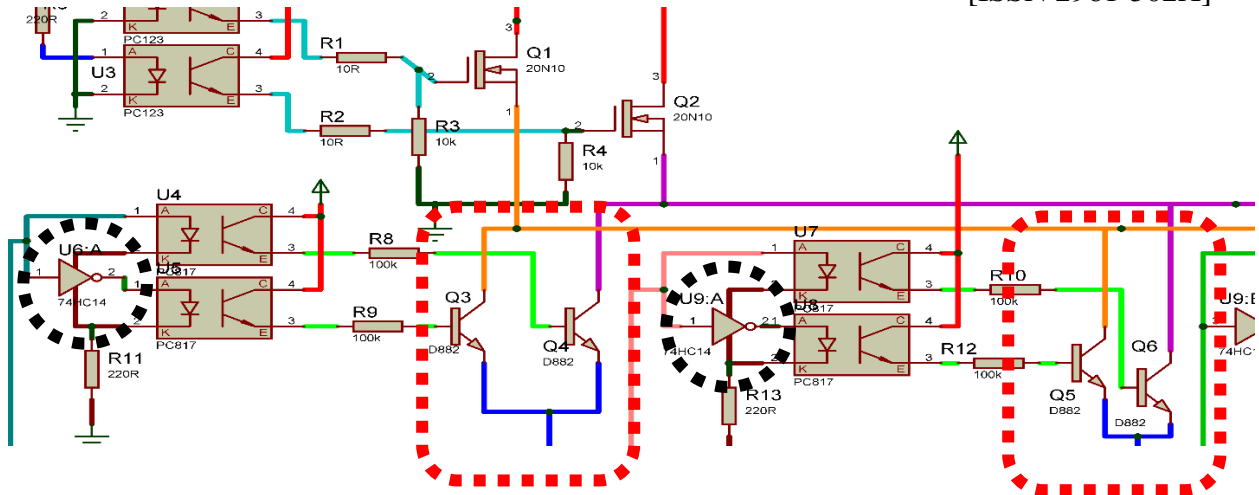
*Figure 6 - Operation of BJTs and Inverters*

74HC14 Schmitt triggered hex inverter used to feed the complement of microcontroller output to other transistor. Simply, if any lamp is driven by rail-a, it should disconnect from rail-b. Otherwise, current will loop between rail-a and b. According to this method, able to enhance the number of channels by connecting transistor pairs to common rails and need the change the specification of main Q1 and Q2 MOSFETs according to power requirement.

All inputs (IR sensors) are connected with PORTA from A0 to A5. When dealing with PORTA for GPIO operations (General Purpose Input Outputs) it is necessary to disable other peripherals specially ADCs. All outputs connected with PORTB from B0 to B4. The main
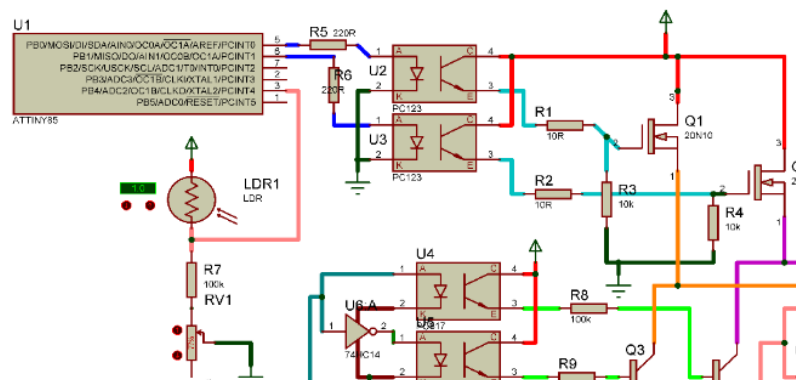


*Figure 1 - LDR Operation*

operations relevant to vehicle detection is performed by PIC16F877A. For PWM, another 8-pin microcontroller was employed which is AtTiny85 which is one of the smallest IC of Atmel company. It allows for 3 analog inputs and 2 PWM outputs. These two PWM outputs used to manipulate the Q1 and Q2 PWM power MOSFETs. And single analog input to feed the LDR reading.

**_Real World Implementation -_**
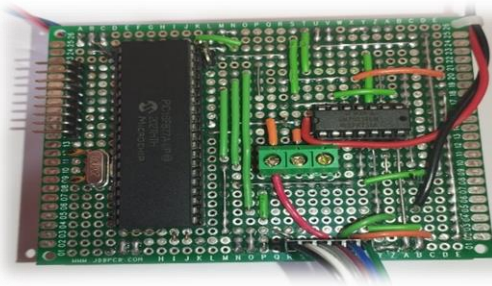


_Figure 7 - PIC16F877A Main Microcontroller & Hex inverter 74LS14_
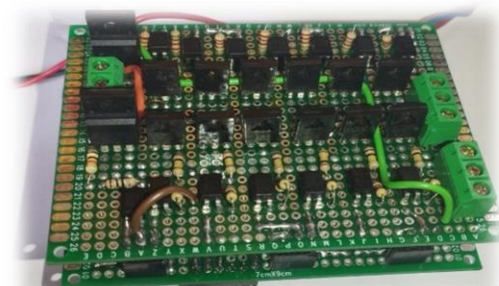


**_Figure 8- Power Electronic controlling board_**
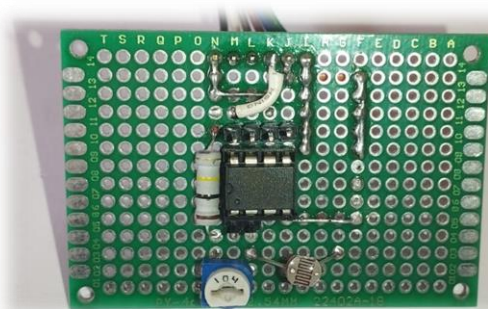


_Figure 9 - AtTiny85 base PWM controller_
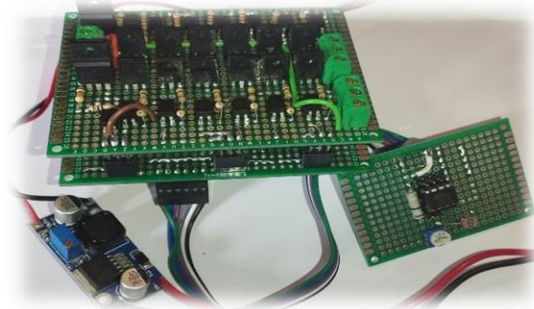


_Figure 10 - Entire System Controlling Board_

**_Specialty of designed multiplexing method -_**

If common MUX considered which is available at market, its primarily designed for entertainment purposes, particularly for led designs and decorations so, propagation delay isn't a critical parameter. Typically, it's not matched to this type of applications which is stability is important. Because of the considerable propagation and selection delay its not suitable. The main difference of the designed MUX is stability and low fluctuations and reliability. Due to the presence of two common rails, manipulating the light intensity individually is made easy without causing interruption to the main vehicle detection program, resulting in a higher response for vehicle detection. As well as expanding the number of lights is convenient without affecting the connected lights. These are the main specialties of the designed multiplexing method.
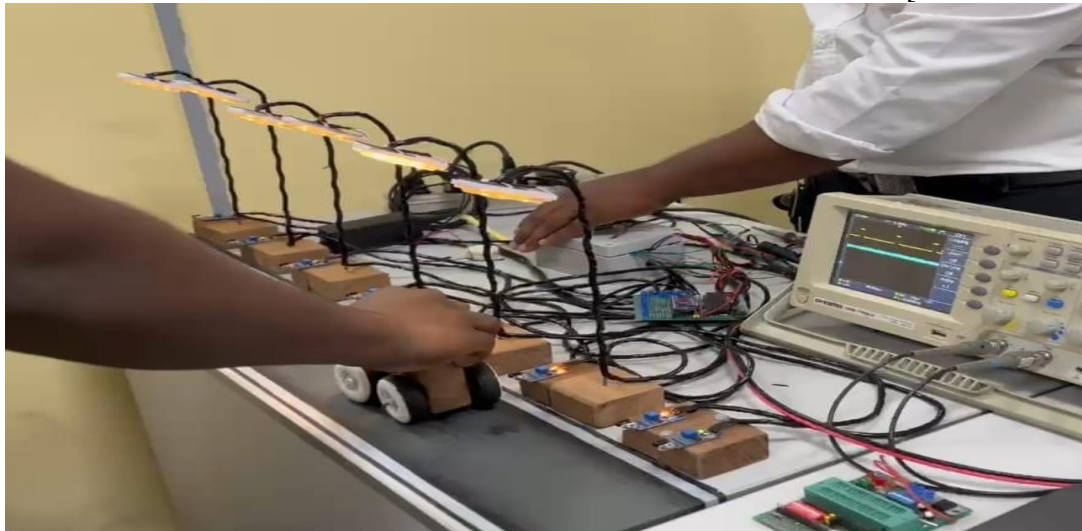
*Figure 2 – End result.*

**Result and Discussion**

First time, as internal peripherals (CCPs and ADCs) of PIC16F877A was used. But there was a fluctuation at output. Because microcontroller updates its registers in each execution cycle relevant to CCPs and ADC. Because this microcontroller is single core. It not allows for parallel processing. Therefore, another microcontroller is used in order to enhance smoothing capacity and reliable of the system. Optocouplers used to keep the Galvanic isolation between high voltage side (12v – 100v) and low voltage side (5V- microcontroller side). As well as optocouplers work as totem pole driver. Because 20N10 (Q1 & Q2) are not logic level MOSFETs. So, it needs around 10V to fully switch on. The biasing voltage & current of PC123 optocoupler is 1.2V & 20mA so, microcontroller able to handle the output without having stress.

**Conclusion and Recommendation**

For this prototype, normal IR sensors has been used which have very low range (few centimeters). In real world application, it can't use for vehicle detection. So instead of the normal IR sensors, industrial IR sensors should be use for better vehicle detection.

As well as in this system, two corresponding nearby placed IR sensors (which vehicle can instantly overlap both sensors) at the start to distingue pedestrians and vehicles. If two pedestrians cross both sensors at instant, system won't be able two understand whether its vehicle or pedestrian. So, to overcome that problem need to use PIR sensors.

Instead of wired connections, if able to use any wireless communication method like RF, its more convenient to use. Because if its remotely operational, only power supply needed.

Also, signals from IR sensors can be attenuated because of the long length of wires. Because these sensors working under 5V logic level. So, in real world implementation necessary to use repeaters to amplify the signals. The best option is wireless communication method can be used for all sensors as well.

Need to improve feedback mechanism to self- diagnosis. It can be very useful for fault identification.

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# DESIGN AND IMPLEMENTATION OF AN AUTOMATED SOLAR PANEL CLEANING ROBOT

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## Abstract

This study presents the development of an Automated Solar Panel Cleaning Robot to optimize solar panel efficiency. Focused on addressing the limitations of manual cleaning methods, our interdisciplinary approach integrates mechanical design, robotics automation, and sensor technology. The robot employs a cautious yet effective cleaning mechanism with a non-corrosive solution, ensuring surface preservation. A Bluetooth-controlled interface enables precise navigation and cleaning operations. Methodologically, the robot's framework, wheel traction, cleaning mechanism, and component selection are systematically detailed. Key findings emphasize the robot's adaptability to varying panel sizes, its stability, and operational safety. This research contributes an innovative, cost-effective, and eco-friendly solution vital for sustaining solar energy systems.

**Keywords**: Robotics Automation, Mechanical Design, Solar Panel Cleaning Techniques

## Introduction

With the ever-increasing demand for clean and renewable energy sources, solar power has emerged as a crucial solution to combat environmental challenges and reduce carbon emissions. Solar panels, as key components of solar energy systems, play a pivotal role in capturing and converting sunlight into electricity. However, their effectiveness can be significantly hindered by the accumulation of dirt, dust, and other contaminants on their surfaces. Regular and efficient cleaning of solar panels is essential to maintain their optimal performance and maximize energy production. In response to the need for an effective and sustainable solution, it's proposed for a development of a Solar Panel Cleaning Robot. Our project focuses on creating an innovative robotic system that can clean solar panels with the utmost care and precision. The primary objective is to prevent damage to the delicate surface of the solar panels while ensuring the effective removal of contaminants. To achieve this, the robot is designed to apply cleaning forces cautiously, utilizing a specially formulated cleaning liquid that is both efficient and non-corrosive. The Solar Panel Cleaning Robot project brings together a multidisciplinary team, pooling expertise in mechanical design, robotics automation, sensing and perception, electrical and power systems, control systems, and safety features. Through seamless collaboration, the aim to create a reliable and eco-friendly cleaning solution for solar panels, contributing to the sustainable energy landscape. In this research, the theoretical foundations and technical aspects are explored for underpinning the Solar Panel Cleaning Robot's development.

The accumulation of dirt, dust, and contaminants on solar panels reduces their efficiency and energy output. Manual cleaning methods are inefficient, labor-intensive, and costly, particularly for large-scale installations. An automated cleaning system is needed to ensure maximum energy generation while minimizing costs and safety risks. By leveraging advanced engineering technologies, the development of a solar panel cleaning solution becomes essential. This approach optimizes energy production, reduces expenses, and promotes a sustainable and efficient maintenance strategy for solar power systems.

The objectives include conducting literature research to explore current trends and challenges in solar panel cleaning robots, proposing a conceptual design based on the findings, designing and implementing the robot, and rigorously testing and analyzing its performance. Through interdisciplinary collaboration and technological innovation, this project endeavors to contribute to the development of a cost-effective, efficient, and environmentally friendly solution for optimizing solar panel efficiency and maximizing energy production. This project aims to design, develop, and implement a solar panel cleaning robot that can be controlled via a Bluetooth app. The robot autonomously identifies dirty or contaminated areas on solar panels and performs effective cleaning operations using the robot.

**Methodology**

In Methodology, the materials and components have been carefully selected to ensure the effective use of a 20*20mm V slot Aluminum box bar as the robot's profile provides a robust and lightweight framework that's crucial for structural integrity and easy assembly. This aluminum framework allows us to build a reliable foundation for our robot while keeping it relatively lightweight. For the robot's movement, four toy car tire wheels have been chosen, each individually controlled by DC motors. These wheels offer excellent traction on the solar panel surface, which helps prevent the robot from slipping or straying off its intended path during cleaning. Additionally, four nylon tires on the robot's edges further enhance its grip and stability.

The cleaning mechanism, located in the middle of the robot, is also controlled by a DC motor. This mechanism is designed with soft brush material to avoid any risk of scratching the photovoltaic panel's surface. The weight distribution of the robot is evenly supported by the brushes themselves, ensuring balanced and secure operation.
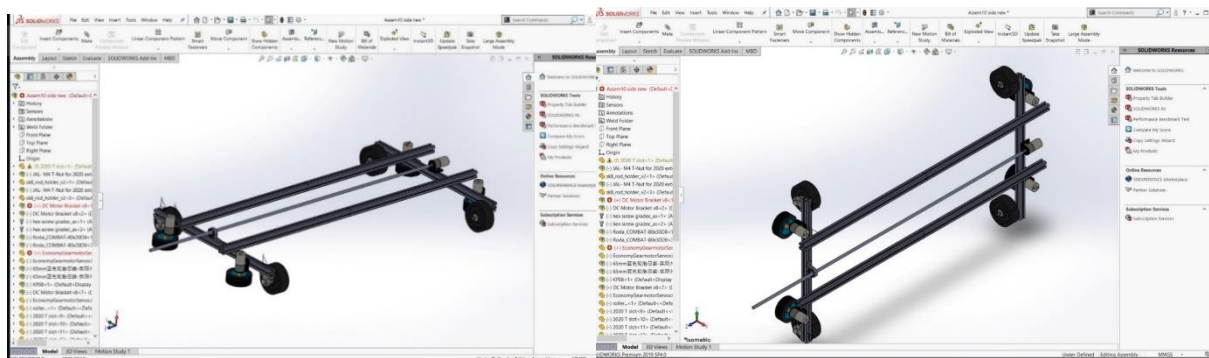


*Figure I Mechanical Design*

Our robot is adaptable to various panel sizes due to its extendable feature, providing flexibility for different solar panel configurations. It's equipped with a microcontroller, an L293D motor controller, an HC06 Bluetooth module, a 10A power supply, a water pump, and a water tank. These components work together to facilitate forward and backward movements, which can be controlled via a simple Bluetooth app. This technology ensures that our robot can be operated safely and effectively without causing any damage to the photovoltaic panels.

Weight Calculation:

Volume (V):

$V = 20$ mm x $20$ mm x $200$ mm $= 80,000$ mm³

Weight of aluminum (W_aluminum):

W_aluminum $= 80,000$ mm³ * (1 in³ / 16,387.1 mm³) * 0.098 lb/in³

Thermal Conductivity:

Assume $\Delta T = 10$ °C and $L = 200$ mm $= 7.874$ in:

$Q = k * A * \Delta T / L$

The surface area (A) can be calculated as 2 * (length * width + length * height + width * height).

Cost Considerations:

Specific cost per unit weight for the aluminum alloy:

$C =$ Cost per unit weight * W_aluminum
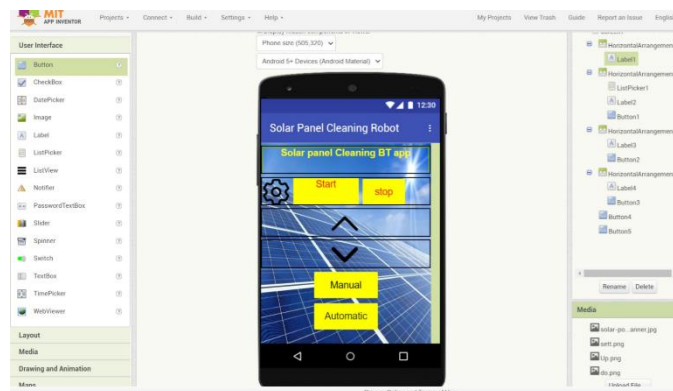


*Figure II Self-designed Bluetooth App*

**Design and Implementation**

In the design description section of the research paper, meticulous attention was given to crafting the Automated Solar Panel Cleaning Robot. The robot's framework utilized a lightweight yet sturdy 20*20mm V slot Aluminum box bar, ensuring structural integrity and ease of assembly. Equipped with four toy car tire wheels controlled by DC motors, it boasted exceptional traction on solar panels. Employing a soft brush cleaning mechanism and precise weight distribution ensured surface preservation. Integration of a microcontroller, Bluetooth module, and water system facilitated seamless and safe operation via a user-friendly app. This comprehensive design allows adaptability to various panel sizes, ensuring effective and damage-free cleaning.

*Hardware Implementation*

The hardware implementation phase of our research involved meticulous component selection to ensure the Solar Panel Cleaning Robot's efficiency. The framework utilized a robust 20*20mm V slot Aluminum box bar for structural integrity and easy assembly. Four toy car tire wheels, each independently powered by DC motors, provided exceptional traction on solar panels, preventing slippage. Incorporating a soft-bristle cleaning mechanism centrally controlled by a DC motor ensured surface preservation. Equipped with essential components like a microcontroller, motor controller, Bluetooth module, water pump, and tank, the robot facilitated controlled movements via a user-friendly Bluetooth app, guaranteeing safe and effective operation during solar panel cleaning.
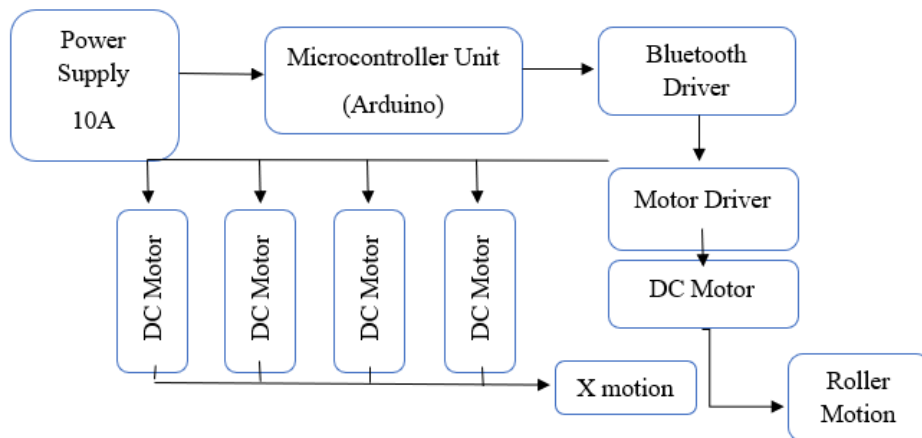


*Figure III Block diagram for the Methodology of    designed solar panel cleaning robot*
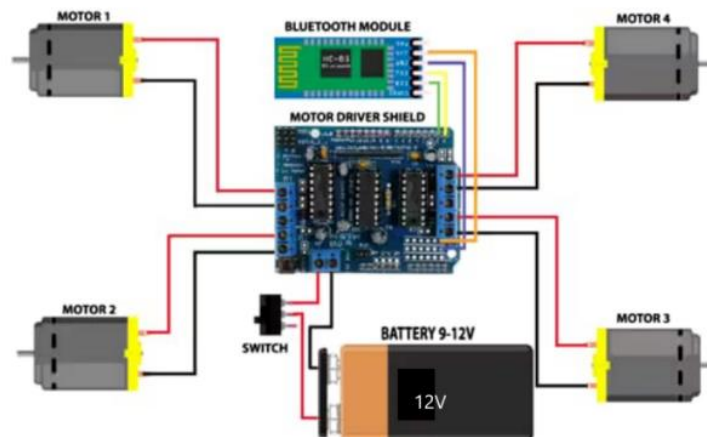


*Figure IV Circuit Diagram of Solar Panel Cleaning Robot*

***Software Implementation***
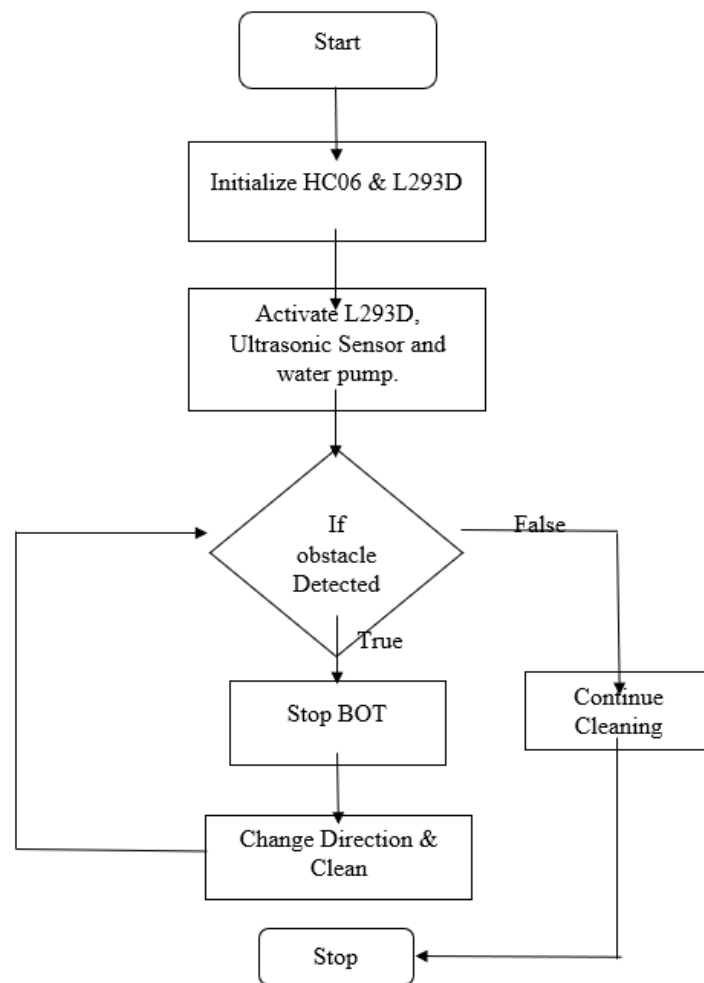


*Figure V Flow Chart*

**Results and Discussion**

The designed cleaning robot is capable of moving bidirectionally inorder to clean the solar panel using a soft and safety brush cleaning mechanisms. If an obstacle is detected, it's capable of changing the direction by itself and continue to clean the panel. Once the dust is removed, the water pump system is activated to clean the panel. In the prototype, the water is used in the pump, but if needed the suitable chemical could be used to avoid corrosion and for cleaning purpose. The complete system can be controlled by a bluetooth app. And the cleaning robot can be operated in automatic mode or manual mode. The controlling system and the battery is kept in the control box.
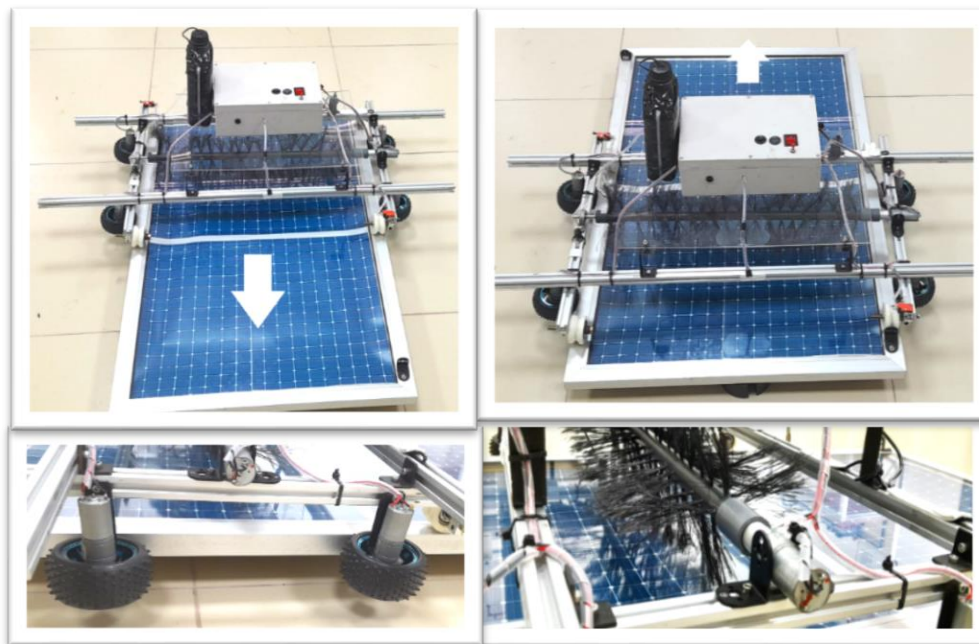
*Figure VI Solar Panel Cleaning Robot Prototype*

**Conclusion and Recommendation**

This study introduces and develops an innovative solution, the Automated Solar Panel Cleaning Robot, to meet the crucial need for efficient and sustainable maintenance of solar energy systems. Interdisciplinary collaboration in mechanical design, robotics automation, and sensor technology has led to the meticulous crafting of a robot capable of delicately cleaning solar panels with precision and care. The robot's design features a robust yet lightweight aluminum framework, ensuring structural integrity and ease of assembly. Equipped with four toy car tire wheels individually controlled by DC motors, the robot achieves exceptional traction on solar panel surfaces, enhancing stability and preventing unintended deviations during cleaning operations. Additionally, the inclusion of a soft brush cleaning mechanism, centrally controlled by a DC motor, ensures surface preservation, mitigating any risk of damage to the photovoltaic panels. The hardware implementation phase focused on careful component selection, prioritizing efficiency and reliability. Integration of essential components such as a microcontroller, motor controller, Bluetooth module, water pump, and tank enables controlled movements and precise cleaning operations through a user-friendly Bluetooth app interface. This technological framework guarantees the safety and effectiveness of the robot's operation, promoting a sustainable and eco-friendly approach to solar panel maintenance. This research presents a cost-effective, efficient, and environmentally friendly solution to optimize solar panel efficiency and maximize energy production. The Automated Solar Panel Cleaning Robot not only overcomes the limitations of manual cleaning methods but also sets the stage for sustainable maintenance strategies in the renewable energy sector. As the demand for clean energy continues to escalate, this innovative approach underscores the critical role of technological advancements in sustaining solar energy systems for a greener future.

Further development of Solar panel cleaning robots will aim to design the smart solar cleaning automation robot to efficiently clean solar panels in large solar plants. It follows a systematic cleaning process where it begins by cleaning one row of large solar panels. Once the cleaning of a row is completed, it moves to a mobile platform or cart, which serves as a guidance system. The robot is guided along a path with tracks or grooves on this platform, allowing it to transition to the next row of solar panels for cleaning. This sequential approach ensures thorough and methodical cleaning of solar panels across the entire plant.

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# HOME FETAL MOVEMENT AND DISTRESS DETECTION

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**Abstract**

The burden of losing a baby is not just local to Sri Lanka, but is a universal nightmare. Existing clinical fetal monitoring devices are costly, inaccessible, emitting radiation, and prone to false positives, thus the Home Fetal Movement and Distress Detection device was developed. Its primary objective is to provide continuous, comfortable, and non-invasive fetal monitoring during the final trimester for expectant mothers worldwide. Employing an Arduino UNO, a single accelerometer for fetal movement, and a specialized fPCG acquisition board with low-cost microphone sensing technology for monitoring fetal heart rhythm, the device includes a GSM-based alert system for instant distress notifications to the mother, proxy, and emergency services. Using MATLAB for digital signal processing, zero false negatives in detecting fetal movements were achieved, validated against an open-source database. Simulation and hardware testing substantiate the efficacy of the fPCG acquisition board and alarm system, ensuring the prompt identification of fetal distress.

**Keywords:** Fetal Distress, Fetal Heart Rate and Movement detection, GSM alerts, Home monitoring, Self-applicable.

## Introduction

The stillbirth rate (per 1000 births) in Sri Lanka has increased from 6.54% in 2015 to 6.9% in 2021 (Family Health Bureau Sri Lanka, 2021) despite global technological breakthroughs in remote and home-health monitoring through these past 7 years. This burden is not local to our island but all around the world where a stillborn rate of 1.9 million was recorded in 2019 alone, making such cases "Neglected Tragedies" (UNICEF DATA, 2020).

Reduced fetal movements or signs of fetal distress can go unnoticed by the mother on the account of her still being able to feel her baby's movement when she shifts position, even when fetal death is confirmed (NHS,2021). A study conducted by Monasta et al. (2020) revealed that 72% of IUFDs occurred above 30 weeks of gestational age and concluded that adoption of evidentiary diagnostic protocols could help in preventing future Intrauterine Fetal Deaths (IUFDs) and reduce the diagnostic gap between its known and unknown causes, revealing the importance of continuous monitoring. The current standard of care, cardiotocography (CTG) requires accurate probe placement by a trained professional and the lack of automated analysis, episodic measurement with the necessity for serial clinical visits, particularly burdens mothers in rural areas, limiting access to perinatal care. Studies link CTGs of compromised fetuses to false positive assurances and an inability to prevent catastrophic perinatal events despite increased caesareans (Kwon & Park, 2016) and while ultrasound being considerably safe, its

recommended selective use raises the need for more frequent, economic fetal health-and-distress monitoring, even more so at home-environments.

This device will help prevent IUFD, reducing diagnostic gaps and fetal abnormalities. It enhances fetal survival, especially in areas with limited hospital access, promoting higher compliance with prenatal care and alleviating maternal psychological stress. Economically, the cost-friendly design ensures accessibility to continuous monitoring for diverse socio-economic backgrounds, minimising hospital visits and associated expenses. This approach is particularly reassuring for financially constrained expecting mothers, reducing transport costs and ensuring peace of mind with continuous at-home monitoring.

Through a review of similar electronic fetal monitoring devices by Mhajna et al.(2021), Delay et al.(2021), Abeywardena et al.(2021), Yang et al.(2019), Yuan et al.(2019), Lai et al.(2018), Khandoker et al.(2018) and Boeing et al.(2012) as pictured below in Figure 01, the fetal signal processing algorithm, optimum type, number and places of sensors were determined to ensure low complexity, power consumption and high reliability, cost effectiveness, ease of operation, portability and comfort of the device.
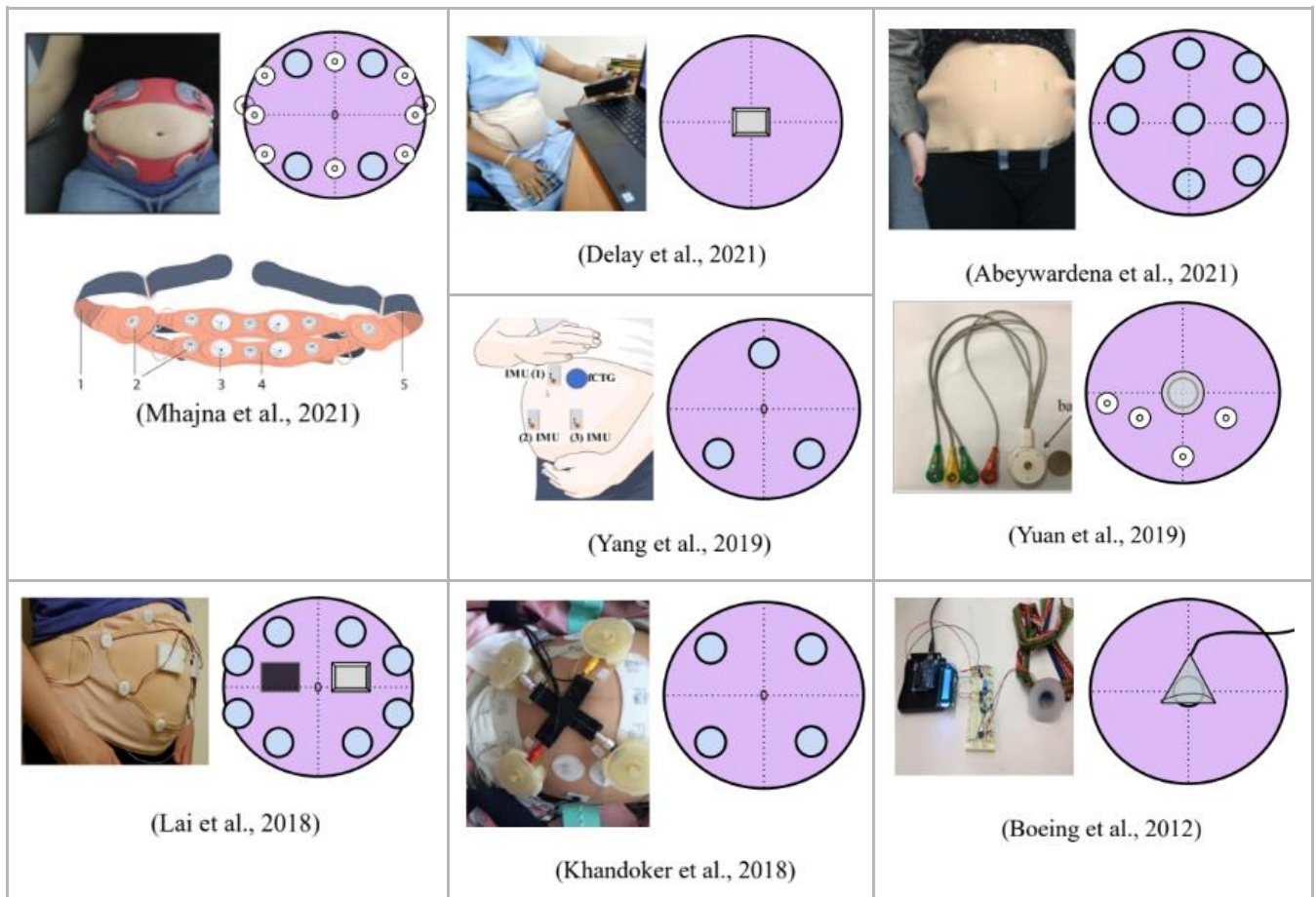


*Figure 01: Visual Comparison of fetal monitoring devices by different researchers.*

**Methodology**

Figure 02 below shows the overall block diagram for hardware implementation of the device. It consists of a single digital MPU6050 accelerometer to count fetal movements (FMs), placed on the middle of the maternal abdomen where fetal kicks are most frequent, a sensitive CA0106 electret condenser microphone to record the fetal heart rate (FHR), placed slightly lower, where fetal heart sound is loudest, capable of detecting FHR frequencies around 20-200Hz (Boeing et al.,2012). The analog output from the electret is first pre-processed using an Amplifier Filter Unit(AMU) for data acquisition before being sent to the control unit—an 8-bit Arduino UNO. A laptop is used for signal processing raw accelerometer data which is transmitted back to the system through serial communication to feed the fetal distress detection algorithms. Outputs include a 16x2 LCD interfaced with an I2C module for displaying FHR and FM count, an alarm system; LEDs alert the patient at home while emergency services (EMS) and the smartphone of a proxy contact are alerted using a power efficient SIM800L GSM module. An On/Off button initiates/halts the monitoring process and an external battery is used for long term, portable recording.
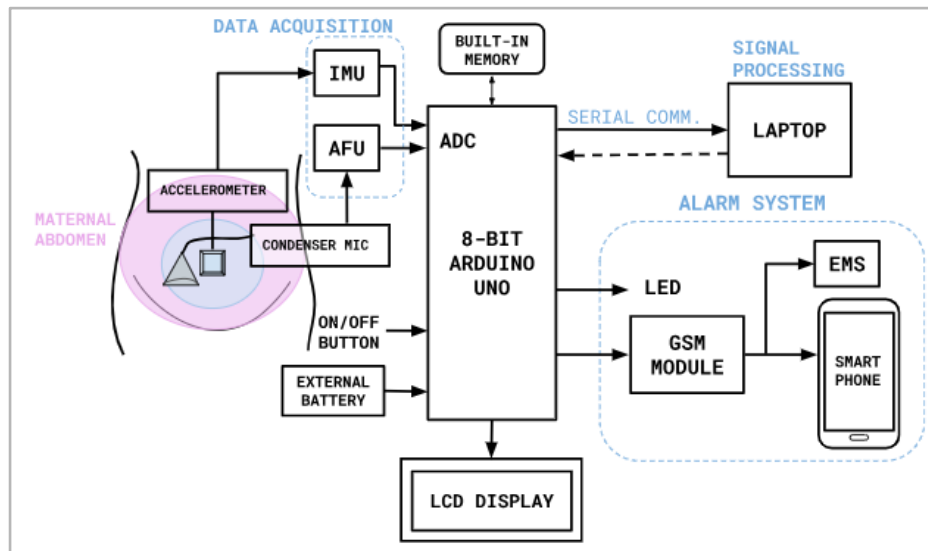


*Figure 02: Block diagram*

*1)Pre-amplification and Filtering- Fetal Heart Rate Detection*

The condenser microphone cannot be directly interfaced with the Arduino UNO; the signal must be pre-amplified to increase the amplitude of the fetal heart to a voltage that can be detected by the MCU and filtered to retrieve the useful frequencies of the signal for anomaly detection.

To construct the amplifier, the Op-Amp NE5532 was used due to its 60dB superior open gain and requiring an adequate power supply of 5V from the UNO. The equation below was used to set a gain of 2, keeping the impedance of R1 = 0 and R2 = ∞.

$$Gain\ (A_V) = \frac{V_{OUT}}{V_{IN}} = \ 1\ + \frac{R_1}{R_2}$$

To remove the high noise attenuation of the amplified signal, two second order Sallen Key filters were cascaded together to form a 4<sup>th</sup> Order low pass Butterworth filter due to its steep

filter response. This allows the signals with $f_c > 200$Hz to be attenuated at a higher magnitude, allowing the retrieval of just the fetal heart sound at intensity $> 60$dB. For this, the LM741 was chosen as it is low cost, freely available and fits the required specifications such as the required Gain Bandwidth, (GBW) $\geq 100 \times 200(f_c) = 20$kHz.

As custom capacitor values are hard to come by the Sallen-Key design simplification where Gain=1 and filter components are set to ratios was followed by letting *R1=mR, R2=R, C1=C, C2=nC* and *K=1* and using the equation:

$$f_c = \frac{1}{2\pi RC\sqrt{mn}} \ and \ Q \ = \frac{\sqrt{mn}}{m+1}$$

To ensure proper functioning of the amplification and filtration circuit, a simulation was carried out using Proteus™ Software (Figure 03).
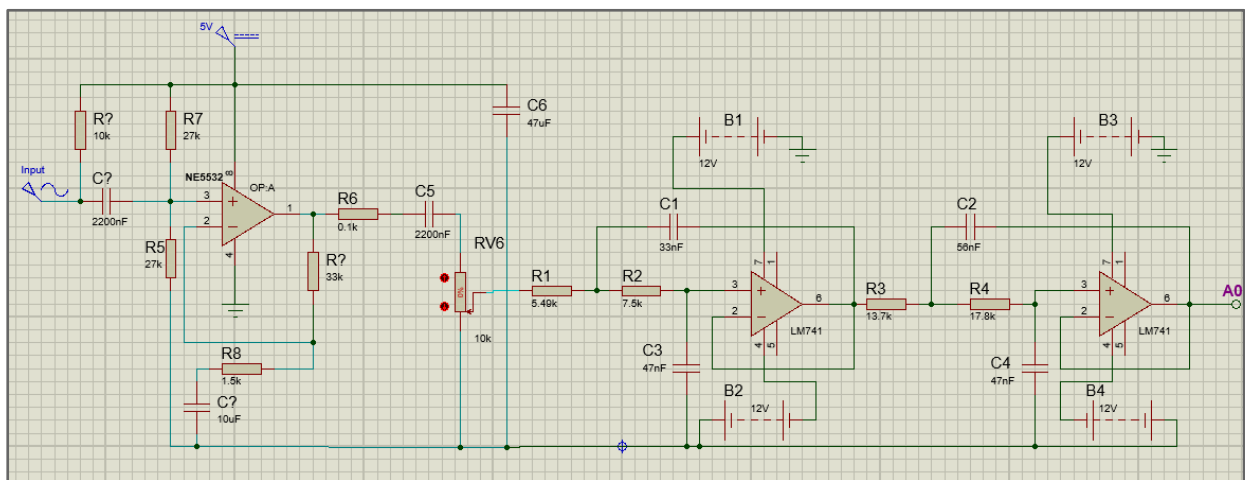


*Figure 03: Simulation set up for fPCG acquisition circuit*
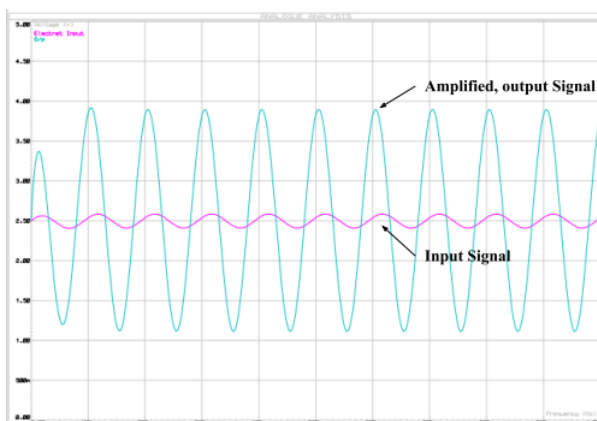


*Figure 04: Time Domain simulation of designed fPCG preamplifier.*
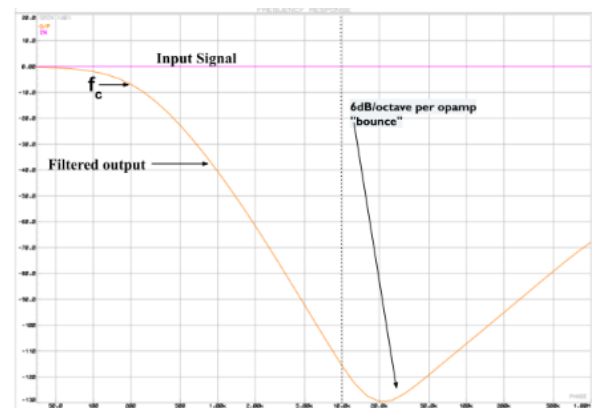


*Figure 05: Frequency response of designed fPCG 4th Order Butterworth LPF.*

Both the filter and amplifier show the desired amplification and steep frequency response, the two circuits were implemented as one for acquisition of fetal heart sounds for FHR monitoring.
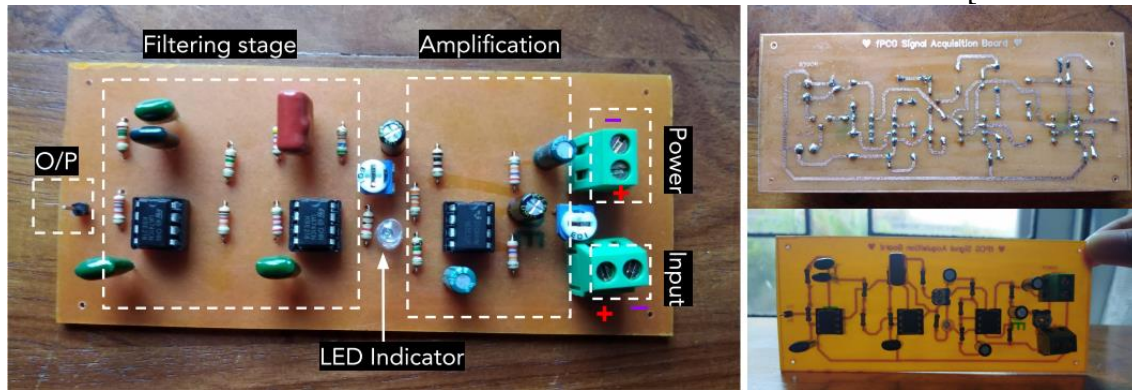
*Figure 06: Built fPCG acquisition PCB; front and back view*

*2) Acoustic Cone Amplifier - Passive Amplification*

Due to the variety of sounds picked up by the microphone such as external (ambient) noise and distortion caused by maternal movement artefacts, a hollow cone (Figure 07) that mimics the curvature of the Pinard fetoscope and whose inner dimensions fit the electret, is used for passive amplification of the fPCG signal.
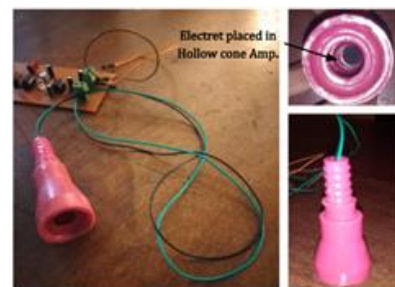


*Figure 07: Acoustic cone amplifier*



*Figure 08: Designed maternal belt*

*3) Maternal Belt- Long Term Monitoring*

A comfortable, wide elastic belt was fabricated using ultra-soft Jersey-knit material, chosen for its non-allergenic, breathable, and elastic properties. The tan colour matches Sri Lankan skin tones. The belt accommodates various body sizes, maintaining sensor positions with an embedded accelerometer and condenser on rubber foam. Straps made of soft cotton, hand-sewn on either side, secure the belt around the abdomen for a proper fit.

*4) Alarm System- Indicating Fetal Distress*

As the compact SIM800L GSM module runs on a 3.7-4V supply, an external power supply of a single 3.7V 1000mAh Lithium battery was used. A 16V 2200uF electrolytic capacitor helps maintain a stable power supply for the module during transmission bursts and a PCB Antenna allows uninterrupted transmission when encased.
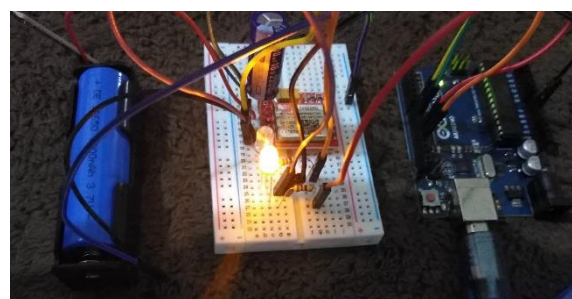


*Figure 09: GSM module implementation*

To implement text messages, a Dialog 4G SIM card was inserted, RxD and TxD pins connected to pins D8 and D9 of the Arduino respectively (Figure 09) and a void function

"sendTextMessage" was created to send customised alert messages to the proxy contact and EMS when the FHR and movement count relayed fetal distress symptoms. For displaying FHR and FM count, an I2C module was interfaced with the 16x2 LCD for a faster data display rate. This reduces the number of pins required and connects to SDA and SCL pins of the Arduino. To connect to the Arduino I2C bus for serial display, the I2C address was first determined. Three 5mm LEDs were used to indicate different warning signs, Green - Reassuring fetal status; Yellow - Deteriorating fetal condition (Low FM count) and Red - Fetal Distress (Emergency status).

### 5) Digital Signal Processing- Fetal Movement Detection

An open-source dataset by Pierre et al. (2019) containing signals from 16 pregnant mothers via a single accelerometer sensor ($f_s$=500Hz) on the abdomen was utilised. The figures below outline the steps involved in detecting FM using MATLAB. Figure 10(a) visualises the fetal movement signal in all 3 axes which is then fused in (b) to retrieve the main signal using the equation:

$$A_{xyz} = \sqrt{(A_x)^2 + (A_y)^2 + (A_z)^2}$$
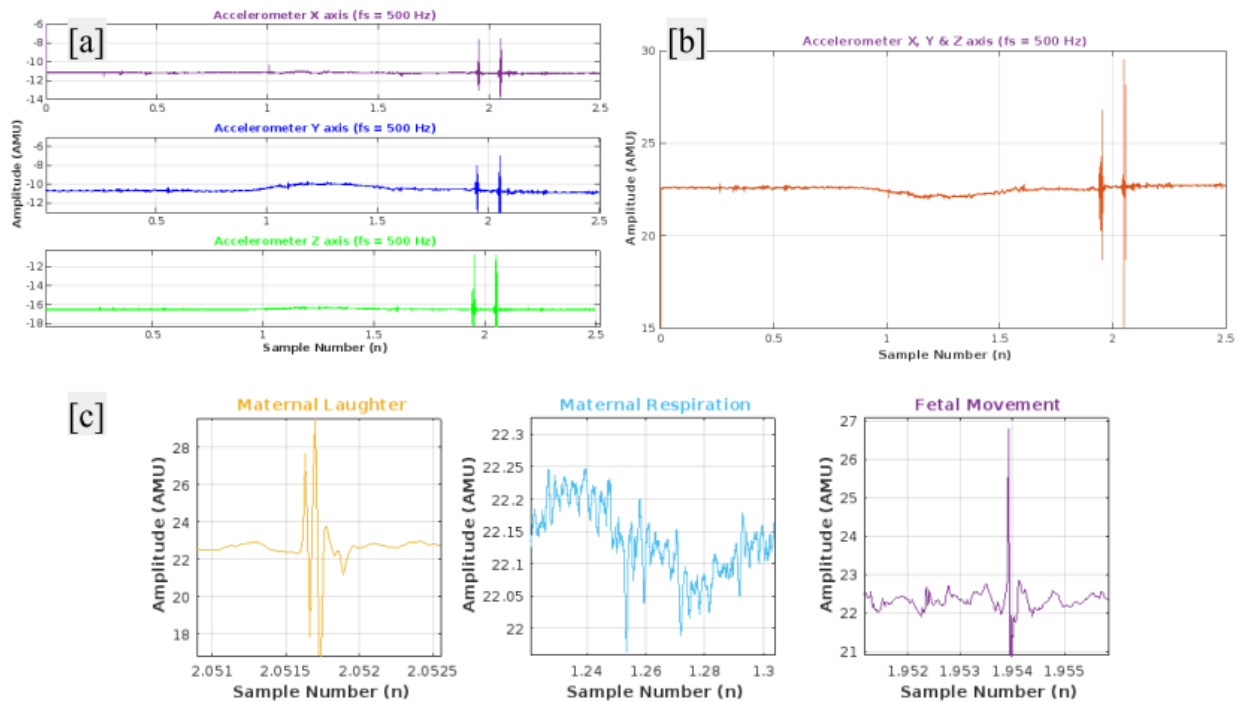


*Figure 10:(a) Data in xyz axis (b)Fused accelerometer data (c) Noise embedded in FM signal*

Filtering was done using a High order IIR (Notch) filter to remove high frequency artefacts pictured in Figure 10(c) such as maternal laughter which is similar in amplitude (≈28 AMU) to fetal movement (≈27 AMU) and low frequency breathing movements (22.25 AMU) while extracting the FM signal using the following digital filter transfer function:

$$h(n) = \frac{1}{T}\left[\frac{1-Z^{-1}}{1-0.99Z^{-1}}\right]$$

Once the signal is successfully detrended as shown in Figure 11(a), the dataset containing values for Maternal perception (pink) were subplotted in line with the filtered signal (blue) to accurately determine FM which gave a peak value of 0.2 AMU. This was set as the peak detection threshold to count fetal movements (Figure 11(c)).
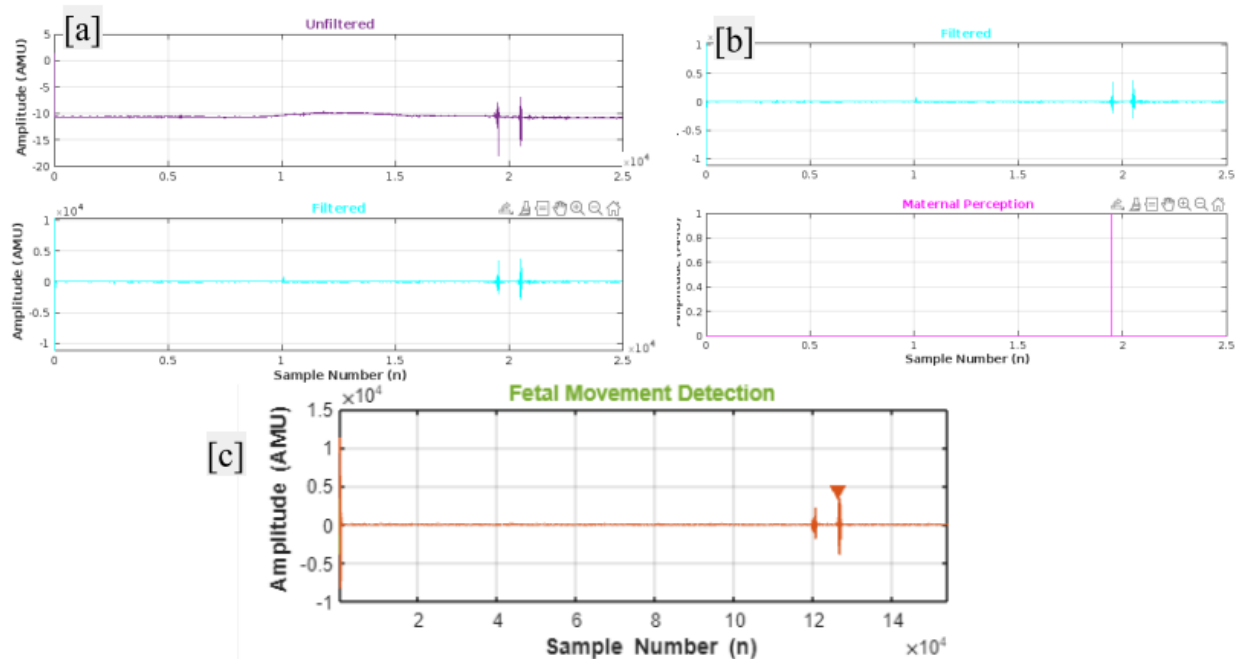


*Figure 11: (a)Unfiltered vs filtered FM signal (b)Maternal perception of FM  (c)FM count*

*6) Design Algorithm*

The flowchart in Figure 13 below illustrates the algorithm performed by the microcontroller. Once signal acquisition and filtering of the two signals is achieved, the FHR (normally 120-160bpm) can be counted in 6-second intervals and multiplied by a threshold of 10 to give the average heartbeat, with 300ms delay in between each beat. For FM, the normal period of fetal rest lies between 22-75 minutes (Abeywardhana et al.,2018) and so if
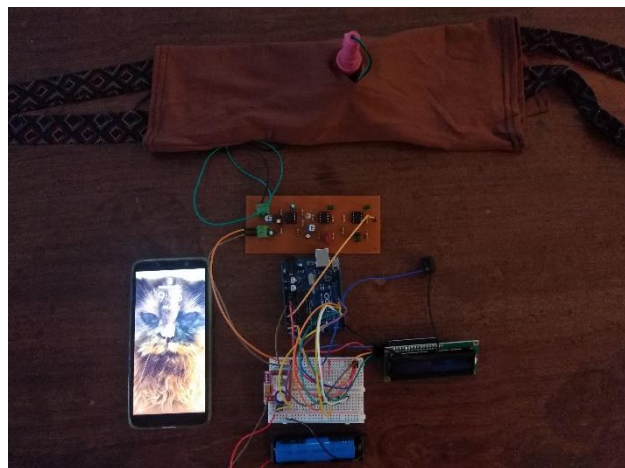


*Figure 12: Total Hardware Implementation*

movement is felt after t>4500 seconds, then FM count is low.  The LCD and LEDs will be made to change accordingly to represent the current fetal status depending on the FM count and FHR and if fetal distress is detected the alarm system is initiated.
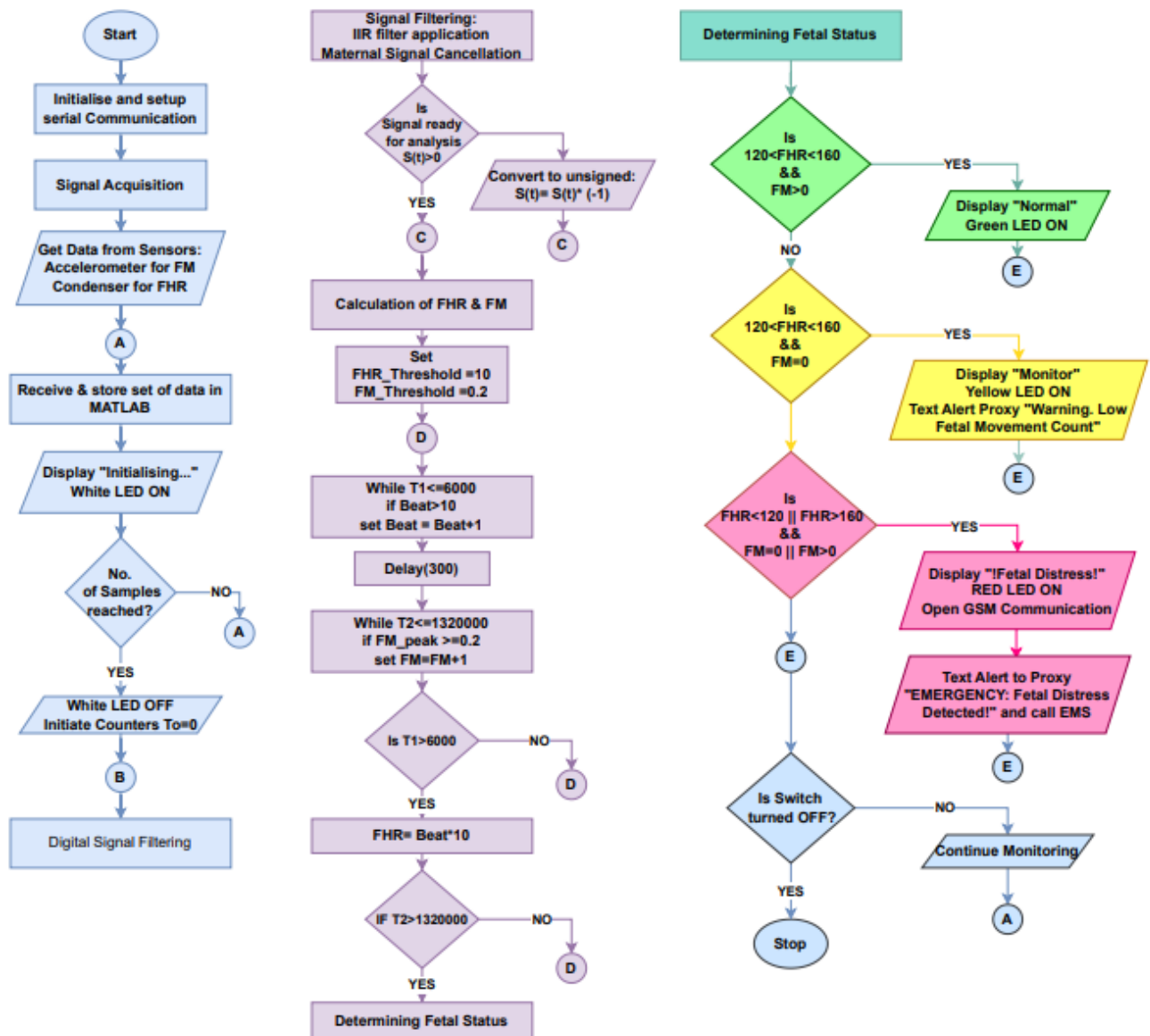
*Figure 13: Flowchart*

Due to the small scale of this project, testing of the fPCG acquisition board was conducted using Proteus Simulation software and a heart WAV. file from SoundJay (2023) in order to see the resulting output of the designed filter and amplifier. The FM Count algorithm was tested by running the algorithm with five different accelerometer sample data taken from the same database by Pierre et al.,(2019) used for its implementation. The results were validated by holding maternal perception as the ground truth.

**Results and Discussion**

As can be seen in Figure 14 below, the input signal (pink) has been successfully amplified (blue) with a 60dB gain. Figure 15 shows the amplified signal (orange) being appropriately filtered to obtain a clean fetal heart sound signal while preserving useful signal data.
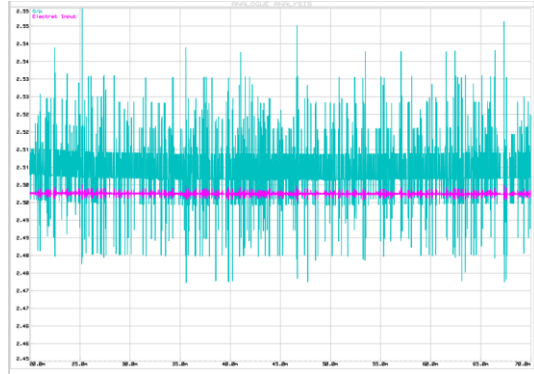


*Figure 14: fPCG amplifier output.*



*Figure 15: fPCG filter output.*

The graph shown in Figure 16 prints the number of fetal movements counted by the algorithm. As can be seen, the algorithm has successfully counted the two peaks (green) corresponding to fetal movement (FM). Validation of this result can be determined by analysing Table 09 below.
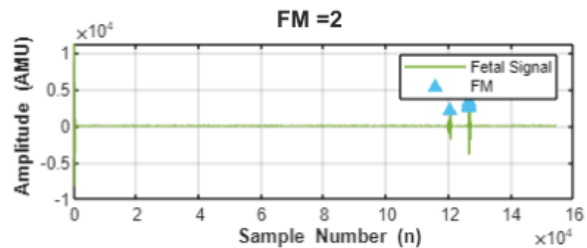


*Figure 16: Result of FM algorithm*

Table 01:Test results-counted FMs| $fs$=500Hz

| Sample Name* | Counted Fetal Movements | |
|---|---|---|
| | Maternal Perception | Algorithm |
| 154100 | 1 | 1 |
| 450663 | 1 | 2 |
| 451049 | 0 | 0 |
| 451421 | 2 | 4 |
| 451601 | 0 | 0 |
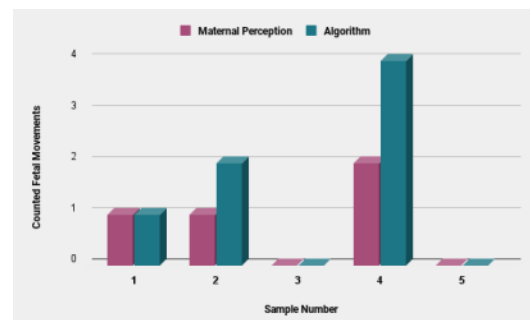


*Figure 17: Bar graph of counted FMs*

There were two instances where the algorithm detected twice as many fetal movements while maternal perception (MP) declared only one FM. This could either be due to the small time window between two instantaneous fetal kicks which the mother perceived as one FM or, it could be the occurrence of maternal laugh which lies in the same amplitude as the FM signal. Since the accelerometer data was taken from an open-source database, there was no way of

identifying when maternal laugh occurred. However, as testing of the FM signal processing algorithm (fmSP) was based on the assumption that the MP was the ground truth, results showed that while there was some variation in number of FM counts, the fmSP algorithm produced zero false negative results. More comparative tests (i.e. clinical ultrasounds) must be run to determine whether the proposed device is capable of identifying fetal movements that are unable to be perceived by the mother herself.

Table 02: Summary of Initiation and Alarm System Testing results

| Components | Variable | Expected Results | Final Outcome | Success |
|---|---|---|---|---|
| Initiation | Initialisation of system | White LED ON, LCD displays "Initialising" | White LED ON Displays: "Fetal Monitor Initialising…" | YES |
| Alarm System | Reassuring Fetal Status | Green LED ON FHR & FM within normal range. | FHR=140 BPM FM= ACT Displays : "Normal" Green LED ON | YES |
| | Low Fetal Movement count. | Yellow LED On Warning Text: Low FM Count | FHR=140 BPM FM= LOW Displays : "Monitor" Texts to Proxy : "Warning: Low Fetal Movement count" Yellow LED ON | YES |
| | Non reassuring fetal status: | Red LED ON FHR & FM outside normal range: Fetal distress | FHR=162 BPM FM= ACT Displays : "!Fetal Distress!" Texts to Proxy : "EMERGENCY: Fetal Distress Detected!" Red LED ON<br><br>FHR=116 BPM FM= LOW Displays : "!Fetal Distress!" Texts to Proxy : "EMERGENCY: Fetal Distress Detected!" Red LED ON | YES |

As can be seen from Table 10 above and Figure 18 & 19 below, all components of the alarm system were successful.
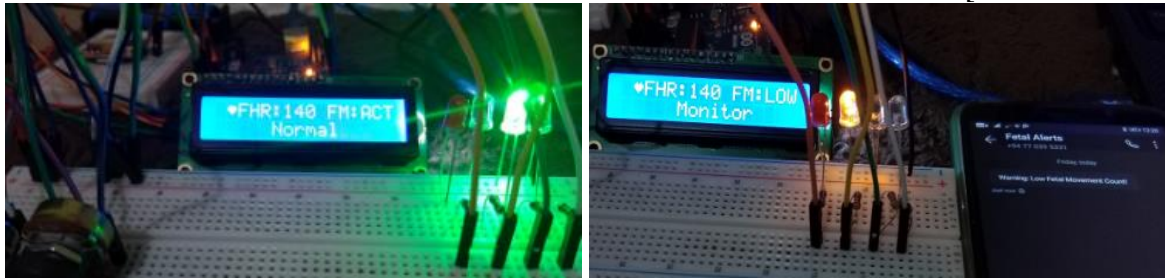
*Figure 18: Alarm system outputs*
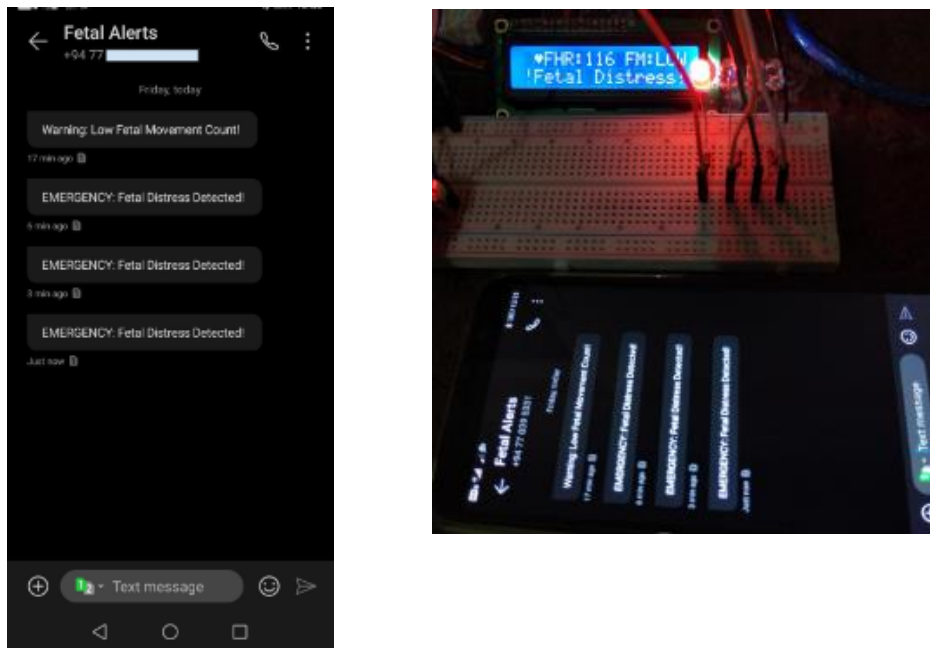


*Figure 19: GSM Alert texts indicating non-reassuring fetal status*

## Conclusion

All components of the proposed device were successfully implemented and the fetal movement algorithm showed no false negative results, thereby fulfilling all the proposed aims and objectives of the Home Fetal Movement and Distress Detection Device, offering expectant mothers a sense of comfort and security, saving one fetus at a time.

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# AIRS' 23

## *Chapter 04:*
## HEALTH SCIENCE

# A REVIEW OF HIV-RELATED CARDIOMYOPATHY

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## Abstract

Involvement of cardiac diseases in HIV positive patients has become a discussion in modern science for several decades. In this review among cardiac diseases, cardiomyopathy holds a special attention. According to several research studies there is a prevalence of cardiomyopathy in HIV positive patients in comparison with general public. There are several mechanisms which cause cardiac cell damage such as cytokine activity, focal myocarditis, immune system dysregulation and some ART drugs. Studies have been carried on to understand the tendency of cardiomyopathy in HIV positive patients using transthoracic echocardiography and clinical findings. According to those researches heart failure in HIV patients tend to present with preserved ejection fraction. Better prognosis in cardiac involvement was noted in patients who had increased accessibility to antiretroviral therapy (ART). Importance of starting and continuation of ART is also emphasized.

**Keywords:** Antiretroviral treatment (ART), HIV, Cardiomyopathy, CD4, CD8

## Introduction

In the era of ART, the mortality and morbidity correlated with AIDS have considerably diminished, converting HIV infection into a controllable chronic condition. Nevertheless, individuals who are suffering from HIV infection experience a higher susceptibility to non-aids related conditions including malignancies, liver issues, cardiovascular problems, and bone diseases. Often these are conditions that build up with aging. This heightened threat is related to immune dysfunction prior to initiation of ART, incomplete immune recovery with ART, adverse effects of ART and lifestyle factors (Longenecker *et al.,* 2016). The depletion of CD4 T cells and stimulation of chronic CD8 T cells can be considered identifiers of HIV infection. Successful ART not only maintains accurate CD4 cell counts but also normalizes the CD4/CD8 ratio (Mussini *et al.,* 2015). Due to the continued decrease in the number of CD4 cells and the inverse ratio of CD4 and CD8 cells, as well as the incomplete immune recovery caused by successful ART, there is a high risk of developing non-AIDS conditions consist of cardiovascular disease (Mussini *et al.,* 2015). Despite the progress in managing HIV as a chronic condition, individuals with HIV face an increased risk of non-AIDS-related complications, with cardiovascular problems emerging as a significant concern.

Although there is an understanding of CVD in HIV-infected patients, the consequences of the intricate pathobiology of HIV infection on myocardial architecture and the myocardial dysfunction in people living with HIV is not fully -scovered/ understood. This review aims to examine the specific impact of HIV infection on myocardial architecture and function, with a focus on the correlation between HIV and cardiomyopathy. While cardiovascular diseases in HIV-infected patients are recognized, the profound effects of HIV on myocardial structure and

function, particularly in the context of cardiomyopathy, remain largely unexplored. In the community, left ventricular hypertrophy (LVH) represents a specific sign that could lead to ventricular arrhythmias, heart failure, or death after a myocardial infarction or reduced ejection fraction of the LV. A contributing factor to clinical heart failure is that diagnosis of diastolic dysfunction often occurs in the final stages of the disease advancement (Gerber *et al.,* 2013). Numerous reasons underlying cardiomyopathy, including cytokine activity and cell damage, inflammation in cardiac cells, and immune system effects, are discussed in this systematic review.

**Methodology**

Determining the relationship between cardiac problems and HIV-positive individuals was the goal of this review study. Without limitations, the systematic review study carried out following the Prisma (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) protocol was searched in internationally recognized search engines including PubMed, NCBI, Scopus and Google Scholar (Page *et al.,* 2021). The first publications on this subject were made in 2016. For the current systematic review study, 44 studies were first accessed. After removing 12 identical studies from different databases, 32 studies remained. Based on the inclusion and exclusion criteria, 7 of the 32 studies that remained were eliminated.

**Identification**
- Pubmed (11), NCBI (7), Scupus (4), and Google Scholar (22)
- Total 44
- Excluded repititive studies N=12

**Screening**
- Screened studies N=32

**Eligibility**
- Full-text studies evalated for eligibility N=12

**Include**
- Studies included in the qualitative synthesis N=12
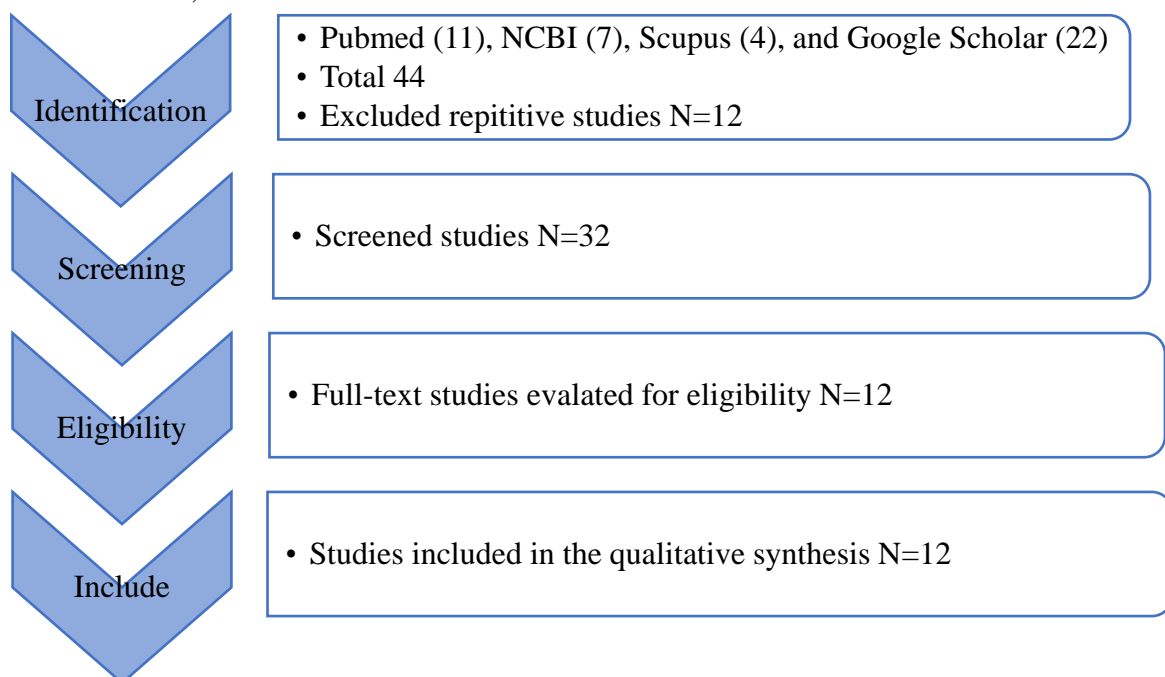
In this systematic review, using individuals who have been identified as HIV positive, Individuals with proven cardiomyopathy or heart failure associated with HIV infection, measures of heart function, such as echocardiographic parameters, clinical outcomes, and biomarkers, were taken into consideration as inclusion criteria. On the other hand, studies that only include people who are not HIV positive, that do not provide sufficient evidence of HIV-related cardiomyopathy, and studies with small sample sizes or insufficient statistical power were deemed to be excluded.

**Results and Discussion**

Table 1 Comparison of the results of echocardiography in four distinct HIV-positive patient samples.

| | | Ref 1 (HIV (+) n=51) | Ref 2 (HIV (+) n=153) | Ref 3 (HIV (+) n=50) | Ref 4 (HIV (+) n=36) |
|---|---|---|---|---|---|
| **References** | | (Manner et al., 2017) | (Cetin et al., 2021) | (Utama et al., 2019) | (Cerik et al., 2019) |
| Demographic Characteristics | Age (y) | 46.2 (41.0–54.2) | 36.77 ± 10.25 | 30.60 ± 5.58 | 39.86 ± 10.55 (20–63) |
| | Male Gender (%) | 72.5 | 148 (97) | 33 (66) | 29 (80.6) |
| | Current smoking (%) | 27.5 | 86 (56) | 16 (32%) | 24 (66.7) |
| | BMI (kg/m²) | 24.1 (22.2–26.2) | 24.79 ± 2.6 | 20.52 ± 2.40 | 25.56 ± 4.55 (19.1–41.1) |
| Infection | CD4 cell count (cells/ µL) | 559 (385–658) | | | |
| | CD8 cell count (cells/ µL) | 958 (678–1340) | | | |
| | CD4/CD8 | 0.6 (0.4–0.8) | 0.50 | 0.275 (0.02-1.39) | |
| | Time since HIV diagnosis (y) | 10.7 (7.9–19.1) | | | |
| | Duration of ART (y) | 7.7 (5.4–11.0) | 0.1 | | |
| Pressure | SBP (mmHg) | 116 (108–124) | 109.64 ± 12.95 | | 118.6 ± 7.5 (105–135) |
| | DBP (mmHg) | 73 (69–80) | 67.12 ± 8.33 | | 75.7 ± 6.1 (65–86) |
| Echocardiography | LVEF (%) | 66 (60–71) | 59.33 ± 2.55 | | 63.2 ± 4.0 (55–70) |
| | IVS (mm) | 8.0 (8.0–9.0) | 8.61 ± 1.23 | | 9.89 ± 1.26 (8–13) |
| | PW (mm) | 9.0 (8.0–9.0) | 8.60 ± 1.21 | | 9.14 ± 1.18 (7–11) |

Variation of above-mentioned demographic characteristics shows a tendency of cardiomyopathy in males of late thirties in age specially smokers. Pre existing hypertension increases the risk in cardiac failure (Table 1).

Living with both HIV and cardiomyopathy is a complex combination of two chronic conditions. Patients often have to follow complex drug regimens. In other words, apart from ART, medicines are also needed for heart health. Chronic illnesses have a significant psychosocial impact on the mental and emotional well-being of individuals. People living with HIV still face discrimination and social stigma, and cardiomyopathy adds an additional layer of complexity. Symptoms of clinical heart failure and HIV cardiomyopathy carries a similarity. Cough, exertional dyspnea, orthopnea, lower extremity edema and paroxysmal nocturnal dyspnea are common presenting symptoms. Time for presentation varies according to the etiology. Patients with HIV may be asymptomatic or may present with symptoms of acute heart failure. Patients with diastolic dysfunction tend to be asymptomatic while in acute myocarditis with severe symptoms (Baliga et al., 2013). With the increased reachability to ART drugs phenotype of the HIV cardiomyopathy has changed over time. With increased use of ART, Heart failure with preserved ejection fraction (HFpEF) has become the predominant incident in HIV population who has cardiomyopathy (Freiberg et al., 2017). Development of ART has drastically reduced the mortality of HIV patients. Several mechanisms realize the cardiomyopathy in patients with HIV such as direct viral infection, cytokine activity, focal myocarditis, side effects of ART, immune system dysregulation, and ischemia. If a HIV patient is diagnosed with cardiomyopathy, it's better to start him on ART and continue it according to therapeutic guidelines for a better prognosis. The potency and safety of the developed treatments in the population considered have been repeatedly confirmed, on the other hand it is clear that the level is below that of the general population with advanced heart failure. For

the treatment of patients in the final stages of heart failure, it is advisable to refer them to centers with experience in treating people with HIV and to provide high-quality care (Table 2).

Table 2 – Mechanisms of cardiomyopathy HIV infected patients

| Effect | Mechanism | Description |
|---|---|---|
| Cytokine Activity and Cell Damage | The function of Cardiac Myocytes direct HIV infection: | Comprehensive research is necessary to provide customized HIV cardiomyopathy treatments. Recognizing is essential for heart problems and HIV medication that works. (Gianella *et al.*, 2020). |
| | HIV Infection Facilitated by Ebstein-Barr Virus (EBV): | EBV increases CD4+, allowing cardiac myocytes to become infected with HIV. Interactions between viruses may affect HIV in cardiac cells. (Wu *et al.,* 2016) |
| | Inflammatory cells infiltrating Cardiac myocytes: | HIV entrance into cardiac myocytes is facilitated by infiltration of inflammatory cells. (Ivanov *et al.*, 2016). Similar to macrophages, HIV-positive cells cause cardiac myocytes to undergo apoptosis. (Schuster *et al.*, 2018). |
| | The pathway of proinflammatory signaling and Cytokines: | Leaky macrophages secrete TNF-alpha, IL-6, and IL-1 cytokines. TNF-alpha and IL-6 affect fibrosis, contractility, and remodelling of the heart. (Herold *et al.*, 2013). |
| | Cytokine's effects on cardiac tissue: | HIV patients have higher levels of TNF-alpha and IL-6, which affect heart health. Reduced CD4+ levels are correlated with increased iNOS and TNF-alpha. (Schuster *et al.*, 2018). |
| | Association with Cardiomyopathy: | HIV cardiomyopathy risk is increased by high viral loads and low CD4+ (Ivanov *et al.*, 2016). The cytokines TNF-alpha and iNOS are involved in cardiomyopathy (Gianella *et al.*, 2020). |
| | Impact of Biochemistry on Cardiac Function: | TNF-alpha and iNOS are associated with aberrant remodeling and decreased contractility (Ivanov *et al.*, 2016). A lower level of CD4+ is correlated with higher amounts of HIV cardiac myocytes (Herold *et al.*, 2013). |
| Inflammation in Cardiac Cells | HIV Patients having a higher risk of myocarditis: | HIV-positive people who have co-infections and immunological dysregulation are at risk for myocarditis (Sayyoulidis *et al.*, 2019). |
| | Myocarditis frequency Among HIV Cardiomyopathy Individuals: | In 50% of HIV patients with cardiomyopathy, there is evidence of myocarditis. HIV-related myocarditis is more likely when there are indications of systolic dysfunction (Tschöpe, *et al.*, 2021). |
| | Histological Characteristics of HIV-Associated Myocarditis: | Histological investigation of HIV myocarditis reveals CD8+ T cell infiltration. HIV-associated myocarditis shows a characteristic CD8+ infiltrate, in contrast to non-HIV myocarditis. (Ammirati *et al.*, 2020). |
| | Relationship to the Cytomegalovirus (CMV): | Compared to controls, CMV is associated with myocarditis in the HIV group. Cardiotropic viral infection was present in all 15 HIV cardiomyopathy patients, with CMV present in 7% of cases. (García-Torre *et al.*, 2021). |

| | Additional Viral diseases linked to HIV cardiomyopathy: | Besides CMV, 64% of cases have Epstein-Barr virus (EBV), 50% have herpes simplex virus, and 14% have parvovirus B19. These are other bacterial co-infections (Watanabe *et al.*, 2020). |
|---|---|---|
| | Connection to Hepatitis C Virus (HCV): | Compared to patients with just HIV, individuals with coupled HIV/HCV infection have higher brain natriuretic peptide (BNP) levels, which has been linked to HCV (Sayyoulidis *et al.,* 2019). |
| | Opportunistic infections which cause Myocarditis development: | In individuals with AIDS and HIV, myocarditis may be caused by a variety of opportunistic organisms. Atypical mycobacteria, Histoplasma capsulatum, Toxoplasma gondii, Mycobacterium tuberculosis, CMV, and Trypanosoma cruzi's reactivation of Chagas disease are among these infections (Ammirati *et al.*, 2020) |
| Effect of Immune System | HIV and ART's effects on the Immune system | The immune system is impacted by HIV and Highly Active Antiretroviral Therapy (ART). The heart is adversely affected by these impacts. (Sweet *et al.*, 2018). |
| | Increased Cardiac Autoantibody Levels in HIV Patients | HIV-positive patients had greater levels of cardiac autoantibodies. A study indicates that these autoantibodies may cause myocarditis in HIV patients (Sayyoulidis *et al.,* 2019). |
| | Results of an endomyocardial biopsy: | In endomyocardial biopsies, HIV patients have overexpressed cardiac autoantibodies. Autoimmunity is a direct cause of myocarditis and remains active even in the presence of viruses. (Lawal *et al.*, 2020). |
| | Eosinophils and Immunoglobulin-E (IgE) over-expression: | Patients with HIV might overexpress eosinophils and immunoglobulin-E (IgE). This phenomenon is more prevalent in patients who have advanced to AIDS and have lower CD4+ levels (Lawal *et al.,* 2020). |
| | Connection to Cardiac Dysfunction: | Cardiac Dysfunction in HIV patients may result from upregulation of eosinophils and IgE. A case study indicated that elevated expression of eosinophils and IgE can lead to eosinophilic myocarditis (Sweet *et al.*, 2018). |
| | Immune Dysregulation's Clinical Consequences: | Heart failure in HIV is caused by immunological imbalance. HIV myocarditis is associated with autoantibodies, IgE, and eosinophils. (Sayyoulidis *et al.,* 2019). |
| | Immune Reconstitution Inflammatory Syndrome (IRIS): | IRIS is a condition marked by an acute and unusually rapid immune system recovery following HARRT commencement. IRIS has a unique correlation with severe myocarditis, highlighting the part immune reconstitution plays in cardiac problems (Vinhaes *et al.*, 2021). |

HIV infected patients with cardiomyopathy requires a synchronized therapy with ART drugs and cardiac drugs such as beta blockers, ACE inhibitors and diuretics etc. ART drugs will minimize the viral load while cardiac drugs work on symptoms of heart failure (Schuster *et al.*, 2018).

*Gaps and Limitations*

Long-term studies are required to fully comprehend the course and long-term outcomes of HIV-related cardiomyopathy, to monitor cardiac problems throughout time, and to assess the effects of various therapies on overall prognosis. In order to develop appropriate management options, research on the effects of co-infections such as hepatitis C and comorbidities on HIV-related cardiomyopathy is necessary to understand their contributions to cardiovascular outcomes. The literature may be lacking in its examination of the effects of psychosocial factors, such as stress, mental health, and socioeconomic position, on the onset and treatment of cardiomyopathy in HIV-positive people (Longenecker *et al.,* 2016).

*Global view point*

Global health organizations and policymakers are working to develop comprehensive strategies to manage these two chronic disease conditions. Global organizations play a special role in advocating for the needs of patients with HIV-related heart diseases. Health diplomacy is important for sharing knowledge, best practices and working together to manage HIV and its related complications, thus improving cooperation between different nations (Gerber *et al.,* 2013).

*Management*

Guideline directed medical therapy from American College of Cardiology (ACC) and the American Heart Association (AHA) including cardiac resynchronization therapy is recommended for HIV patients with heart failure specifically with reduced ejection fraction (Alvi *et al*., 2018). The existing guidelines are not specific tests for HIV patients and are based on tests for people with normal heart failure (Bozkurt *et al.,* 2016).

The goal of ongoing research is to optimize antiretroviral therapy for HIV-positive patients while minimizing the risk of cardiovascular side effects and taking into account viral suppression. Research has looked into therapies that target inflammation, oxidative stress, and other factors linked to the development of cardiomyopathy in order to protect the heart in people living with HIV. Studies are looking at how lifestyle modifications and physical activity affect the management of cardiomyopathy in HIV-positive people, highlighting the importance of these factors for general cardiovascular health. Current clinical trials investigate novel therapy strategies for HIV-related cardiomyopathy, providing patients with state-of-the-art care and advancing scientific understanding. The combination of remote monitoring and telemedicine improves access to healthcare and makes it easier for people with HIV-related cardiomyopathy to have their cardiac condition continuously monitored (Mehdiani *et al*., 2016).

Diastolic dysfunction and cardiac steatosis are caused by ART and HIV, which have a complicated interaction. However, diastolic dysfunction causes a change in cardiovascular risk from systolic dysfunction (Lipshultz *et al.,* 2013). In cases of worsening heart failure, special attention is paid to advanced therapies such as left ventricular assist devices (LVAD) and orthotopic heart transplant (OHT). LVAD and OHT are considered in 'Stage D' of heart failure according to ACC/AHA classification. With positive survival rates, successful cases of LVAD and OHT have been reported (Mehdiani *et al*., 2016). Although successful results are provided

with evidence, HIV patients' access to treatment is limited due to social stigma. If any interaction occurs between heart failure medications and ART, those cases should be referred to specialists and to be managed at specialized centers. Careful monitoring is needed in use of drugs with narrow therapeutic window such as digoxin. Digoxin is used in life threatening arrythmias. (Conte *et al.,* 2016).

**Conclusion and Recommendations**

To understand HIV cardiomyopathy, provide customized therapies, and meet specific needs, specialized research is essential. It is imperative to comprehend efficacious treatment approaches, given the complex effects of HIV on the heart. These trials improve clinical care by guaranteeing individualized strategies for people who have heart problems in addition to HIV.

Use of ART in large scales has prolonged the survival of patients with HIV and other related complications. Cardiomyopathy with systolic or diastolic dysfunction is a common finding among patients with HIV. Low CD4 counts have been linked to diastolic dysfunction and left ventricular hypertrophy, which highlights the important role that immunological state plays in HIV-positive people's cardiovascular health. Finally, a relationship between low CD4 counts and both Left ventricular hypertrophy and Diastolic dysfunction in a demographically adequate sample of PLWH has been illustrated during the review of the significant archive of echocardiograms.

In particular, we recommend that studies to be conducted for the assessment of HIV cardiomyopathy treatment. Special attention towards the CMP in HIV people is needed as advanced therapeutic options remain less available to them in comparison to general public.

Awareness regarding the HIV and its complications among general public should be optimized in order to reduce related cardiac conditions. For this purpose distance monitoring techniques such as social media or telemedicine could be more effective in cost and time consumption. Public health representatives should held the responsibility in reaching out general public for related health education.

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# REPURPOSING OF DRUGS TO TREAT ANTIBIOTIC-RESISTANT BACTERIAL INFECTIONS IN SRI LANKA

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**Abstract**

The dissemination of Antibiotic Resistant Bacteria (ARB) in Sri Lanka is a major health crisis that is further aggravated by the current economic crisis and the failure to promote surveillance measures and relevant regulatory procedures to control further dissemination of ARB and antibiotic residues. Repurposing drugs that are currently available for equal distribution across the country is essential as we as a country are at the threshold of an antibiotic-resistant infection crisis. Databases such as the Food and Drug Administration, European Medicines Agency, DrugBank, PubChem, and ChEMBL were used to curate a list of drugs with similar structure and function to the antibiotic of ampicillin, amoxicillin and ciprofloxacin. The resulting list was further optimized based on chemical structure similarity, pharmacophore similarity, biological action and antibacterial spectrum and Absorption, Distribution, Metabolism, Excretion, and Toxicity (ADMET) profiles to obtain the best alternative drugs. This optimized list was then used to identify drugs that are available on the State Pharmaceuticals Corporation (SPC) of Sri Lanka. Results of this study revealed that only two drugs of benzylpenicillin and cephalexin was found to have the highest similarity to ampicillin and amoxicillin while none of the alternative drugs for ciprofloxacin matched with the list of drugs from the SPC database.

**Keywords:** Amoxicillin, Ampicillin, Antibiotic resistance, Ciprofloxacin, Drug repurposing

**Introduction**

The rapid dissemination of Antibiotic Resistant Bacteria (ARB) is a major crisis as it may lead to a serious public health crisis. ARB are rapidly spreading around the country facilitating its development and dissemination by the wide network of fresh water bodies of the country. At the threshold of a nation-wide pandemic, we as a country require fast and sustainable solutions to tackle the infection and treat those affected by it (Al-Hashimi et al., 2021; Ayukekbong et al., 2017).

Ampicillin is a semi-synthetic derivative of the antibiotic penicillin which functions as a broad-spectrum antibiotic used against both gram-negative and gram-positive bacteria (Peechakara et al., 2023). Similarly, Amoxicillin is the G-derivative of the antibiotic penicillin and is commonly used to treat wide range of infections caused by both gram-positive and gram-negative bacteria (Slay et al., 2022). In relation to Sri Lanka, ampicillin and amoxicillin are commonly used as over the counter antibiotics that is used to treat both bacterial infections in humans and in animals (Dadgostar, 2019; Darby et al., 2022). Ciprofloxacin on the other hand is used as a broad-spectrum antibiotic in treating gram-positive and gram-negative infections (Sharma et al., 2017).

Considering the current economic crisis of the country, the emergence of bacterial infections that are resistant to first-line antibiotics such as ampicillin, amoxicillin and ciprofloxacin can result in detrimental outcomes. However, developing novel antibiotics and/or importing novel antibiotics to the country would be time-consuming while exerting a huge burden on the health sector of the country.

Thereby, one of the most promising strategies would be repurposing of already available drugs to treat a specific antibiotic-resistant bacterial infection. Drug repurposing provides several advantages such as immediate use and distribution, lower cost, higher safety and the availability of data on pharmacokinetics and ADMET properties.

There are various antibiotic alternatives to common first line antibiotics based on literature and other clinical studies. However, this study aims to conduct a novel investigation on repurposing drugs, exploring options that include antibiotics or even other types of drugs that are used to treat different diseases. The key objective is to identify drugs that are currently available in the country which can be both readily accessible and affordable, nation-wide by all citizens of the country. To continue the objective of being able to provide sustainable and affordable drugs, the State Pharmaceuticals Corporation (SPC) was used as the official drug database, to ensure maximum benefit of this study to all citizens of the country, where the medications could be easily accessed by government clinics and government hospitals nation-wide. Thereby, this study aims to use literature and computational tools to find already available drugs in Sri Lanka with similar biological action to the antibiotics of ampicillin, amoxicillin and ciprofloxacin.

**Methodology**

*Data collection*

Databases such as the Food and Drug Administration, European Medicines Agency, DrugBank, PubChem and ChEMBL were used to create a dataset of FDA-approved drugs and commercially available drugs that contained structural similarity in relation to the 2-dimensional structure and 3-dimensional conformation of ampicillin, amoxicillin and ciprofloxacin using chemical structure similarity scores and pharmacophore similarity scores from Swiss Similarity (Bragina et al., 2022; ChEMBL, 2023.; European Medicines Agency, 2023.; FDA, 2023.; PubChem, 2023.)

*Optimization of the potential alternative drugs*

Thereafter, the database was further optimized based on four criteria as shown in Table 1. Thereby, features such as pharmacophore similarity score, chemical similarity score and properties related to the mechanism of action, antibacterial spectrum and the Absorption, Distribution, Metabolism, Excretion and Toxicity (ADMET) profile were evaluated to curate the optimized list.

Table 1: Criteria used to curate drugs that show high molecule mimicry and functional similarities.

| Criteria | Relevant parameters used |
| --- | --- |
| Chemical Structure Similarity | The Swiss Similarity tool was used to generate the similarity score through the use of the combined 2-dimensional and 3-dimensional |

| | |
|---|---|
| | screening methods to identify drugs with high structural similarity to ampicillin, amoxicillin and ciprofloxacin. |
| Pharmacophore Similarity | Through literature, several pharmacophoric descriptors such the beta-lactam ring, the phenyl ring, the amino group and carboxyl group were used as the defining descriptors unique to ampicillin, amoxicillin and ciprofloxacin. Thereby, the Swiss Similarity tool was used to generate a pharmacophore similarity score. |
| Biological action and antibacterial spectrum<br><br>ADMET Profiles | Analysis on the biological action, antibacterial spectrum and ADMET properties can be used to evaluate the functional properties, pharmacodynamic and pharmacokinetic properties that would further help in classifying the most appropriate drugs. |

*Comparing the optimized drugs to drugs currently available in Sri Lanka*
The optimized drug list was mapped against the official drug database of the State Pharmaceuticals Corporation (SPC) of Sri Lanka to identify alternative drugs that are currently available in the country (State Pharmaceuticals Corporation of Sri Lanka, 2023) .
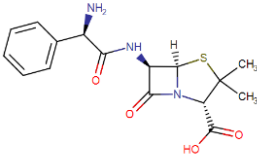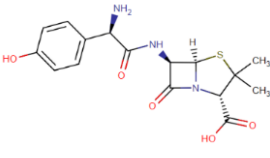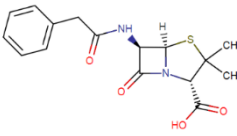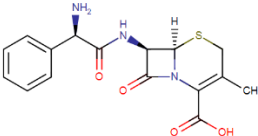
**Results and Discussion**
Repurposing of Ampicillin, Amoxicillin and Ciprofloxacin using medicines currently available as per the SPC database produced alarming results. Thereby, only two drugs of Benzylpenicillin and Cephalexin were found to have similar chemical structure and biological function to both ampicillin and amoxicillin while no alternatives were found to the drug Ciprofloxacin in the SPC database as given in Table 2.

As per the objective, the original list curated from several official drug databases contained both antibiotics and other drugs that treat other diseases such as elvitegravir which is used in the treatment of HIV infection (Mete et al., 2021). However, finding alternative drugs that are not limited to antibiotics which was an objective of the study was deemed futile considering that only two antibiotics were found from the SPC database as opposed to the curated list of around 400 potential drugs that were obtained from the combination of several official drug databases as outlined in the methodology.

Table 2: Comparison of the structural and functional properties of the resulting alternative drugs in comparison to ampicillin and amoxicillin.

| Properties | Ampicillin/ Amoxicillin | Benzylpenicillin | Cephalexin | Reference |
|---|---|---|---|---|
| **Chemical Structure Similarity** | 1 | 0.999 | 0.974 | (Bragina et al., 2022) |
| **Pharmaco phore similarity** | 1 | 0.543 | 0.747 | (Bragina et al., 2022) |

| Chemical structure | Figure 1: Two-dimensional chemical structure of Ampicillin.<br><br><br><br>Figure 2: Two-dimensional chemical structure of Amoxicillin.<br><br> | Figure 3: Two-dimensional chemical structure of Benzylpenicillin.<br><br> | Figure 4: Two-dimensional chemical structure of Cephalexin.<br><br> | (PubChem, 2023b, 2023a, 2023d, 2023c) |
|---|---|---|---|---|
| **Molecular Weight (g/mol)** | 349.4 - Ampicillin 365.4 - Amoxicillin | 334.39 | 347.39 | |
| **Antibiotic Spectrum** | Broad spectrum antibiotic working against both gram-negative and gram-positive bacteria | Narrow spectrum antibiotic against Gram-positive bacteria.<br>a | Broad spectrum antibiotic working against both gram-negative and gram-positive bacteria | (Bodey & Nance, 1972; Pedretti et al., 2011b, 2011a; Tanrisever & Santella, 1986) |
| **Mechanism of action** | Both ampicillin and amoxicillin belong to the class of aminopenicillins and functions in inhibiting cell wall synthesis. | Benzylpenicillin belong to the class of natural penicillin's and involves in inhibiting cell wall synthesis while promoting cell lysis. | Cephalexin is a first-generation cephalosporins that promotes cell lysis. | |
| **Administration** | Main form of administration includes oral administration | Benzylpenicillin is absorbed through intramuscular or | Cephalexin is administered orally. | (Gartlan et al., 2023; Gordon et al., 1972; Herman & Hashmi, 2023) |

| | | subcutaneous injection. | | |
|---|---|---|---|---|
| **Dosage** | The available dosage listed under the SPC database is 125mg/5ml. | The available dosage listed under the SPC database is 600mg. | The available dosage listed under the SPC database is 500mg. | (State Pharmaceuticals Corporation of Sri Lanka, 2023) |
| **Resistance against beta-lactamases** | One of the key mediators in the development of antibiotic resistance in bacteria are influenced by the ability of bacteria in producing beta-lactamases. Thereby, both ampicillin and amoxicillin are found to be susceptible to beta-lactamases thus promoting resistance. | Considered to be more susceptible for beta-lactamases. | Cephalexin is less susceptible for beta-lactamases due to its cephalosporin structure. Therefore, Cephalexin can be deemed as a better alternative drug than Benzylpenicillin to both Ampicillin and Amoxicillin. | (Bui & Preuss, 2023; Bush & Bradford, 2016; Mora-Ochomogo & Lohans, 2021; Worthington & Melander, 2013) |

**Conclusion and Recommendations**

This study utilizes an innovative approach as it combines computational tools and literature to identify potential drugs for repurposing to treat ampicillin, amoxicillin and ciprofloxacin resistant bacterial infections in Sri Lanka. The key significance of this study is that this computational approach of finding alternative drugs produces a large output of results based on chemical structure and pharmacophore similarity and subsequently uses literature to further optimize the list through consideration of other pharmacokinetic and pharmacodynamic features. This enables to produce a more comprehensive list of drugs that may not belong to the same class or type of the antibiotic-resistant drug allowing novel discoveries that may not be previously found through literature or clinical studies.

The major limitation of this study arises from the limited number of medications available in the official SPC database for use in Sri Lanka. This is a major limitation and risk as this study proves and confirms that emergency second-line alternatives to commonly used antibiotics such as ampicillin, amoxicillin and ciprofloxacin is very low or absent completely for distribution by the SPC. It is important that the medical health sector have alternative medications as opposed to waiting until a major public health crisis occurs to seek alternative solutions which could require higher costs and longer time to actually obtain medications for

public distribution and use. At the same time, implementing strict control measures and other appropriate procedures to prevent further dissemination and development of antibiotic resistant bacteria is vital to control the issue of antibiotic resistance.

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# APPLICATION OF REVERSE TRANSCRIPTASE PCR TO DETECT RNA EXTRACTED FROM NASAL SWABS EXPOSED TO DIFFERENT ENVIRONMENTS

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## Abstract

Diagnosis of upper respiratory infections involve collection of invasive specimens. RNA degrades in the presence of RNase, chemicals. Compromised RNA quality affects accuracy of RNA-based applications. Hence conservation of RNA in biological samples is important. This study aims to investigate: the suitability of nasal swabs as a non-invasive approach to collect RNA, the ability of 70% ethanol to preserve quality of RNA extracted from nasal swabs at room temperature and whether exposure of nasal swabs to detergent affects the quality of RNA extracted. 12 nasal swabs were either exposed to 70% ethanol, detergent for 0,4,8,24 hours at room temperature. Following exposure, the recovery quantity and integrity of extracted RNA was assessed. Exposing nasal swabs to 70% ethanol or concentrated detergent at room temperature conditions is likely to compromise integrity of RNA. Nasal swabs appear to be a promising minimally-invasive specimen to collect quality RNA for successful RT-PCR applications.

**Key words:** Detergent, Ethanol, Nasal Swabs, RNA, RT-PCR,

## Introduction

Upper respiratory infections diagnosis involves collection of invasive specimens. Invasive collection of specimen limits the diagnosis of respiratory infections to a particular population excluding infants, children, older and sick individuals as they might find the process of invasive specimen collection extremely inconvenient. Nasal swabs involve a minimally invasive procedure of collection compared to invasive nasopharyngeal swabs as it doesn't require a deep insertion of the swab into the nostrils (Callahan et al. 2021), (Blaschke et al. 2011).

Compromised RNA quality affects accuracy of resultsgenerated by RNA-based applications including RT-PCR (Poovakka et al. 2018). Conservation of RNA quality for accurate and reliable downstream RNA based applications such as RT-PCR (Falsey, Criddle &amp; Walsh 2006) is therefore important. Several existing techniques utilized to preserve RNA quality such RNAlater and -80°C storage require extreme conditions such as -80°C freezers and remains costly. Preserving quality of RNA in biological samples using such mediums/techniques is inconvenient in poor isolated regions. Hence, RNA-based diagnostics applications are greatly limited in such areas. The need for an alternative medium that can preserve RNA quality in specimens at room temperature is therefore exceedingly great in such areas.

rious chemicals can cause RNA degradation (Brisco & Morley 2012). Detergents are utilized in inactivation of hazardous viruses (Welch et al. 2020) for RT-PCR and are incorporated into cell lysis buffers (Linke 2009). Therefore, any negative effect of detergent on RNA quality could affect accuracy of results generated from downstream applications.

This study was therefore conducted to investigate:

Suitability of nasal swabs as a minimally-invasive approach to collect RNA for RT-PCR detection.

Ability of 70% ethanol to preserve integrity of RNA extracted from nasal swabs for successful RT-PCR at room temperature.

To investigate whether exposure of nasal swabs to detergent affects the quality of RNA extracted from nasal at room temperature.

The results generated from this study could provide an indication regarding:

The suitability of nasal swabs as a minimally invasive specimen to collect RNA for RT-PCR diagnosis.

The suitability of 70% ethanol as an alternative medium to store nasal swabs in order to preserve RNA integrity at room temperature in poor isolated areas for RNA-based applications.

The suitability of utilizing detergent for inactivation of hazardous viruses in nasal swabs for RT-PCR applications and incorporating detergent into cell lysis buffers.

**Methodology**

*Sampling and exposure to various exposure conditions at room temperature*

12 cotton tipped plastic shaft nasal swabs were collected from the donor.

The different conditions the swabs were exposed to has been tabulated in Table **1**.

Table 1: The different exposure conditions of the 12 nasal swabs

| Exposure condition | Number of swabs immersed | Contact time in respective exposure condition (hours) at room temperature |
|---|---|---|
| 200µL of 70% ethanol in 2ml Eppendorf tubes | 4 | 0, 4, 8 or 24 |
| Non-diluted concentrate of liquid hand wash detergent in 2ml Eppendorf tubes | 4 | 0, 4, 8 or 24 |
| Empty 2ml Eppendorf tubes (controls) | 4 | 0, 4, 8 or 24 |

*RNA Extraction*

RNA was extracted from the 12 swabs using Size fractionated Silica protocol.

*RNA Quantification*

The effect of 70% ethanol or detergent on the recovery yield of extracted RNAwas determined using Nano-drop One UV-Visible spectrophotometer.

*Reverse Transcription Polymerase Chain Reaction*

RT-PCR was conducted on the 12 RNA extracts using Applied Biosystems thermocycler. Reverse primerABL3 and forward primer A2 primer were used amplify a 300bp region in the ABL1 housekeeping gene (Cross, N et al. 1993). The total RT-PCR reaction volume was 25µL in each tube.

*RNA Integrity Assessment*

The effects of room temperature exposure to 70% ethanol or detergent at various durations on RNA integrity
and the suitability of nasal swabs to collect RNA was assessed by performing Agarose gel electrophoresis on the PCR amplicons. The cDNA bands on gels were visualized using Geldoc imaging system.

*Optimization of RT-PCR*

Optimization of RT-PCR was conducted utilizing a single nasal swab collected from the same donor (referred as optimization nasal swab throughout the report) in order to determine the optimum conditions for silica-based RNA extraction and RT-PCR that would permit successful amplification of target RNA and whether subjecting nasal swab to size fractionated silica-based RNA extraction yield RNA of quality sufficient to be detected and amplified by RT-PCR. The optimization nasal swab was not exposed to any special conditions or storage duration.

**Results**

*UV-Vis Spectrophotometric Analysis of RNA Recovery Quantity*

The variation in RNA concentration between the nasal swabs has been depicted in Figure **1**.
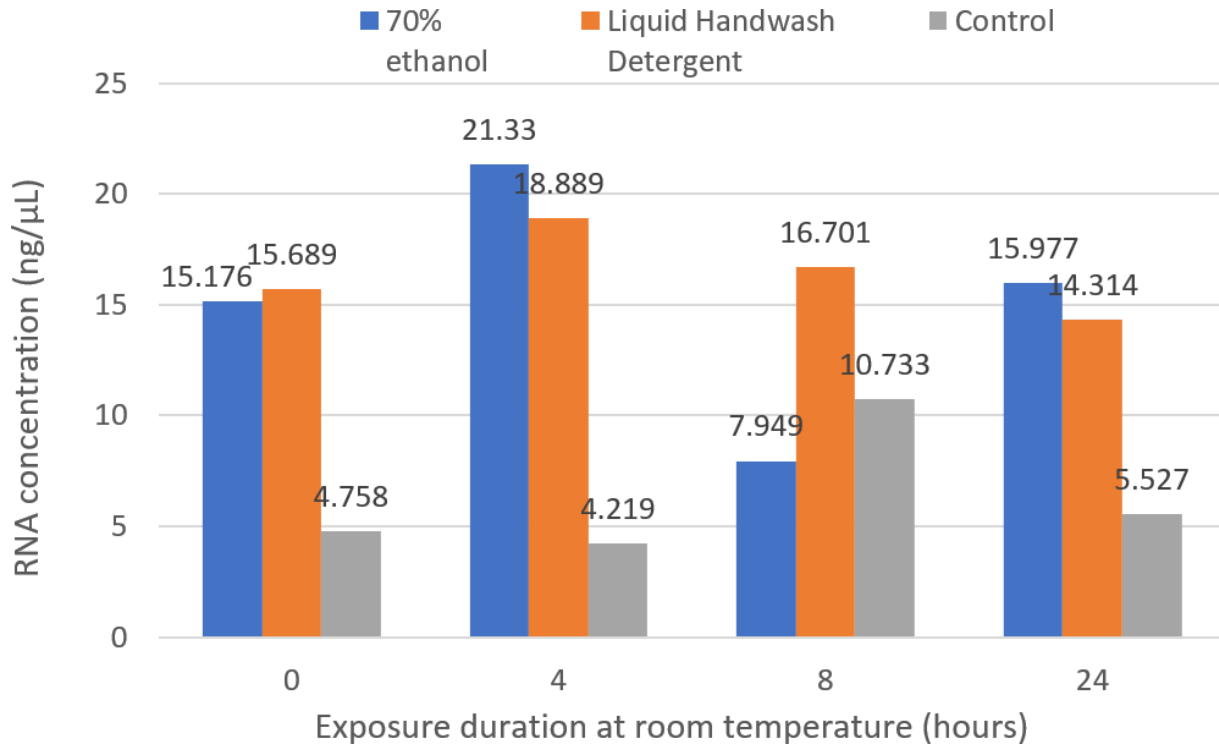
*Figure 1: The variation in RNA concentration between individual nasal swabs of each exposure group: 70% ethanol exposed, detergent exposed and control groups and between the 3 groups against exposure durations: 0,4,8 or 24 hours at room temperature.*

In overall, the RNA concentrations of the nasal swabs exposed to 70% ethanol or detergent for 0,4,8,24 hours at room temperature were greater than that of control nasal swabs.

***Agarose Gel Electrophoresis Analysis of RNA Integrity (RT-PCR Amplicons)***

The agarose gel electrophoresis results of PCR amplicons generated from RNA extracts of control, detergent exposed and 70% ethanol exposed nasal swabs held at room temperature for 0,4,8,24 hours has been depicted in Figure **2**, **3** and **4**, respectively**.**
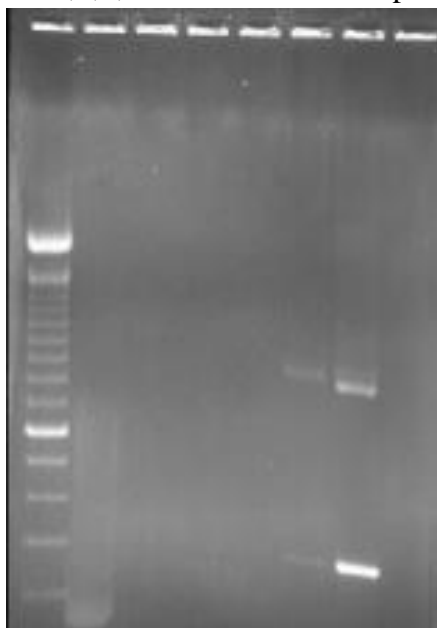


*Figure 2: Bands observed when PCR amplicons of RNA extracted from control nasal swabs held at roomtemperaturefor0, 4, 8 or 24hours were run on agarose gel. Lane 1- 4.5 µL of 100bp DNA ladder.*

Lanes 2, 3, 4 and 5- 10 µL PCR amplicons generated from7µL RNA extract of control nasal swabs held at room temperature for 0, 4, 8or 24 hours, respectively. Lanes 6, 7 and 8- 7 µL PCR amplicons generated from 7 µL RNA extracts of positive control1, positive control 2 and negative control, respectively.
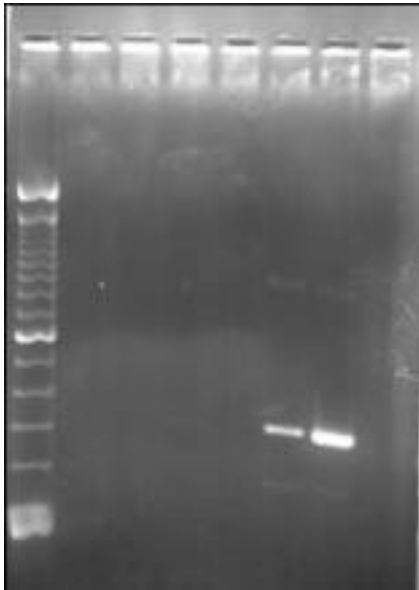
*Figure 3: Bands observed when PCR amplicons of RNA extracted from nasal swabs exposed to 70% ethanol were run on agarose gel. Lane 1- 4.5 μL of 100bp DNA ladder.*

Lanes 2, 3, 4 and 5- 10 µL PCR amplicons generated from 7µL RNA extract of nasal swabs exposed to 70% ethanol at room temperature for 0,4,8 or 24 hours, respectively. Lanes 6, 7 and 8- 7 µL PCR amplicons generated from 7 µL RNA extracts of positive control 1, positive control 2 and negative control, respectively.
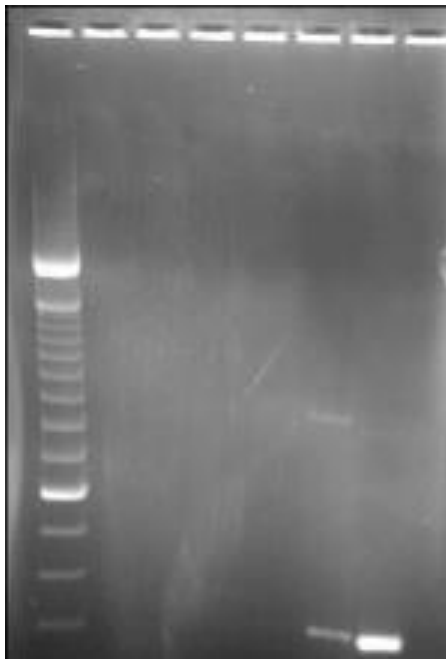


*Figure 4: Bands observed when PCR amplicons of RNA extracted from nasal swabs exposed to liquid hand wash detergent were run on agarose gel. Lane 1- 4.5 μL of 100bp DNA ladder.*

Lanes 2, 3, 4 and 5- 10 µL PCR amplicons generated from 7µL RNA extracts of nasal swabs exposed to liquid hand wash detergent at room temperature for 0, 4, 8 or 24 hours, respectively. Lanes 6, 7 and 8- 7 µL PCR amplicons generated from 7 µL RNA extracts of positive control 1, positive control 2 and negative control, respectively.

The PCR amplicons of control, detergent exposed and 70% ethanol exposed nasal swabs held at room temperature for 0,4,8,24 hours along with negative controls did not demonstrate bands. Both positive controls 1 and 2 however exhibited 300 bp bands along with bands around 800bp.

***Agarose Gel Electrophoresis Analysis of RT-PCR Amplicon Generated from Optimization Nasal Swab During RT-PCR Optimization.***

The agarose gel electrophoresis results of PCR amplicon generated from RNA extract of optimization nasal swab during RT-PCR optimization when volumes of RNA, RT and PCR master mixes were remained unchanged and when the volumes were halved has been depicted in Figure **5** and **6**, respectively.
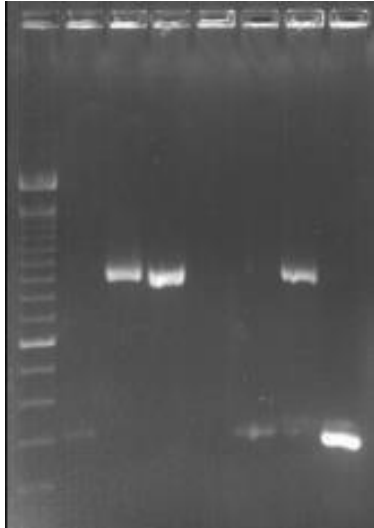
*Figure 5-Bands observed when PCR amplicon of RNA extracted from optimization nasal swab were run in parallel to PCR amplicons of buccal swab and face mask RNA extracts that were available in the laboratory on agarose gel during RT-PCR optimization. Lane 1- 4.5 µL of 100bp DNA ladder.*

Lane2-12µL PCR amplicon generated from 5µL RNA extract of optimization nasal swab. Lanes 3 and 4- 12 µL PCR amplicons generated from 5µL RNA extracts of buccal swab. Lane 5- 12 µL PCR amplicons generated from 5µL RNA extracts of facemask swab. Lane 6-disqualified. Lane7-12µL PCR amplicons generated from 5µL RNA extracts of positive control 2 and positive control 1, respectively.
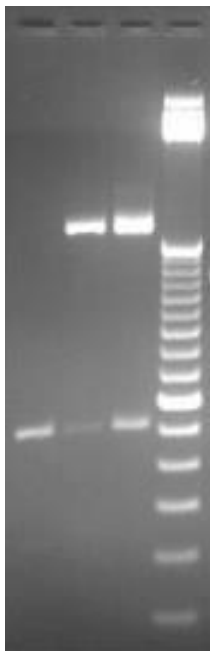


*Figure 6: Bands observed when PCR amplicon of RNA extracted from optimization nasal swab were run on agarose gel during RT- PCR optimization. Lane 1- 12µL PCR amplicon generated from 7µL RNA extract of optimization nasal swab.*

Lane 2 and3-12 µL PCR amplicons generated from 7µL RNA extracts of positive control 1 and 2, respectively. Lane 4-4.5µL of 50bp DNA ladder. 300bp bands were demonstrated by PCR amplicons of optimization nasal swab and both positive controls 1 and
2. Bands around 800bp were observed by PCR amplicons of buccal swab and both positive controls 1 and 2.

**Discussion**

RNA degrades by acidic or alkaline hydrolysis when the pH of RNA extract is <5.5 or >8.5 (Farrell Jr. 2017), (Wozniak et al. 2020). RNA Degradation produce shorter fragments that fail to get amplified during RT-PCR resulting in reduced amplification and detection sensitivity (Bridge 2016), (García Fernández et al. 2020). Exposing nasal swabs to concentrated detergent could have contaminated the final RNA extract with high concentrations of residual detergent resulting in a pH alteration of the extracts (<5.5 or >8.5) leading to possibleRNA degradation in detergent exposed extracts of all-time durations. This could have affected the 260nm absorbance leading to an overestimation in RNA concentration for the detergent exposed

groups and promoted acidic or alkaline hydrolysis of RNA resulting in the absence of bands (Figure **4**).

RNAse degrades RNA. Ethanol preserves nucleic acids by causing denaturation of proteins such as RNase (Wang, Yu & Wu 2021). 70% ethanol preserves RNA integrity at 4°C while at room temperature conditions such an effect is notobserved (Su et al. 2004). Importantly, lesser concentrations (0.01-10%) of ethanol has been found to preserveRNA integrity at 4°C (Poovakka et al. 2018). The absence of PCR amplicons (Figure **3**) could thereforeindicate the inability of 70% ethanol to denature endogenous RNase at room temperature conditions  and thereby preserve integrity of RNA extracted from nasal swabs.

Despite the lack of amplification demonstrated by the control nasal swabs (Figure 2) RNA extracted from optimization nasal swab utilized during RT-PCR optimization steps were successfully amplified demonstrating the 300bp PCR amplicon throughout optimization steps (Figures **5 & 6**).

## Future Recommendations

The nasal swabs were exposed to a single concentration of detergent therefore the likely negative effects of
detergents on RNA quality observed could have been a result of the particular concentration used being
exceedingly high to observe an uncompromising effect. In addition, ethanol concentration and temperature at
which RNA is exposed to ethanol could affect the ability of ethanol to preserve RNA integrity by denaturing RNase.

Future investigations are required to further validate the indications made in this study regarding the effects of 70% ethanol and detergent on RNA quality and gain broader insight into their effects. By exposing nasal swabs to various concentrations of detergents the concentrations of detergent at which RNA quality is minimally and highly affected at room temperature can be determined. Exposing nasal swabs to various concentrations of ethanol including 70% at various exposure temperatures including room temperature permits a definite conclusion to be drawn regarding the actual ability of 70% ethanol to preserve RNA integrity at room temperature as it could reveal the optimal temperature required for 70% ethanol to preserve integrity of RNA extracted from nasal swabs and optimal concentration of ethanol required to preserve integrity at room temperature.

## Conclusion

Exposing nasal swabs to 70% ethanol at room temperature or concentrated liquid detergent is likely to compromise RNA quality. 70% ethanol may not be a suitable alternative medium to store nasal swabs in order to preserve RNA integrity at room temperature conditions for accurate RT-PCR applications in poor isolated areas. Incorporating high concentration of detergents into cell lysis buffers and the use of concentrated detergent in the inactivation of hazardous viruses in nasal swabs for RT-PCR diagnostic applications is therefore likely to significantly compromise quality of extracted viral RNA leading to the generation of false negative results. Nasal swabs are promising minimally invasive specimens for the collection

of RNA which can be successfully amplified by RT-PCR for upper respiratory infection diagnosis. Nasal swabs could greatly minimize the need and use of invasive nasopharyngeal swabs and aspirates facilitating in diagnosis of respiratory infections among infants, children, older and sick individuals.

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# INCIDENCE AND DISTRIBUTION PATTERNS OF ANTIBIOTIC-RESISTANT BACTERIA IN SRI LANKA

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## Abstract

Mostly spread by untreated effluents from man-made sources such as wastewater treatment facilities and hospitals, antibiotic-resistant bacteria (ARBs) are a worldwide public health crisis. By analyzing the effects of human-activities, urbanization, and water quality on the growth and spread of ARB, this study seeks to determine the prevalence of ARB in surface freshwater bodies in the Western Province. Antibiotic Susceptibility Testing is primarily used as the molecular technique in the analysis against three antibiotics of amoxicillin, ampicillin and ciprofloxacin used in the study. The results of this study indicate a high incidence of ARB in all the sample sites proving that incidence and distribution of ARB is positively associated with urbanization and human-activities. Additionally, published research analysing the water quality of sampling locations in relation to temperature, pH, dissolved oxygen and biological oxygen demand were also proven to contribute to the development and dissemination of ARB.

**Keywords:** Antibiotic Resistant Bacteria, Human-activities, Surface freshwater bodies, Urbanisation, Water quality.

## Introduction

Antibiotic resistance is a global public health issue, causing increased morbidity and mortality rates (World Health Organization, 2020). Antibiotic Resistant Bacteria (ARB) have developed resistance due to unprocessed water discharge practices and the exponential increase in antibiotic use. In Sri Lanka, zoonotic and bacterial diseases are a serious public health issue, leading to extended hospital stays, higher death rates, and a financial strain on the health sector (Darby et al., 2022). ARB spreads in surface freshwater bodies through the release of untreated effluents from various human activities. Urbanization, a sign of higher population density, further hastens the growth and spread of ARB in freshwater bodies.

This study seeks to investigate the incidence of ARB in surface freshwater bodies in the Western Province of Sri Lanka while investigating insights for the ARB distribution patterns in relation to urbanization, water discharge patterns of human activities and water quality.

## Methodology

### *Ethical Approval*

The ethics decision of "Approved Standard" was granted on 06/02/2023 under the project reference number UG-6806.

*Study Area*

To illustrate how urbanization and human activities affect antibiotic resistance, five sites corresponding to each district of the Western Province were chosen (see Table 1).

Table 1: Overview of the Sampling sites used in this study.

| Districts | Sampling site | Surface Freshwater body analysed | Effluents from associated human-activities |
|---|---|---|---|
| **Colombo District** | Colombo | Beira Lake | Multiple human activities and sources of effluents |
| **Gampaha District** | Ragama | Ragama Canal | Hospital wastewater |
| | Dandugama | Dandugam Oya | Animal farm wastewater |
| | Seeduwa | Aththanugalu Oya | Wastewater treatment plant effluents |
| **Kalutara District** | Pelpola | Keppu Ela | Lacks prominent influence from human activities |

*Sample Collection*

Using sterilized jars at a distance of 30 to 50 cm from the water's surface to keep any surface film out of the jar, 250 ml of water was collected from each site.  To assure sample quality, a 24-hour interval was maintained between sample collection and subsequent analysis and to ensure favorable microbiological conditions, the samples were kept at 4ºC.

*Culture and Antibiotic Susceptibility Testing (AST)*

The Luria Broth (LB) Agar media was poured into sterilized petri dishes and inoculated with 1ml of water sample (Clinical and Laboratory Standard Institute, 2020). The bacterial colonies were tested for antibiotic susceptibility using the Kirby-Bauer disk diffusion test. The petri dishes were divided into four regions, and antibiotic disks corresponding to ampicillin, amoxicillin, and ciprofloxacin were placed in the middle of each region and the petri dishes were then incubated at 37ºC for 24 hours.

Table 2: Clinical Laboratory Institute Standard zones of inhibition (Clinical and Laboratory Standard Institute, 2020).

| Antibiotic category | Antibiotic disk content | Bacterial species tested | Diameter of Standard Zones of Inhibition (mm) | | |
|---|---|---|---|---|---|
| | | | Resistant | Intermediate | Sensitive |
| **Ampicillin (AMP)** | 10 µg | All Enterobacterals | $\leq 13$ | 14 – 16 | $\geq 17$ |

| Amoxicillin (AML) | 10 µg | All Enterobacterals | ≤ 13 | 14 – 17 | ≥ 18 |
|---|---|---|---|---|---|
| Ciprofloxacin (CIP) | 5 µg | All Enterobacterals except *Salmonella* spp. | ≤ 21 | 22 – 25 | ≥ 26 |
| | | For *Salmonella* spp. | ≤ 20 | 21 – 30 | ≥ 31 |
| | For the inclusion of *Salmonella* spp. and other Enterobacterals including *Escherichia coli*, the diameter of standard zone of inhibition used for ciprofloxacin was 20mm. | | | | |

**Results**

Table 3: Summary of antibiotic resistance shown by bacterial colonies as per the standard zones of inhibition.

| Sample Site | Amoxicillin-resistant bacteria colonies | Ampicillin-resistant bacteria colonies | Ciprofloxacin-resistant bacteria colonies |
|---|---|---|---|
| **Colombo** | Present | Present | Present |
| **Ragama** | Present | Present | Present |
| **Dandugama** | Present | Present | Present |
| **Seeduwa** | Present | Present | Present |
| **Pelpola** | Present | Present | Present |

**Discussion**

***Variations in Colony Density of cultured water samples***
The colony density, representing the number of colonies per unit area of culture medium is closely associated to the bacterial concentration present in water samples. The descending order of colony density comprises; Colombo, Dandugama, Ragama, Seeduwa and Pelpola. The colony densities in Pelpola and Colombo were ranked the lowest and the greatest, respectively. According to the Department of Census and Statistics (2022), one explanation for this would be that Colombo has a larger population than Pelpola.

Similarly, when considering related human activities, Beira Lake is highly polluted due to the outflow of significant volumes of raw wastewater from various human activities, which has also contributed to a high concentration of bacteria (Weerasinghe and Handapangoda, 2019). Comparably, Dandugam Oya's direct release of waste from livestock farms has elevated bacterial concentration, ranking Dandugama the second highest in regards to colony density. Contrastingly, Pelpola had the lowest colony density due to the lack of a significant human source releasing effluents, whereas Seeduwa had the second lowest due to wastewater processing before disposal.

As shown in Table 3, AML, CIP, and AMP-resistant bacterial colonies were found in the cultures of all sample sites. In comparison to Pelpola, the elevated bacterial concentrations at other sampling sites suggest that urbanization and the effect of human activities greatly influence the incidence of ARB.

### Effect of human activities and water quality in the development of ARB

#### Direct discharge of wastewater containing ARB into surface fresh water bodies

Due to of the release of unprocessed effluents over time, Beira Lake has become a highly polluted fresh water body in the Western Province which is reconfirmed by the significant concentration of ARB found in Beira Lake.

Hospital effluents also contain substantial concentrations of antibiotics and ARB, contributing to the development and propagation of antibiotic resistance. In Sri Lanka, ARBs have been detected in effluents from various hospitals, highlighting the influence of inadequate waste management on ARB growth in surface freshwater bodies (Liyanage and Manage, 2016). Thereby, the presence of ARB in Ragama as shown in Table 3 further confirms the influence of inadequate hospital effluent management on the development of ARB in freshwater bodies. ARBs have also been found in wastewater from Sri Lankan farms raising poultry and farm animals, including *Stenotrophomonas species*, *Bacillus species*, and *Staphylococcus species* (Herath et al., 2016). The elevated incidence of ARB in Dandugama further supports the notion that effluents from poultry and livestock husbandry contribute to ARB development in surface freshwater bodies.

Wastewater Treatment Plants (WWTPs) are important contributors to antibiotic resistance, as they provide environments that contribute to the development and distribution of ARB and ARGs. The discovery of ARB at Seeduwa as given in Table 3 further supports the notion that ARB are not completely removed by current water purification methods.

ARB spreads throughout the country due to surface freshwater sources carrying ARB combining with other bodies of water. Pelpola, a sample site with minimal impact from urbanization and human activities, serves as a warning about the high incidence of ARB in surface freshwater bodies that are already flowing within water bodies of Sri Lanka.

### Effect of water quality of surface freshwater bodies on the development of ARB

Table 4: Physicochemical Properties of freshwater of Beira Lake (Central Environmental Authority, 2019; Idroos & Manage, 2014; Kamaladasa & Jayatunga, 2007).

| Water Quality Parameter | January 2013 – January 2014 | May – October 2017 | Maximum tolerance limit |
|---|---|---|---|
| **Water temparature (ºC)** | 27.3 – 29.9 | 30 – 36 | < 40 |
| **pH** | 5.08 – 9.93 | 6.38 – 11.26 | 6.0 – 8.5 |
| **Dissolved Oxygen (mg/L)** | 3.11 – 6.18 | 4.0 – 18.0 | < 6 |

| Biochemical Oxygen Demand (mg/L) | - | 3.82 – 18.17 | < 3 |
|---|---|---|---|

Table 5: Physicochemical Properties of freshwater of Aththanagalu oya at Seeduwa Kotugoda road bridge (sampling location) (Central Environmental Authority, 2019; Pathirana et al., 2012).

| Water Quality Parameter | 2012 | Maximum tolerance limit |
|---|---|---|
| pH | 6.0 – 8.5 | 6.0 – 8.5 |
| Dissolved Oxygen (mg/L) | < 6 | < 6 |
| Biochemical Oxygen Demand (mg/l) | 1 | < 3 |

Table 6: Physicochemical Properties of freshwater of Dandugam Oya (Central Environmental Authority, 2019; Mendis et al., 2020).

| Water Quality Parameter | January – December 2017 | Maximum tolerance limit |
|---|---|---|
| Water temparature (ºC) | 29.10 – 29.90 | < 40 |
| pH | 6.98 – 7.42 | 6.0 – 8.5 |
| Dissolved Oxygen (mg/L) | 2.8 – 5.0 | < 6 |
| Biochemical Oxygen Demand (mg/L) | 26.1 – 33.5 | < 3 |

Other than direct discharge of ARB, water quality corresponding to physicochemical properties such as temperature, pH, Biological Oxygen Demand (BOD) and Dissolved Oxygen (DO) other constituents of water, play a crucial role in the survival, growth and dissemination of ARB(Liyanage and Yamada, 2017).

Tables 4 and 6 show that while Beira Lake and Dandugam Oya's water temperature remains below the maximum tolerance limit, it has been rising over the years, reaching 36 ºC in October 2017 and potentially reaching 40 ºC or higher as of 2023. According to several researches, it is reported that temperature and antibiotic resistance in bacteria have a proportional relationship. Resistance acquisition mechanisms such as Horizontal Gene Transfer (HGT) are temperature dependent and the increased survival and growth of ARB at higher temperatures relates to increased selection and dissemination of ARB (Idroos & Manage, 2014). On the other hand, temperature affects the stability of antibiotic residues which promote antibiotic-resistance. For instance, beta-lactam antibiotics had a higher degradation rate at 37ºC(Samara et al., 2017) Therefore, the rise in temperature in both Beira Lake and Dandugam Oya can be deduced to contribute to the development of ARB.

The pH of Beira Lake has been rising above the tolerance limit over the years and in 2017, it was reported to have an alkaline pH. According to Weerasinghe and Handapangoda (2019), alkaline pH increases solubility of nutrients which promotes eutrophication of water bodies

resulting in increased growth of cyanobacteria and the production of toxins (microcystins) which contributes to the development of ARB. On the other hand, the pH of Dandugam Oya and Aththanagalu Oya remains in the tolerance range. However, the effect of pH on ARB does not show a uniform correlation. A variety of isolates such as *Staphylococcus* and *E. coli* shows increased resistance at low pH (6.5) while some isolates such as *Bacteroides fragilis* and *Proteus mirabilis* showed comparatively less resistance at pH 6.5(McArdle et al., 2018; Thomas et al., 2012). Furthermore, it was discovered that pH also plays a critical role in the prevalence of antibiotics residues in surface water (Mendis et al., 2020).

The DO reported at Aththanagalu Oya and Dandugam Oya was below the tolerance limit while DO reported at Beira lake was higher than the tolerance limit. The amount of DO in water also shows varying effects on the development of ARB. Gupta et al., (2016), reported that *Pseudomonas aeruginosa, Staphylococcus aureus* and *Klebsiella pneumoniae* showed increased resistance to aminoglycoside, macrolide and β-lactam antibiotics at anoxic conditions, while decreased resistance to tetracycline and tigecycline antibiotics were observed at hypoxic conditions. Furthermore, Zhuang et al., (2017), reported that the expression of ARGs such as sodB and feoB1in *Magneto spirillum gryphiswaldense* decreased at hypoxic conditions leading to decreased antibiotic resistance. Therefore, the exact effect of DO on varying oxygen conditions with respect to the sampling locations needs further analysis.

BOD is an indicator of organic pollution and correlates to eutrophication. The BOD of Beira Lake and Dandugam Oya was four times and eleven times the threshold value respectively. High eutrophication characterized by abundant growth of water hyacinths in the Dandugam Oya and the presence of cyanobacterial blooms (intense green color water) in Beira Lake further confirms this. High BOD levels are reported to positively correlate with the prevalence of ARB(Kubera, 2021). On the other hand, BOD of Aththanagalu Oya was reported to be lower than the threshold. Treatment processes such as anaerobic basins and activated sludge found in Ekala WWTP are standard BOD reduction methods which may have contributed to the decreased BOD levels (Nilsson et al., 2018).

Furthermore, water constituents such as cyanobacteria, Microcystins and Polycyclic aromatic hydrocarbons (PAHs) have also been linked to the development of antibiotic-resistance. PAHs were found to be abundant in the Beira Lake which may occur through the discharge of hydrocarbons from fuel, organic metabolism and incomplete combustion. Studies report that PAHs induce molecular and physiological mechanisms such as HGT of ARGs and stress response pathways promoting the development of ARB (Maurya et al., 2021).

Furthermore, studies have provided evidence for the presence of high concentrations of cyanobacterial blooms and cyanotoxins (produced by cyanobacteria) in the Beira Lake which are a consequence of eutrophication (Idroos and Manage, 2014). It was reported that Microcystins which are the most predominantly available cyanotoxins in freshwater, accelerate the dissemination and abundance of ARGs especially in relatively senile water bodies such as lakes (Zheng et al., 2018). Additionally, the concentration of Microcystins was reported to be directly proportional to the efficiency of conjugation promoting HGT of ARGs between bacteria which further accelerates the dissemination of ARB (W Li et al., 2021).

**Conclusion and Recommendations**

The study validates the existence of Antibiotic Resistant Bacteria (ARB) in the Western Province's surface freshwater bodies, and finds a significant correlation between the incidence of ARB and patterns of wastewater outflow and urbanization. Thereby, the effect of urbanization and wastewater discharge patterns of human activities were proven to have a close association with the prevalence of ARB in surface freshwater bodies. Future research on a larger variety of antibiotics and further investigations on specific physicochemical characteristics of surface freshwater bodies can be used to better understand antibiotic resistance and the drivers that contribute to their development. Subsequent research could also utilize the isolation of morphologically distinct colonies and subsequent single colony formation through the streak plate approach. In conclusion, antibiotic resistance is a major public health threat that requires immediate infection control protocols and continuous monitoring to further control the spread of ARB before this crisis turns into epidemic in the country.

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# COMPARING EXTREME TEMPERATURE AND RAINFALL WITH AVERAGE METEOROLOGICAL CONDITIONS ON DENGUE TRANSMISSION IN SOUTH ASIA

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**Abstract**

Dengue fever (DF) is a serious health concern that has spread worldwide rapidly. The changes in weather patterns due to increasing climate change have resulted in fluctuations in temperature and rainfall, which significantly impacts the transmission of dengue fever in South Asia. The analysis of the impact of temperature and rainfall on the transmission of Dengue Fever was conducted using current and trustworthy publications from sources like Google Scholar and PubMed. The highest transmission of DF occurs at 26–29°C, while temperatures below 25°C lower the risk of infection. Heavy rainfall lowers the risk of DF by eliminating mosquito breeding sites, while moderate rainfall increases it. This review also highlights the response to dengue fever in South Asia and based on the findings, modern strategies, and renewed mosquito-borne health policy guidelines to prevent and control dengue fever infection in South Asia can be approached.

**Keywords**: Climate change, Dengue transmission, Extreme weather, South Asia, Temperature & Rainfall

## Introduction

Dengue fever is a disease that is transmitted by infected female mosquitoes, particularly *Aedes aegypti* and *Aedes albopictus* (Bhatt *et al*., 2013). It is a growing public health concern worldwide and poses a greater threat in tropical regions with wet and dry climates, especially in South Asian regions (Bhatt *et al*., 2013; Ebi and Nealson, 2016). In fact, 75% of global cases of dengue fever are reported in South Asian countries (WHO, 2023). Dengue fever is most prevalent in South and Southeast Asian regions (Wang *et al*., 2023).

The risk of DF transmission is increasing due to various factors such as rapid urbanization, population growth, lifestyle changes, increased vector-human contact, travel, and climate change (Chakravarti, Arora, and Luxemburger, 2012). However, climate change has a greater impact, affecting temperature, rainfall, and humidity which, in turn, affects the virus-vector-host triangle.

Based on the Notre Dame Global Adaptation Initiative (ND-GAIN) country index, South Asian nations are more susceptible to climate change (Khatoon *et al*., 2023). This is primarily due to their tropical location, where they experience both wet and dry climates, making them prone to extreme temperature deviations and high rainfalls. Temperature and rainfall patterns are closely linked with the biology and transmission of vector-borne diseases (Kulkarni, Duguay and Ost, 2022). While there have been numerous studies on the potential spread of dengue

fever in relation to climate change and changing weather patterns, the impact of extreme weather conditions on the risk of dengue fever infection has been less explored.

The main objective of this review is to compare and understand the trends in dengue fever transmission under extreme weather conditions, such as heavy rainfall and high temperatures.

**Methodology**

A thorough search was conducted on Google Scholar, PubMed, and Web of science to find related research articles on the transmission of dengue fever in South Asia and its connection to climate change, published between 2010 and the present day. The search resulted in 31 papers, out of which 25 focused on the potential impact of global climate change on dengue transmission. The review also includes relevant publications from the World Health Organization (WHO) concerning dengue. The primary focus of this review was on 12 articles that exclusively covered South Asian and Asian regions. These 12 articles were analyzed to determine the impact of climate changes, such as temperature, rainfall, and extreme weather on the transmission of dengue fever in South Asia.

In the review, extreme temperature is defined as weekly mean temperatures at the 10th percentile and 90th percentile (Kranc *et al*., 2021, Zhang *et al*., 2019), while extreme rainfall refers to precipitation at the 90th percentile (Yang *et al*., 2020).

**Results and Discussion**

*The epidemic of dengue transmission in South and Southeast Asia (SEA)*

The SEA Region has 10 countries with dengue-endemic areas, where 1.3 billion people are at risk of contracting dengue fever, out of 3.5 billion people living in dengue-endemic countries worldwide **(WHO, 2023)**. Dengue fever is a prevalent illness in South Asia, caused by meteorological changes and prone to disastrous weather extremes such as droughts, floods, and cyclones due to strong seasonal monsoons (IPCC, 2007a; Senaratne and Rodrigo, 2014). According to the World Health Organization (WHO), dengue fever is most widespread in Asia, accounting for 70% of global cases **(WHO, 2023)**. Bangladesh, Malaysia, the Philippines, and Vietnam reported a high number of cases in 2019, with Afghanistan reporting its first-ever case of dengue transmission in the same year **(WHO, 2020b)**. India, Indonesia, Myanmar, Sri Lanka, and Thailand are among the 30 most highly endemic countries in the world **(WHO, 2023)**.

The alarming increase in dengue cases in the SEA region can be attributed to population growth, inadequate water supply, poor sewer, and waste management systems, an increase in global commerce and tourism, global warming, changes in public health policies, and the development of hyper-endemicity in urban areas. The dengue burden in the SEA region is high due to a lack of effective treatment and sustainable vector control, making it a significant public health concern **(WHO, 2023)**.
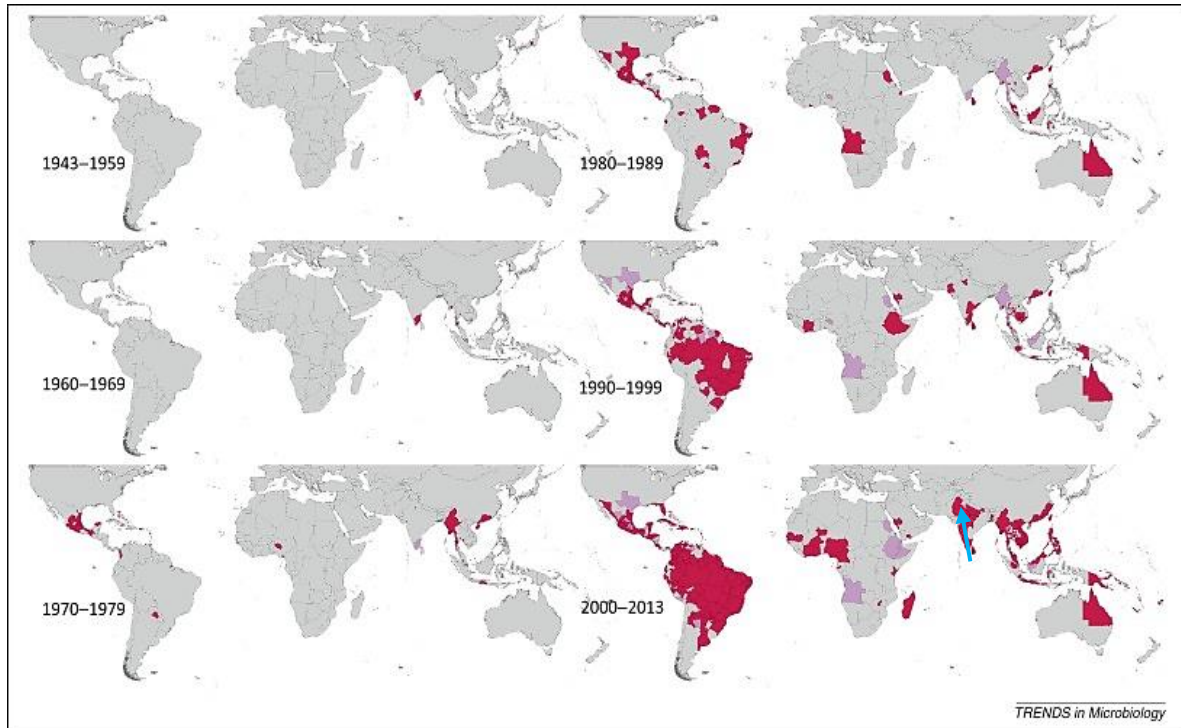
*Figure 1- Global history of each Dengue virus type from 1943 to 2013 shows a rise in dengue incidence in South Asian regions (shown by the arrow) (Messina et al., 2014).*

### *Effect of temperature and rainfall on the dengue transmission*

The dengue virus's transmission is influenced by various meteorological factors such as rainfall and temperature (Naish et al., 2014). The mosquito vector responsible for the transmission of dengue fever is greatly affected by temperature, rainfall, and humidity (Patz *et al.,* 2005). The life cycle of mosquitoes is dependent on weather conditions, and the primary vector of dengue fever, *Aedes aegypti*, thrives in regions with favorable environmental factors like temperature, rainfall, and humidity (Lambrechts and Failloux, 2012)

Temperature and rainfall are two vital factors that impact the environmental suitability for the transmission of mosquito-borne infectious diseases. Various studies have projected the transmission potential of dengue fever under climate change and have indicated an increased incidence of the disease, along with geographic expansions to non-epidemic areas (Baylis, 2017; Butterworth *et al*., 2017).

**Table 1 :** Indicating the impact of temperature and rainfall on dengue transmission

| | **Effect on dengue transmission** | **Reference** |
|---|---|---|
| **Temperature** | Affects development, survival, reproduction, and biting rates of mosquitoes, and the rate at which they acquire and transmit viruses. *A. aegypti* and *A. albopictus*, exhibit a transmission peak between 18–34°C. The maximal | (Mordecai *et al.,* 2022**).** |

| | transcription occurs in a range from 26–29°C. Affects development of the pathogen inside the mosquito's body or Extrinsic incubation period (EIP) | |
|---|---|---|
| **Rainfall** | heavy rainfall (above 550mm) can eliminate breeding sites, while moderate rainfall can lead to an increase in breeding sites, which in turn increases the risk of disease transmission. Decline in the number of DF incidences of 24-h precipitation levels exceeding 50 mm. | (Campbell-Lendrum *et al.* 2015; Nuraini *et al.* 2021; Colón-González *et al.*, 2013). |

*Evidence for the Correlation between temperature and rainfall on the transmission of dengue fever in South Asia*

A recent study conducted by Wang *et al*. (2023) in four Asian countries found that temperature and rainfall have an impact on the transmission of dengue.

**Table 2 :** Dengue Fever and Meteorological Data in four Asian regions studied from 2012 to 2020 (Wang et al., 2023)

| Location / Country | Total dengue cases | Mean incidence rate / 10000 per year | Daily mean temperature (°C) | Daily rainfall (mm) |
|---|---|---|---|---|
| Chiang Mai / Thailand | 35,216 | 22.90 | 26.91 | 2.89 |
| Colombo / Sri Lanka | 112,757 | 52.11 | 28.06 | 6.89 |
| Selangor / Malaysia | 409,704 | 72.35 | 28.17 | 8.10 |
| Singapore | 126,962 | 25.34 | 27.87 | 6.28 |

When analyzing the results in Table 2, it is evident that Selangor had the highest number of dengue cases due to its high average temperature and rainfall. In contrast, Chiang Mai had lower cases of dengue due to its lower mean temperature and daily rainfall. South Asian regions are more vulnerable to climate changes, and significant temperature and rainfall deviations are seen more prominently (Khatoon *et al*.,2020). Studies support this trend and show the risk of dengue transmission is higher in South Asia with high mean temperatures and rainfall (Bal and Sodoudi,2020; Davis *et al*., 2021).

. The threshold of extremely cold or hot conditions is defined by using the 10th or 90th percentile as per the extreme weather definitions (Kranc *et al*., 2021; Zhang *et al*., 2019).
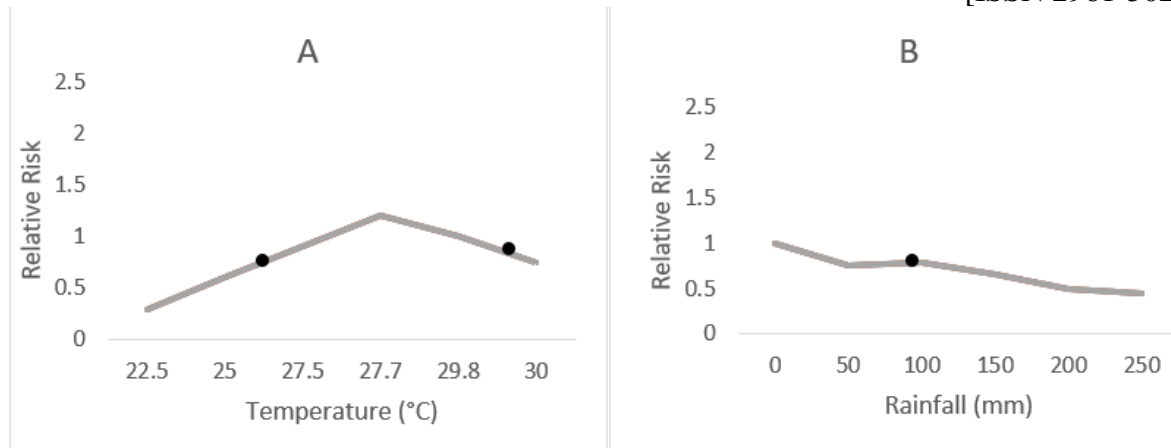
*Figure 2- Transmission of dengue fever with respect to weekly mean temperature (A) and total rainfall (B). Dots show the 10<sup>th</sup> and 90<sup>th</sup> percentiles of temperature and 90<sup>th</sup> percentile of rainfall (Wang et al., 2022).*

As in Fig.2, it was found that temperatures below 25 ˚C were significantly associated with a lower risk of Dengue Fever (DF) infection as compared to the median temperature of 27.7 ˚C at the 10th percentile. However, an extremely high temperature of 29.8 ˚C indicated a decreased DF risk, although the association was not found to be significant at the 90th percentile. Compared to no rainfall (0mm), weekly rainfall at the 90th percentile (i.e. 94.0 mm) showed significantly decreased DF risk (Wang *et al.*, 2022). In contrast, Cheng *et al.* (2021) linked heat waves, heavy rainfall, and an increased risk of dengue outbreaks. Their research found that there was a risk increase of 115-251% approximately 6 weeks after heatwaves, and a 173-258% risk increase 6-13 weeks after extremely heavy precipitation. Nosrat *et al.* (2021) supported this finding by demonstrating that dengue transmission increases during extreme rainfall due to a rise in mosquito egg abundance.

**Table 3 :** Comparison between the influence of different meteorological conditions on dengue fever transmission

| | Temperature | | | Rainfall | | |
|---|---|---|---|---|---|---|
| | **Mechanism** | **Risk of transmission** | | **Mechanism** | **Risk of transmission** | **Reference** |
| **High Tempe ra-ture** | vertical transmission of DF is more noticeable for temperature values within the range of 16°C to 26°C | higher risk | **High Rainfall** | More rainfall increases the number of aquatic mosquitoes and breeding sites | higher risk | (Taghikhani and Gumel, 2018) (Benedum e t al., 2018; Morin et al., 2013) |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Low Mean Tempe ra-ture** | *A. aegypti* exposed to temperature fluctuations at low temperatures have a shorter virus EIP than in constant temperature conditions | higher risk | | | | (Carrington *et al*., 2013) |
| **Extrem e high Tempe ra-ture** | When temperature surpasses the optimal threshold, the mortality of the DF vector increases, and the infection decreases to temperatures greater than 28°C. Hatching rate of mosquito eggs decrease as the temperature increases from 29°C to 35°C | lower risk | **Extreme Rainfall (can have both negative and positive impacts on dengue transmiss ion)** | Extreme rainfall affects the aquatic vector. Heavy or extreme rainfall (90th percentile) can wash away mosquito eggs, larvae, and pupae But also, mosquito egg abundance seen in extreme rainfalls increase risk | lower risk | (Paul *et al*., 2021; Taghikhani and Gumel, 2018;) (Wang *et al*., 2023) (Wang *et al*., 2022) (Nosrat *et al*., 2021) |
| **Extrem e low temper at-ure** | Below 25°C a lower risk of the DF infection is seen | lower risk | | | | (Wang *et al.,* 2022) |

However, adult mosquitoes can still survive in extreme cold temperatures in tropical countries (Brady *et al*., 2013), which means that the reduced risk of DF infection may not continue. Seah *et al*. (2021) have confirmed with a 1°C increase in maximum temperature from 31°C, the risk of DF decreases by 13.1% over six weeks. Moreover, Hemme *et al*. (2009) have discovered that *A. aegypti* immatures were absent in containers with a water temperature surpassing 32°C. If the temperature continues to rise due to climate change, the hatching rate may decrease further (Mohammed and Chadee, 2011), leading to a reduction in the *A. aegypti* population in both wet and dry seasons (Chadee *et al*., 2007). As per reasoning

(Table 2), high temperatures resulting from climate change could lead to an increase in the transmission of dengue fever in South Asia. However, if the temperature exceeds specific threshold values, the risk might decrease. Nevertheless, extreme weather conditions can cause other issues such as the spread of waterborne infectious diseases, elevated sea surface temperature, and sea levels (Bezirtzoglou, Dekas and Charvalos, 2011; Chowdhury *et al.*, 2017).

**Conclusion**

Compared to temperate areas, tropical regions like South and Southeast Asia are expected to have more favorable conditions for dengue fever vectors in the future, which may lead to different dengue fever transmission patterns. Therefore, it is crucial to study the impact of temperature on dengue transmission, as it can affect the transmission of the dengue virus by mosquitoes. Warmer temperatures contribute to an accelerated EIP, and rapid virus spread, leading to an increase in mosquitoes. Lower temperatures, on the other hand, can reduce the risk of dengue infection. Extreme temperatures beyond the threshold may decrease the DF transmission risk as it can increase mosquito mortality. Average rainfalls create favorable breeding places for mosquitoes, thereby increasing the risk of DF. However, heavy rainfalls in extreme conditions can flush out mosquito eggs and larvae. Understanding the changes in dengue fever risk due to extreme weather and mean climatic conditions is crucial for implementing prevention methods. The determinations of this research can act as a base for conducting a comprehensive study across South Asian nations in the future. The study can also guide public health experts, clinicians, and policymakers to fight climate-related dengue transmission in South Asia.

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# KNOWLEDGE AND AWARENESS ON THALASSEMIA AMONG YOUNG POPULATION IN KURUNEGALA DISTRICT, SRI LANKA

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## Abstract

Thalassemia is an inherited blood disorder that can be encountered all around the world. The disease is considered to be the most common single genetic disorder that can also be diagnosed among the Sri Lankan population. Kurunegala is recognized as one of the major districts in Sri Lanka that has a high prevalence for the disease. Therefore, it is important to take the necessary steps to reduce the severe burdens of the disease by enhancing awareness towards it. This descriptive cross-sectional, questionnaire-based online survey was conducted to evaluate the knowledge and awareness of thalassemia among the young population in Kurunegala district. The majority of the participants were female (59%). 81.8286, 79.3333, 76.8400, 82.3667, and 85.9333 mean values were calculated for the general understanding, signs and symptoms, diagnostic techniques, treatments, and prevention of thalassemia, respectively. A significant difference in knowledge was observed among people with different occupations and educational levels.

**Keywords:** Awareness, Knowledge, Kurunegala District, Thalassemia, Sri Lanka

## Introduction

Thalassemia is well known around the globe as one of the most common recessive monogenic disorders that causes the human body to produce abnormal forms of alpha and beta globin proteins, the two major constituents of hemoglobin. Since the condition is inherited, the mutated gene code for the above-mentioned globin portions are passed down from affected parents to their offspring. Thalassemia major is the most severe form of the disease which required a life-long blood transfusion to maintain the desired hemoglobin level in the blood and following iron chelation therapy to reduce excess iron overload (Nandarathna et al., 2022). The disease has shown a significant impact including ineffective erythropoiesis, chronic anemia, and iron accumulation, which ultimately leading to clinical complications of thalassemia such as splenomegaly, extramedullary erythropoiesis, leg ulcers, thrombophilia, and bone deformities (Asadov et al., 2018). These severe outcomes cause several socio-economic and educational dilemmas for families with thalassemia patients.

WHO (2022) estimations revealed that this genetic condition results nearly around 56,000 thalassemia births annually worldwide especially among populations in Greece, Italy, Middle East, South Asia, and African descent. In Sri Lanka, 2.8% of β-Thalassemia carrier frequency was reported with approximate 2000-3,500 recognized thalassemia patients in the year 2022 (Eleftheriou and Angastiniotis, 2021, p. 83), while the majority was concentrated in Kurunegala, Anuradhapura, and Colombo districts (Premawardhana et al., 2019). The estimated birth incidence of thalassemia in Sri Lanka in the year 2022 was around 0.18/1000

livebirths (lbs) and 0.02/1000 lbs with HbS/β-thalassemia (Eleftheriou and Angastiniotis, 2021, p. 83). The highest number of thalassemia incidences in Sri Lanka are reported in the Kurunegala district (Nandarathna and Peiris, 2022).

Both government and private sector health care organizations implement several strategies such as public education, population screening, genetic counseling, and antenatal diagnosis in order to raise awareness, knowledge, and attitudes regarding thalassemia among the society. But the effort is insufficient when considering the number of thalassemia carriers who are being detected island-wide, which is increasing in number annually (Warushahennadi et al., 2020).

The cost of a thalassemia major patient for a lifetime (assuming 13.2 years of lifespan) was around LKR 7,093,278 (USD 35,113), and calculated cost for bone marrow transplantation was LKR 5,000,000 (USD 24,751) to LKR 8,000,000 (USD 39,601) (Amarasinghe et al., 2022). Since, Sri Lanka is a developing country, it is difficult to tolerate that much of a cost, hence, preventing this disease should be taken as a priority. On that account, this study is focused on evaluating the current status of thalassemia awareness in Kurunegala district which has a high prevalence for the disease in Sri Lanka, and help in managing the impact of the disease by drawing attention to thalassemia in the youth population because they have a greater contribution in creating new generations.

**Methodology**

This descriptive cross-sectional study was conducted for a one month period of time from 1st September to 1st October 2023. Participants within 20-30 years age group born in Kurunegala district, the capital city of North Western Province, Sri Lanka were invited. The protocol was approved by the Ethics Committee of Cardiff School of Sport and Health Sciences under Project Reference Number UG-7792 on 27th July 2023. Consent form and participant information sheet was sent to the participant. A structured, self-administered questionnaire written in English was developed and distributed through online platforms such as WhatsApp and Facebook. The formal questionnaire includes a total thirty questions and it was divided into five sub-sections to elaborate on the general understating, symptoms, diagnostic techniques, treatment options, and prevention of thalassemia. Sociodemographic characteristics such as age, gender, educational level, and occupation were obtained prior to the main questionnaire. A total of 100 responses were collected for the analysis. Responses were then analyzed using MS Excel and IBM Statistics SPSS version 23.0. The responses were assessed using a five-point Likert scale ranging from 1-5 (1=strongly disagree, 2=disagree, 3=neutral, 4=agree and, 5=strongly agree). Only two questions were scored on a two-point scale (1=no and 5=yes). Higher scores represented better knowledge and awareness. The knowledge score for each category was calculated by adding up the points obtained for the corresponding questions. Descriptive statistics (one-way ANOVA test) applied to compare multiple group means (sub-sections vs. demographic characteristics). $P < 0.05$ was considered significant.

**Results and Discussion**

All participants were fallen under the age group of 20-30. The majority of the respondents were female (59%). The analysis revealed that the total mean awareness score on thalassemia among respondents was at an acceptable level (M = 81.05, SD = 6.02).

The mean values were calculated for each section and compared to the level of awareness on thalassemia in between them.

*Mean scores for each category.*

As presented in below **Table 1,** mean awareness scores for diagnosis (M = 76.8400) and symptoms (M=79.7333) are comparatively lesser than the mean awareness scores for general understanding (M = 81.8286), treatments (M = 82.3667), and prevention (M = 85.9333). Relatively, these mean values are high which indicates a good level of knowledge. Since thalassemia has been present in Kurunegala district for a long time, it can be concluded that there is a better understanding of the disease among the people in their everyday social exposure. However, this table indicates that awareness on diagnosis and treatments is relatively low; hence, more focus should be given to those categories in future awareness programs.

Table 1 : Statistical analysis for each section of the formal questionnaire.

|  | Gen. understanding | Symptoms | Diagnosis | Treatment | Prevention |
|---|---|---|---|---|---|
| **Mean** | **81.8286** | **79.7333** | **76.8400** | **82.3667** | **85.9333** |
| **Median** | 80.0000 | 80.0000 | 76.0000 | 83.3333 | 86.6667 |
| **Std. Deviation** | 8.06610 | 11.00638 | 5.12613 | 7.61437 | 14.24162 |
| **Minimum** | 65.71 | 53.33 | 64.00 | 66.67 | 46.67 |
| **Maximum** | 100.00 | 100.00 | 88.00 | 100.00 | 100.00 |

*Analysis of factors associated with scores.*

One-way ANOVA were conducted at a 5% statistical significance level in order to determine the level of difference in different sociodemographic characteristics.

As presented in below **Table 2** there was a statistical difference in the general understanding of thalassemia in different demographic groups based on gender, educational level, and occupation. In summary, participants who are medical related professionals, and higher educational level have greater understating on thalassemia compared to other participants who are unemployed or non-medical related professionals with a lower educational level. A possible explanation for this variability could be people with higher educational level have more access to information about thalassemia through written publications and the internet and they are also capable of reaching medical facilities such as health insurance, and other necessary health investigations. In contrast medical related professionals have had more contacts with people with thalassemia in their workplaces as well. Therefore, they obviously should have better knowledge. The same reason could be behind the observable significant differences in different occupations and each of the four subsections except prevention of Thalassemia. Even though that is expected, more attention should be focused to enhance the awareness on unemployed,

non-medical related and low educational level group as well. On the other hand, another significant difference can be seen in awareness levels on treatment in different educational levels. This could be due to the higher exposure of advanced degree holders to novel therapeutic strategies such as gene-based therapy and stem cell transplantation and their capability to afford to those expensive curative techniques compared to participants with lower educational levels. Another finding of this research is that the general understanding regarding thalassemia is relatively better among female participants (M = 83.825) than in males (M = 78.954). This could be due to the high contribution of women in making health care decisions for their families and their involvement in prenatal care.

Table 2 : Bivariate analysis of factors associated with scores.

| | | Gen. Understanding | | Symptoms | | Diagnosis | | Treatments | | Prevention | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Mean | Std. Error | Mean | Std. Error | Mean | Std. Error | Mean | Std. Error | Mean | Std. Error |
| Gender | Male | 78.954 | 1.208 | 79.024 | 1.725 | 76.780 | .805 | 84.319 | 1.238 | 83.415 | 2.211 |
| | Female | 83.825 | 1.007 | 80.226 | 1.438 | 76.881 | .671 | 86.278 | 1.647 | 87.684 | 1.843 |
| | P- Value | **0.003** | | 0.594 | | 0.923 | | 0.371 | | 0.141 | |
| Educational level | Advanced degree | 89.643 | 2.656 | 85.833 | 3.892 | 80.500 | 1.774 | 90.667 | 2.443 | 89.166 | 5.054 |
| | Bachelor's degree | 82.645 | 1.022 | 79.630 | 1.498 | 77.111 | .683 | 85.062 | 1.291 | 84.939 | 1.945 |
| | Vocational/ Technical school | 76.471 | 1.822 | 78.038 | 2.670 | 74.824 | 1.217 | 81.389 | 2.354 | 83.531 | 3.467 |
| | Other | 81.088 | 1.639 | 79.047 | 2.402 | 76.381 | 1.095 | 82.119 | 1.958 | 89.205 | 3.119 |
| | P- Value | **0.001** | | 0.405 | | 0.069 | | **0.004** | | 0.525 | |
| Occupation | Medical Related Professionals | 93.445 | 1.475 | 90.981 | 2.357 | 80.471 | 1.188 | 80.471 | 1.188 | 90.196 | 3.456 |
| | Non-medical Related | 78.917 | 0.748 | 76.565 | 1.196 | 76.182 | .603 | 76.182 | .603 | 84.848 | 1.754 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Professionals | | | | | | | | | | |
| Unemployed | 81.512 | 1.475 | 80.784 | 2.357 | 75.765 | 1.188 | 75.765 | 1.188 | 85.884 | 3.456 |
| P- Value | **0.000** | | **0.000** | | **0.005** | | **0.000** | | 0.389 | |

Another similar cross-sectional study that assesses knowledge, attitudes and practice toward thalassemia which is done in the Ibbagamuva divisional secretariat, Kurunegala, with a questionnaire and similar design to our current study, reveals that greater emphasis should be placed to enhance the knowledge through broadly establishing awareness programs in risk areas and by integrating information into the school educational system to benefit young individuals (Nandarathna and Peiris, 2022). However, the original version of the questionnaire was written in English, and the distribution of the same questionnaire among the participants can be considered as a limitation of this project.

**Conclusion**

The overall knowledge and awareness on Thalassemia among the young population in Kurunegala District is in an acceptable level. But more attention should be focused on the symptoms and diagnosis of thalassemia when comparing the mean values for each section. The findings of the study revealed that the participants with higher educational level and those who are working related to health care sector have better awareness than in less educated and unemployed group. Therefore, this study emphasized the need to sort out this gap by establishing proper health care services and advantageous awareness programs among the society.

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# EFFECTIVENESS OF MUSIC THERAPY IN TREATING DEMENTIAPATIENTS: NARRATIVE REVIEW

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**Abstract**

This research includes a total summation on what actually dementia is, the different types of music therapy available, it also includes out of the several different types of music therapy what is the most beneficial and best type, how dementia is caused in people and exactly how music therapy involves in curing the disease. This mostly emphasizes the point that classical music do have a direct influence on treating dementia patients. This research also gives a clear understanding on the epidemiology of the disease, the risk of this disease condition, the several treatments used, specially emphasizing that music therapy has a great effect on this disease, how dementia patients improved their symptoms like cognition, sensorimotor and language gradually, how types of music therapy like soft classical and non-rhythmic instrumental music became effective in curing dementia through quantitative and qualitative analysis using thematic analysis, structured and semi structured views and MAXQDA software, it also proves with evidence that quantitative studies(75% success rate) were much more efficient and precise thanthe qualitative studies done.

**Keywords:** - Dementia, Global burden of dementia, Musical therapy as treatment, Non pharmacological therapy, Qualitative and Quantitative studies.

## Introduction

It is a surprising fact to know that an estimated number of about 5 million adults who were aged above 65 years of age were affected by dementia in the year 2014, and about 14 million are to be prone to this disease by the year 2060 (WHO, 2017). By the time approximately about 50 million people worldwide have this disease of dementia and it is projected to almost triple by the year 2050 (WHO, 2017). According to the latest WHO data published in the year 2020 and according to certain study samples that were done in Sri Lanka it is said that 61% of females and 86% of males between the ages of 65-75 are subjected to this disease called dementia. The overall prevalence rate is found as 3.98 % (CDC, 2018). Dementia is not specifically considered as a disease but a common condition that can be used to address the inability to remember, the inability to think and also problems in taking decisions in daily life (CDC, 2018). Dementia has the ability to convert a healthy individual to a person that struggles in most aspects in theirlives and also make that person a healthcare seeker where care must be provided by others (Wimo & Prince, 2010).

Dementia has many different forms like Alzheimer's disease, vascular dementia, Lewy body dementia, fronto temporal dementia, alcohol related dementia and even HIV associated dementia. Alzheimer's dementia is the most common type of dementia. Alzheimer's is a progressive disease that begins with a mild memory loss and finally leads to loss of ability to

carry on conversations and responses. A person with mixed dementia can evenshow symptoms of both Alzheimer's and vascular dementia. Alzheimer's condition is considered the mild stage of dementia. There are different types of pharmacological as well asnon-pharmacological therapies available for dementia such as taking steps to improve the vascular health, using specific types of drugs for memory and for cognition like cholinesterase inhibitors and memantine, involving in behavior management strategies and certain supportivetherapies like cognitive rehabilitation, physical activities, occupational therapy, pet therapy, aromatherapy and art therapy (Gitlin et al., 2012). Even though dementia is not hundred percentcurable these surgical, pharmacological and non-pharmacological interventions play a great role. Among those some are invasive and some non-invasive, one such non-pharmacological therapy is the "music therapy". Even though the body of evidence for these non- pharmacological therapies are limited there are numerous beneficial effects warrantied with further research done (Neil et al., 2011).

There are different types of music therapy modalities available for this disease. Some of them are singing, music listening, playing musical instruments, song writing and lyric reading (Cooke et al., 2010). Out of all the types of music modalities it is said that listening to music presents the greatest effect on patients with dementia (Moreno et al., 2020). Sacks in 2008 stated that the main aim of music therapy was to address the different emotions, cognitive powers, memory and thoughts and to make the 'self' of the patient stimulate them and bring them to the fore. It is shown that there was a decrease in the symptoms of anxiety and depression as a result of the music therapy effect in most of the qualitative studies done. This music therapy effect was maintained for a period of about 8 weeks in a certain research study and it was found that the individuals felt well and they were also successful in protecting and even transferring the information in short term memory to long term memory through this qualitative study done (Raglio et al.,2008). A film which was screened in 2014 called the 'Alive inside' at the Sundance film festival is also a fine example to show the increasing interests of proving effectiveness of music therapy on dementia. Even though there are so many treatments available, this therapy of using music is considered as the best. It is said that music therapy canimprove the verbal fluency, to reduce the anxiety, depression and also apathy. The fact also proves that most of the musicians who always involve in music activities are 64% less likely to develop conditions like mild cognitive impairment or dementia (Walsh, 2021). It is also specifically said that soft classical music or non-rhythmic instrumental background music are effective in treating dementia. Studies show that stimulating the brain using classical music canenhance the thinking which is also called as the Mozart effect. currently it is said that there isno proper treatment available to cure this disease. However, many qualitative and quantitative studies show that music therapy is a good treatment which is available for dementia management and control. Usually, medicines like donepezil increases the levels of acetylcholine which will improve the brain function and the symptoms, but still has only temporary effects (WHO, 2022). But music works far better than them. Especially the classical music and instrumental music available. It tells that music therapy has a greater ability of boosting the neuroplasticity of dementia patients which helps the network in the brain to grow and change. It is also said that through modern imaging technologies it has been revealed that not only a certain region but different parts of the brain can be processed with music therapy.

The memories of these patients can be awakened by music therapy. For example, a summer hit from a certain person's youth can reawaken the memories of his young age and childhood (Holden, 2021). A music therapy usually contains 20 clinical standardized techniques under 3 categories which are; cognition, sensorimotor and language & speech. Here the first stage of this therapy is to jump start the brain and then bring the conditions to focus. Usually, it is said that fast paced music has the ability to increase the cognition function by stimulating the alertness. After this stage the next stage is to activate the different parts of the brain that are involved in sensorimotor function, it involves activities like tapping the feet to a tune and shuffling to a samba (Holden, 2021).

This systematic review had explored mainly what dementia is, though dementia has several pharmacological therapies, music therapy which is a non-pharmacological therapy has better results with evidences, this work have proved through qualitative and quantitative studies that music therapy could improve most of the symptoms of dementia like vascular health, cognitive rehabilitation, physical activities and even the verbal fluency. This study has not only taken steps to target dementia patients but also to improve the mindset of their caregivers.

***Main Specific Objective:***
- ✓ Evaluate the actual effectiveness of music therapy on dementia by using a systematicreview together with qualitative and quantitative evidences.

***General Objectives:***
- ✓ To identify what dementia is.
- ✓ To understand that music therapy though it's a non-pharmacological therapy it has a better effect on dementia.
- ✓ To prove that quantitative studies better prove the effectiveness of treating dementiacompared to qualitative studies.

**Methodology**

***Search strategy***- A literature search was conducted based on electronic databases like PubMed, NIHS, Google scholar and even the World Health Organization (WHO) websites onalmost all of the research work in a range of around 10 years based on what actually dementiais, the global burden and the epidemiology of this disease, the pharmacological treatments available for this disease, the non-pharmacological therapies available, that music therapy which is a non-pharmacological therapy has a better effect and qualitative and quantitative studies done under the study. The keywords used during the search were 'Dementia', 'Music therapy', Qualitative studies' and 'Quantitative studies' and for clear clarity the methodology section is broken into sections that follow the PRISMA checklist.

***Study Eligibility Criteria*** -The review included some published papers covering most of the elderly population with dementia, the patients suffering with problems related to cognition, sensorimotor and language and speech were given a prominent place. This systematic review includes specific cohort studies that evaluated the conditions of the patients suffering with dementia, their past revival and even the mental status of their caregivers. The selected language was English for all the research articles and both genders were given the priority. The

review excludes some published papers that mentions about different pharmacological therapies as this work focuses more on non-pharmacological therapies for dementia.

***Data extraction -***The initial search led to 803 publications from the existing publishes literature according to the eligibility criteria. After evaluating all the titles, abstracts, total of 12 studies including both qualitative and quantitative studies (Table 1 and 2) were selected. Data were extracted using thematic analysis, structured and semi structured interviews and MAXQDA software.
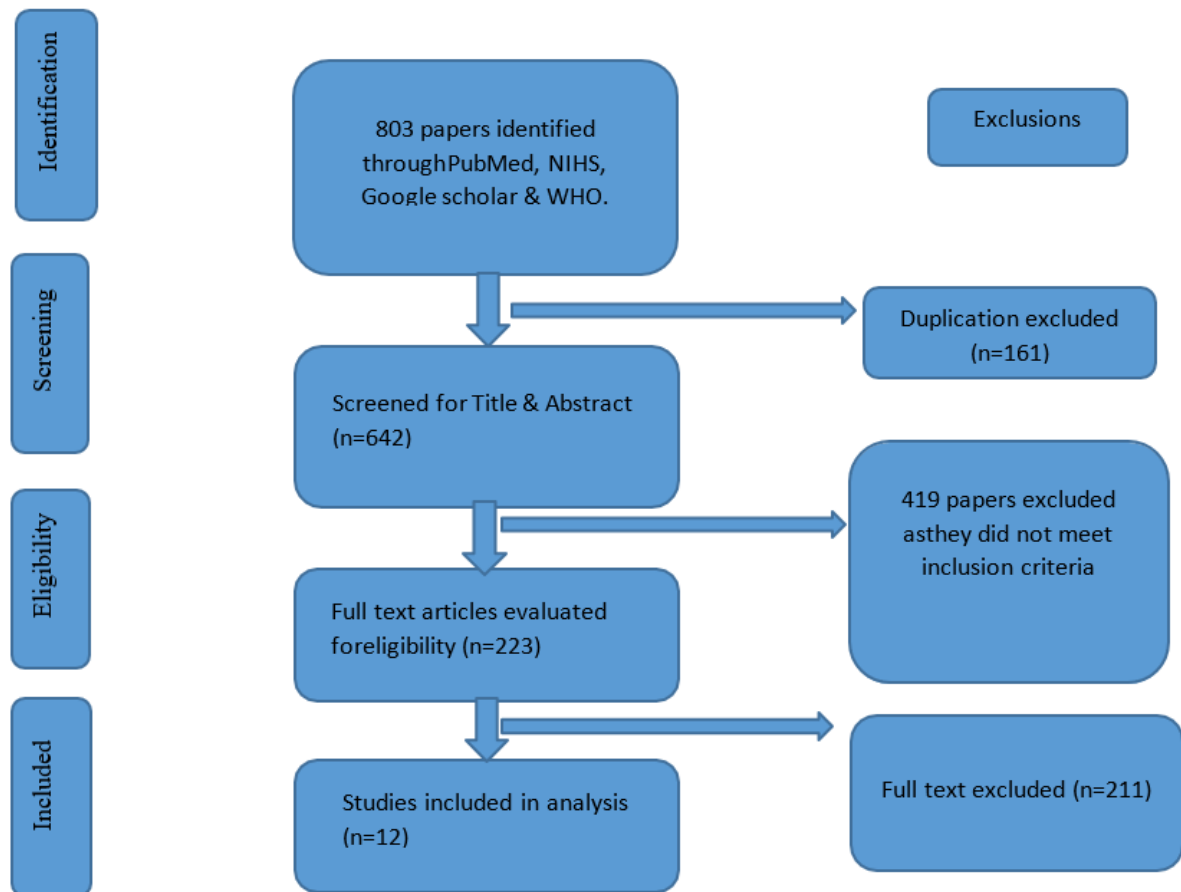


*Figure 2- The PRISMA flow diagram of the study.*

### Results

The results of the study are as follows; the patients with dementia were motivated to participate in several studies but still they faced barriers (Carl, 2021). Furthermore, below table 1 summarizes the several qualitative studies done on Music therapy for dementia.

Table 1- Qualitative studies summarized

| Citation (Author and year) | Study purpose and design | Sample size and study period | Data analysis method | Outcome of study |
|---|---|---|---|---|
| Wall & Duffy,2010 | A study had been done to enhance neurological stimulation through singing sessions. | Involving 20 participants for about 2 months. | Using thematic analysis. | This study clearly shows that music benefits to build a relationship between brain, ear and instruments and as a result of these links there is a positive effect between care givers and dementia patients. |
| Hulme et al.,2010 | Summarizes the fact that therapeutic effect of music is better compared to other pharmacological therapies. | Involving 8 participants for about 2 weeks. | Using structured and semi structured interviews. | This study has shown that music shows effective results in reducing the behavioral and psychological symptoms of dementia. |
| Eldirdiry et al.,2016 | Summarizes qualitative study to show the better effects of combining reminiscence therapy with music. | Involving 20 participants for about 2 months. | Using semi structured interviews. | This study has resulted to increase the social inclusiveness among the dementia patients. |
| Eldirdiry et al.,2016 | Summarizes a qualitative study done to increase the social interactions of dementia patients. | Involving 14 participants about 2 weeks. | Using MAXQDA software. | This study has helped to increase the motivation of dementia patients to involve in social activities. |
| El Haj et al.,2012 | Summarizes a qualitative study that shows that music therapy is effective for memory recalling of dementia patients. | Involving around 10 participants for about 2 months. | Using the method of observations. | This study has shown that there had been a positive impact and there had been a better attention and improved memory in Alzheimer patients. |

The table 2 below shows some of such quantitative studies done by using the techniques such as Meta-analysis (PRISMA) category, critical appraisal programs (CASPe) and RCTs.

Table 2- Quantitative studies summarized

| Author ofstudy | Study design | Study purpose/objectives | Study size | Outcomes of study |
|---|---|---|---|---|
| De la etal.,2016 | An analytical and experimental prospectivestudy without control group. | Evaluates the effectiveness of implementing short music therapy as a tool to reducestress. | n=25 | This study had resulted positively in reducing stress levels of dementia patients. |
| Samson et al.,2015 | Experimental study without control group. | Determines impact of music therapy and other non-pharmacological therapies on Alzheimer patients, compares the effects of both. | n=14 | This study has resulted positively in emotional functions of dementia patients. |
| Narme etal.,2013 | Experimental study without control group. | Verifies the efficacy of music therapy and practicing other pleasurable activities like cooking with Alzheimer patients. | n=18 | This study resulted positively in improving behavioral and emotional disorders of dementia patients. |
| Arroyo et al.,2013 | Experimental study with control group. | Examines the impact of listening to music that is familiar to patient with own self-awareness. | n=20 | This case study showed a positive impactthrough improving self-awareness suchas prospective memory as wellas personal identity. |
| Rita et al.,2017 | An experimental study with control group. | Clearly shows the efficacy of music therapy as a form of | n=45 | This study didn't show anypositive impact. |

| | | Complementary non-pharmacological treatment. | | |
|---|---|---|---|---|
| Onieva et al.,2017 | An experimental study with control group. | Shows the combine effectof music therapy and reminiscence therapy. | n=10 | This study showed an improvement in the symptoms of Alzheimer patients with combination of therapies. |
| Palisson et al.,2015 | An experimental study without control group. | Involves a clear impact on improving verbal effect of dementia patients on music therapy. | n=12 | Through this study it was concluded thatthe texts that was sung wereeasier for dementia patients than the spokentexts. |
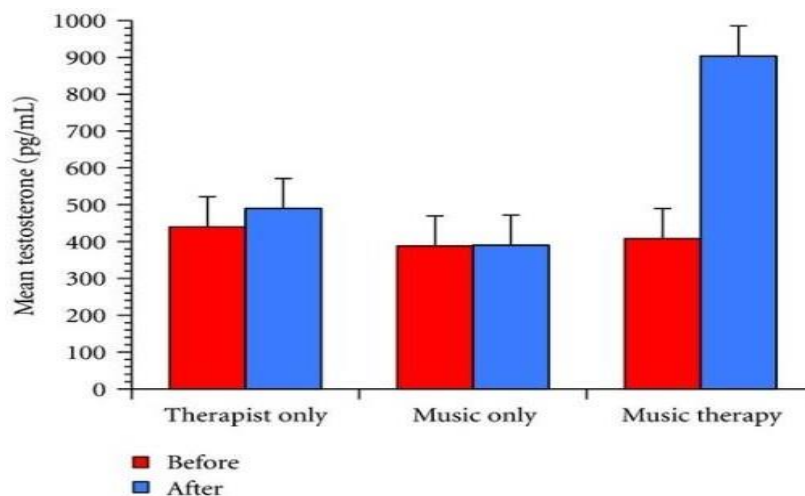


*The figure 1 shows the efficacy of music therapy on dementia through a bar chart,*

Figure 1- The chart showing before and after effects of music therapy on dementia (Sussane, 2019).

## Discussion

Many studies conducted on dementia and Music therapy showed the promising effectiveness of music on dementia management but this study which mainly focused on non-pharmacological therapies found that classical music or non-rhythmic music showed better results and less side effects on dementia. A qualitative study done by Hulme *et al.*, 2010 shows

and concludes that the therapeutic application of the music therapy seems to have a positive effect on dementia. Further, a recent report published by the individuals Cameron and Sosinowicz, 2014 had clearly showed that music therapy has multiple benefits for the patients with dementia and not only for the patients but also for the staff workers and also their caregivers.

Another qualitative study done on patients with dementia by combining reminiscence therapy with music. The aim of this study has been to involve in peer support, to incorporate the social interaction and also to improve the quality of life between the patient with dementia and the care giver because both the parties are equally important in this disease condition. The participants involved in this group activity are; a musician, the care givers of the people with dementia and the patients with dementia. In this activity the care givers and the patients gather in a large circle around the musician and do what the musician instructs. This session had been started with a warm up for the voice as well as the body. The participants are given with song sheets and then they together with the musician should sing along. This study had been done by involving participants from the East Midland areas of UK. After a 2-month period the patients as well as the care givers had been analyzed through an interview which was semi structured and it was finally reported that both the parties, the care givers and the patients had been benefitted by this and especially the ones who have involved and participated in the study were well benefitted. The results of this study showed that the music therapy helps to improve many fields such as:  A good experience being shared by both the parties , Lifting up the spirits of the patients as well as the care givers , a good impact on the memory and a good impact on the relationship between patients and care givers (Clark & Keady, 2002). A further qualitative study was done to consider multiple factors like the role which should be present between the care giver and the patient with dementia, the relationship existing between the participants and the researchers, the background of the research environment and many more. This was done as an impetus that came from the author's preparation for a PhD report to interview the participants with dementia on a qualitative study. There are 3 parties involved in this research process. They are the music therapy researchers, the participants from Remini-sing pilot study who are patients with dementia and the participants from Remini-sing pilot study who are care givers of dementia. The interviews had been conducted via phone as well as through online meetings. Interviews also had been done in a semi structured way. The data were analyzed in a six-step pathway where the inductive thematic analysis method done by the MAXQDA software is conducted. There are several quantitative studies that are available such as RCTs in short, which means randomized control trials, usually RCTs are considered as a form of a scientific experiments which are used to control factors that is usually not under the direct experimental control. There are several examples of RCTs, like clinical trials that are used to compare certain medications, so according to this research conducted certain RCTs had been used to compare the effects of pharmacological therapies in treating dementia and non-pharmacological therapies like music therapy has proven better evidences in these trials. Not only them but also different techniques like brain imaging, as well as scanning methods like PET (Positron emission tomography) scanning, MRI (Magnetic resonance imaging) scanning and even EEG (Electroencephalogram) scans can be done under quantitative studies. It can be seen that 7 quantitative studies had been taken into consideration while out of them it can be

seen that exactly 6 quantities have shown positive results and impacts while 1 out of them didn't show any positive impact out of the study. But still the other 6 which showed positive results were exactly giving expected results. So when taken as a percentage more than 75% of quantitative studies have shown that the effect of the non-pharmacological intervention, that is music therapy has a very clear effect on treating dementia patients.

### *Strengths and Limitations*

The strengths of this systematic review included a clear and comprehensive search strategy to include all the published literature. With all the exclusion and the inclusion criteria 12 studies which were relevant was found which serves the depth analysis of specific populations and age groups. A limitation of the review is that it could focus only on elderly populations but not on other age categories like childhood and young.

### Conclusion

When all information are wrapped up it can be understood that when comparing pharmacological and non-pharmacological therapies, music therapy which is a non-pharmacological intervention has better and effective results which arelong term and also gives promising results to dementia patients as well as theircaregivers and also it decreased the burden upon them. Out of the several qualitative and quantitative studies it was found out that both of them have really good positive impacts on dementia patients but rather than qualitative studies, the quantitative ones better proved that, through the statistical and mathematical data there is a clear effect of music therapy on treating dementia patients without any arguments anddisagreements. When considering future studies of music therapy on treating dementia,it can be said that it needs to be improved since it does not give any side effects and also the application of it is economical rather than heavy dosages of medicine. More high quality longitudinal studies and also study designs that are sensitive to the nature and the severity of dementia should be proposed. Future studies done on music therapy needs to be created in a more defined theoretical model to bring out better focusedoutcomes.

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# A SYSTEMATIC REVIEW ON IMBALANCE OF TESTOSTERONE AND ESTROGEN: CONTRIBUTION ON OBESITY/OVERWEIGHT AND DEPRESSION.

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**Abstract**

This research was done to analyse how an imbalance levels of estrogen and testosterone contribute to obesity and depression. A systematic search was done for investigation on search engines such as google scholar, NCBI and using the most current journal papers published throughout the course of the past ten years, from 2012 to 2022. As comparison to normal weight men (19.4 nmol/l), overweight (15.8 nmol/l) and obese male (12.6 nmol/l) had significantly lower levels of testosterone. When compared to premenopausal women who did not experience depression, those who did (12.8 vs 10.3 nmol/l) had substantially increased testosterone levels. Most of the studies showed obese males have lower testosterone and women's results are inverse to this, showing higher levels of testosterone in obese women. Five studies showed that obese females and males don't have a significant difference in estrogen levels with BMI. Depression in men and estrogen levels have a strong positive relationship.

**Key Words:** BMI, Depression, Estrogen, Obesity, Testosterone.

**Introduction**

Obesity and the depression are among the most common and difficult health issues we confront today due to their rising prevalence around the globe. Whether there is an over- or underproduction of hormones, an imbalance can result in health issues and lead to obesity. Obesity is generally described as having an excessive body weight for one's height, but this straightforward definition conceals an etiologically complicated phenotype mainly linked to excessive adiposity or body fatness, which can manifest metabolically rather than just in terms of physical appearance. The "Body Mass Index" (BMI) is a straightforward index used to categorize humans into three groups: underweight, overweight, or obesity (Safaei *et al*., 2021).

Table 01: BMI categorization of adult weights adapted from (Safaei *et al*., 2021)

| Classification | BMI ($kg/m^2$) | Risk of co-morbidities |
|---|---|---|
| B2.5 Underweight | <18.5 | Low (but risk of other clinical problems increased) |
| Normal weight | 18.5–24.9 | Average |
| Overweight | 25.0–29.9 | Mildly increased |
| Obese | ≥30 | |
| Obese I | 30.0–34.9 | Moderate |
| Obese II | 35.0–39.9 | Severe |
| Obese III | ≥40 | Very severe |

Depression is a severe mental condition that is accompanied by mood abnormalities. It is the second most common cause of disability globally. Along with a worsened quality of life and a reduction in role functioning, it is linked to higher medical morbidity and death rates The World Health Organization (WHO) estimates that there are more than 350 million depressed persons globally, with a rise of roughly 18% over the past ten years and a lifetime prevalence of 15% (Stanikova *et al.*, 2018).

One of the main male sex hormone is testosterone. In order to control the hypothalamic-pituitary -adrenal (HPA)axis, which controls how the body reacts to stress. By limiting the release of cortisol, a stress hormone that has been linked to the emergence of depression, testosterone serves to control the activity of the HPA axis. It is well known that female testosterone levels alter during the menstrual cycle, and that low and high testosterone levels at particular times of the cycle can affect a woman's mood and behaviours. Estrogens are a family of steroid molecules that are mostly released by the ovaries and placenta, with some also coming through peripheral steroidogenic conversion and the male testes. Comparing males and women, estrogen levels are around four times higher in women (Stanikova *et al.*, 2019).

The imbalance of hormones is becoming a serious global epidemic and is sometimes referred to as a silent killer (JK Roop *et al.*, 2018). For the purpose of creating and deciding on more targeted and efficient treatment techniques, identifying the aetiology of depression and obesity is crucial. Hence, the main objectives of this literature review are to understand the relationship between testosterone and estrogen imbalances and being obese in males & females, to know the connection exists between depression and the imbalance of testosterone and estrogen in males & females.

## Methodology

A systemic search using search engines such as Google Scholar, NCBI, PMC, and ResearchGate was done for an investigation on 'Imbalance of Testosterone and Estrogen: Contribution to Obesity, Overweight, and Depression'. Using the most current journal papers published throughout the course of the past ten years, from 2012 to 2022, this article was prepared during a two-month period, from December 16, 2022, to March 16, 2023.
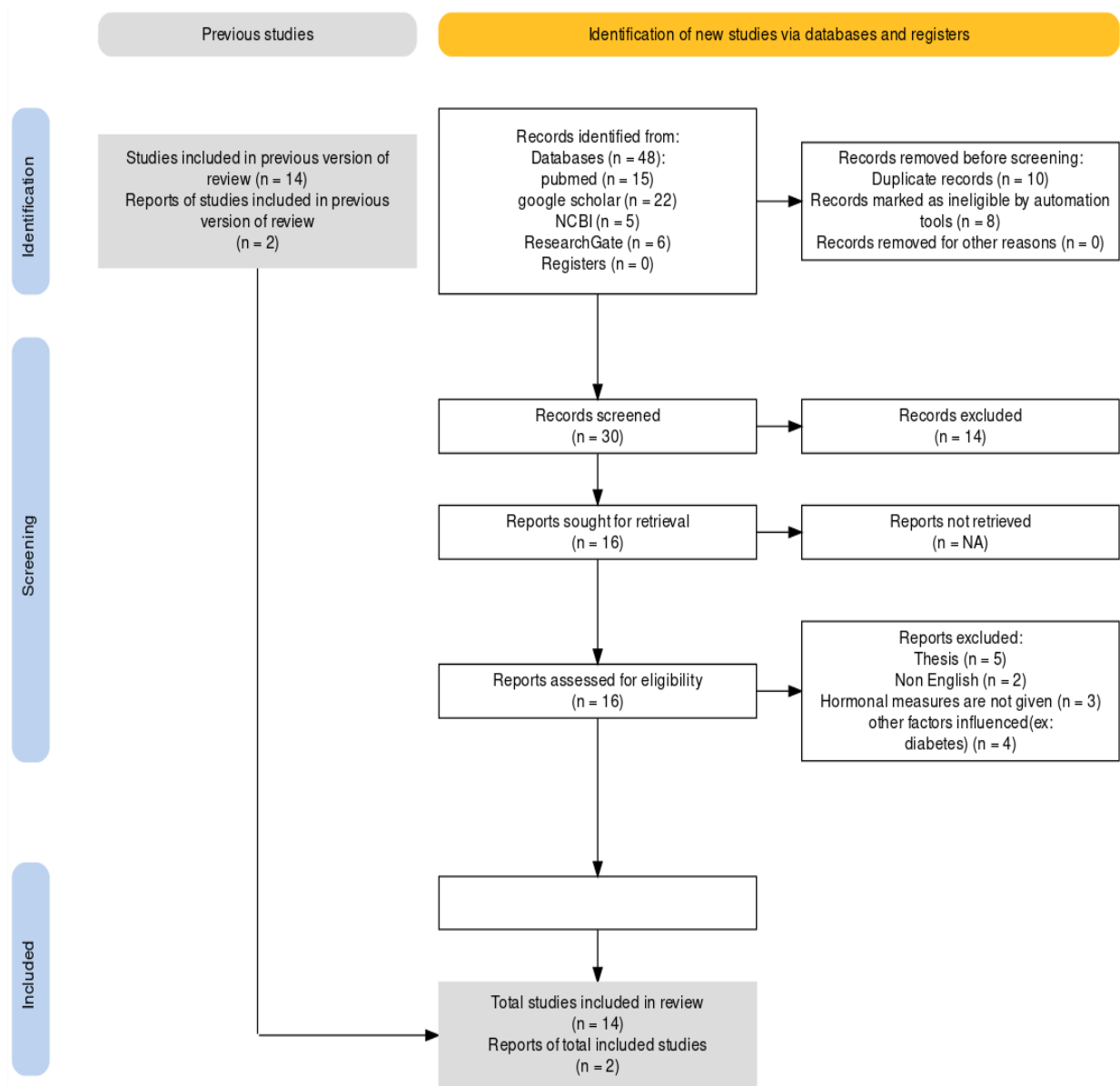
*Figure I: PRISMA flow diagram of study selection*

## Results

Table II: Relationships between Testosterone /Estrogen imbalance and BMI in males.

| Sample | Hormone analysis | | BMI (kg/m²) | References |
|---|---|---|---|---|
| | Testosterone | Estrogen | | |
| 224 healthy males between the ages of 20 and 78 (except | 100(91.9,108) 84.8(76.6,93.4) | 100(88.4,112) 90.8(78.1,105) | <25 25-30 | (Stárka *et al.*, 2020) |

| | | | | |
|---|---|---|---|---|
| for obesity and related symptoms) | 70.4 (60.6,80.9) (nmol/l) | 110(90.1,133) (pmol/l) | >30 | |
| 3925 males in total (2244 age <60) and | 19.4 ± 5.5 15.8 ± 5.2 | 84.9 ± 36.7 85.9 ± 37.6 | <25 25-30 | (Stanikova *et al*., 2018) |
| | 12.6 ± 4.7 | 89.2 ± 39.5 | >30 | |
| (1681 age >60) were used in the | 18.3 ± 5.9 | 82.3 ± 34.2 | <25 | |
| analysis. | 15.9 ± 5.4 | 90.1 ± 41.0 | 25-30 | |
| | 13.8 ± 6.9 (nmol/L) | 97.3 ± 43.0 (pmol/L) | >30 | |
| 400 males in total. | 558.7±184.7 (221.8–923.1) | 23.7 ±9.3 (10.0–63.0) | <25 | (Oztekin U, *et al.,* 2020) |
| 274 (68.5%) of these individuals were infertile due to primary causes, | 444.5±202.3 (225.4–921.4) | 24.5 ±10.7 (10.2–88.0) 2 | 25-30 | |
| 126 (31.5%) were infertile due to secondary causes. | 395.7 ±149.4 (220.4–832.1) (ng/dl) | 5.5 ±9.0 (10.6–50.0) (ng/dl) | >30 | |
| 240 healthy puberty advanced young males from Egypt, aged 11 to 18 years, with tanner stages of two to four. | 3.8±2.24 2.71±2.12 (pg/ml) | 0.07±0.02 0.063±0.07 (nmol/1) | <25 >30 | (Ayman Abd-Elrahman, Fouad and Salah, 2019) |

Table III: Relationships between Testosterone /Estrogen imbalance and BMI in females.

| Sample | Hormone analysis | | BMI (kg/m²) | References |
|---|---|---|---|---|
| | Testosterone | Estrogen | | |
| (3124 women) 970 (31.0%) were premenopausal (45 | 8.9 ± 6.1 pmol/l 12.8 ± 8.3 | There was no discernible relationship | <25 25-30 | (Stanikova *et al*., 2019) |

| ± 6.6 years) and | 15 | | >30 | |
|---|---|---|---|---|
| 2154 (68.9%) were postmenopausal (64.2 ± 8.0 years) | 7.5 ± 5.6 pmol/L | 51.4±149.4 pmol/L | <25 | |
| | 10.6 ± 7.5 | 73.2 ± 211.1 L$^{-1}$, | 25-30 | |
| | 12.1 | 49.2 | >30 | |
| The mean age was 41.4 (SD 3.5) and all women were premenopausal. | | 39.8 pg/mL; 95% CI: 37.0, 42.8 | <25 | (Freeman *et al.,* 2019) |
| | | 34.4 pg/mL; 95% CI: 32.0, 36.9; | 25-30 | |
| | | 32.8 pg/mL; 95% CI: 30.6, 35.2 | >30 | |
| 150 premenopausal women who were referred to the Family Medicine Outpatient Clinic between 2014 and 2015. | 9.75 (0.52–52.88) | 381.7(73.4 –1266.4) | <25 | (Sayın *et al.*, 2019) |
| | 9.61 (2.01–51.46) | 436.8 (110.1–3061.6) 295.5 (73.4–1457.3) | 25-30 | |
| | 7.98 (1.04–49.72) (pmol/L) | | >30 | |

Table IV: Connection exists between depression and the imbalance of Testosterone and Estrogen in males.

| Sample | Hormone analysis | | Depressive (D)/ Not Depressive (ND) | References |
|---|---|---|---|---|
| | Testosterone | Estrogen | | |
| 43 obese males with a mean age of 37.9 years (10.5 SD). None of them had diabetes. | 11.0 ± 3.8 10.1 ± 3.2 | 103 ± 48 136 ± 48 | ND D | (Monteagudo *et al*,2015) |
| 3925 males in total | 16.419 ± 5.751 | 84.453 ± | ND | (Stanikova *et al.*, |

| Sample | Hormone analysis | | Depressive (D)/ Not Depressive (ND) | References |
|---|---|---|---|---|
| (2244 age <60) and | | 36.637 | | 2018) |
| | 17.203 ± 6.830 | 96.310 ± 40.655 | D | |
| (1681 age >60) were used in the analysis. | 15.910 ± 6.149 | 90.535 ± 40.689 | ND | |
| | 15.079 ± 6.183 | 92.708 ± 31.926 | D | |
| sample of 64 men | 1.32 (0.08) 1.54 (0.07) | 28.18 (2.10) 26.72 (1.85) (ng/mL) | D ND | (Rodgers *et al.*, 2015) |
| Participants (aged 18 to 65) from Renmin Hospital at Wuhan University. 137 healthy controls & 412 depressed individuals | 439.53±136.08 331.64±149.37 T, (ng/ml) | 31.08 ± 10.34 29.34 ± 11.82 pg/ml | ND D | (Peng *et al.*, 2021) |
| 240 healthy, puberty advanced young males from Egypt, aged 11 to 18 years, with tanner stages of 2 to 4. | (mean±SD) 2.81±2.32 3.63±2.65 | (mean±SD) 0.07±0.01 0.08±0.02 | D ND | (Ayman Abd-Elrahman, Fouad and Salah, 2019) |

Table V: Connection exists between depression and the imbalance of Testosterone and Estrogen females.

| Sample | Hormone analysis | | Depressive (D)/ Not Depressive (ND) | References |
|---|---|---|---|---|
| | Testosterone | Estrogen | | |
| 3124 women of whom 970 (31.0%) were premenopausal (45 ± 6.6 years) and | 12.9 ± 9.1 10.4 ± 7.0 nmol/L, | | D ND | (Stanikova *et al.*, 2019) |
| | 10 | 62 | D | |

| | | | ND | |
|---|---|---|---|---|
| 2154 (68.9%) were postmenopausal (64.2 ± 8.0 years) | 9.8 | 50 | | |
| 169 females having depression in total were chosen, | | | | (Lei *et al*., 2021) |
| young (age<45 years) | 0.76±2.42 | 77.19±72.48 | D | |
| perimenopausal (45– 55 years) | 0.37±0.13 | 68.68±70.81 | D | |
| elderly groups (age>55 years) | 0.51±0.77 | 33.05±18.43 | D | |
| 262 girls Ages 11–17 years (50.1%) | 32.1 (23.2– 42.9) | | D | (Chronister *et al*., 2021) |

## Discussion

Four studies utilized in this review to show the connection between hormone imbalance and obesity are reported that testosterone levels decreased as body mass index (BMI) increased across male groups (Table:02). (Oztekin U *et al*, 2020; Stanikova et al, 2018; Ayman Abd-Elrahman,2019; Starka, L. *et al.* 2020). Oztekin U *et al*., 2020 found Estrogen levels did not significantly differ across the groups. Starka, L. *et al.* 2020 study shown that estrogen levels in obese males increasing by 10.3% and those in overweight men decreasing by 9.2% when compared to men with a BMI of 18 to 25. Stanikova *et al*.,2018 have a significant advantage due to the fact that they analysed hormone levels in under-60 and above-60 males. Men aged 60 and >60 who participated in research on the connection between obesity and testosterone imbalance discovered similar results (Table:02). The age category of males > 60 years, those who were overweight or obese had considerably greater estrogen levels than men who were of a healthy weight. The lack of highly obese patients in this research (maximum BMI 37 kg/m2) may contribute for the weaker results.

Sayın *et al*., 2019 discovered the total testosterone level was noticeably high in the overweight and obese than normal weight women. The relationships between BMI and Estrogen varied depending on the stage of menopause, according to the significant interaction shown in table 03. Estrogen levels in the premenopausal period were considerably lower in the obese & overweight categories than in the group with normal BMI. But these results were inverse in post menopause women. These findings support the notion that estrogen and BMI are

negatively correlated in premenopausal women whereas positively correlated in postmenopausal women (Freeman *et al*., 2019). Stanikova *et al.,* 2019 found that when compared to female of premenopausal, post- menopausal had greater testosterone levels similar to sayin *et.al*,2019. They noted postmenopausal overweight women had considerably lower estrogen levels than normal weight women. Freeman *et.al* 2019 study used a premenopausal baseline that was precisely characterized, along with concurrent hormone measurements, from which the women moved through the menopausal transition.

According to Stanikova *et al* 2018, Males< 60 years with depressed symptoms reported increased estrogen levels than men without depressive symptoms. Similarly, Monteagudo *et a.,* 2015 investigation showed, those who experienced moderate to severe depression symptoms, had elevated levels of estrogen. Elevated aromatase activity may lead to changes in the brain's estrogen levels in obese males. These changes in estrogen levels, acting on mood-related neuronal regions, would result in depressed symptoms in functionally significant concentrations. Ayman Abd-Elrahm, 2019 & Rodgers *et.al*, 2015 the results of this studies showed that low testosterone levels significantly correlated with depression symptoms (Table:04). Moreover Abd-Elrahm, 2019 research shows there is no significance difference in estrogen levels of depressed men and nondepressed. In comparison to previous studies, the finding of this study is different. This might be because depression is highly complicated, and various variables may have a role. Hormonal changes are between them, although they do not stand alone as a risk factor. The results of Stanikova *et al* 2018 study based on a wider group (sample size 2244 men) may be its more generalizable than from other studies using small,selected groups. Moreover, a strength of Rogers *et.al* ,2019 research is that it mentions subtype of depression, however they only mentioned estrogen levels of men; they fail to go into depth about this.

Women appear to experience at a higher rate than male do, with the risk being two times higher for women. Stanikova *et.al*, 2019 identified premenopausal and postmenopausal women who reported depressed symptomatology to have considerably increased levels of testosterone than women who did not. The fact that testosterone levels greatly enhance the serotonin transporter's affinity raises the possibility that testosterone causes depression by causing synaptic serotonergic depletion through neurogenesis reuptake. Similarly, Lei *et.al* 2021 found that the testosterone levels of the young depressive women were higher than those of the elderly depressed women (Table:05). Compared to the perimenopausal & elderly groups, the young group's estrogen level was significantly higher. It was shown that the intensity of female depression was inversely connected with age. Only Chronister *et al* 2021, which demonstrated that hormone-mood correlations differed by gender, emphasizes how crucial it is to comprehend how differences between boys' and girls' hormone concentrations and moods affect these connections. Only estrogen was shown to be strongly linked to depression in males; for every 10% rise in estrogen levels, the depression score increased. While earlier research has perfectly split women of all ages into groups, this study solely focused on young girls <17. The largest study to date examined correlations between BMI, depression, & sex hormones in more than 3000 women and was conducted by Stanikova *et al*. in 2019. The tight exclusion criteria used in the attempt to demonstrate "clear correlations" were strictly followed, and this

study's commitment to them is one of its strongest points.

**Conclusion**

The results of this study, which examined at the relationships between BMI, sex hormone levels (E2, T), and depression show that hormone alterations are a significant contributor to both obesity and depression. As a consequence of our findings, which showed that testosterone levels were higher in obese women and lower in obese men, we may conclude that an imbalance in testosterone is a contributor in the obesity. Studies on estrogen levels in both males and females have produced a variety of outcomes. Encourage more extensive research to demonstrate the link between estrogen levels and obesity. This study illustrated how testosterone and estrogen levels might be included in a risk model for depression. Depression in men and estrogen levels have a strong positive relationship. However, due to various findings from many investigations, this study cannot conclusively prove that hormone imbalance contributes to women's depression. Can suggest further research be done to get a conclusion on female depression. Future studies can examine recurring variables and their effects on the levels of sex hormones in depressed individuals.

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# AIRS' 23

## *Chapter 05:*
## INFORMATION TECHNOLOGY

# INFANTMOODSENSE: EMOTION RECOGNITION SYSTEM FOR INFANT CRIES

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## Abstract

The project aims to improve the emotional connection between infants and caregivers by using advanced machine learning and signal processing methods to build a predictive model that interprets baby cries. The project also creates an intuitive smartphone app that offers real-time insights into an infant's mood. The Cry Pattern Analysis Module is used to accurately detect emotional states by analyzing pitch, intensity, and temporal patterns in cries. Caregivers can receive personalized insights and recommendations based on real-time cry data. This project combines modern technology and conventional knowledge, enhancing the caregiver-infant bond and demonstrating how technology can meet changing childcare needs. The study emphasizes the importance of creativity and teamwork in improving infant care.

**Keywords:** Infant Emotion Recognition, Cry Analysis, Caregiver Support, Machine Learning, Newborn Well-being

## Introduction

Infant cries are a complex language that caregivers often struggle to understand due to their lack of standard approaches. These cries are used as a form of communication in early life, expressing various requests and feelings. The study aims to create a predictive model using machine learning and signal processing to understand these variations. The goal is to provide a user-friendly smartphone application that provides real-time insights about a child's mood. This innovative idea aims to strengthen the emotional connection between infants and caregivers, while tackling the challenges of contemporary parenting comprehensively and futuristically. The study aims to provide a more accurate and data-driven approach to understanding infant cries and responding quickly.

### *Significance of the study*

The importance of this study extends beyond the development of technology and infant care; it also explores more general topics like human empathy, the influence of innovation, and the relationship between cutting-edge science and ordinary life.

The complexity of comprehending and reacting to baby cries, which are a major form of early-life communication, makes this study extremely important. More accurate, data-driven strategies are needed to analyze cries because traditional methods are often subjective (Birgit Mampe, 2009). A baby's primary means of communicating is through crying, which is an important way for them to express their needs and feelings.

The modern era has seen a decline in the historical reliance on intergenerational support and common knowledge for understanding infant cries, which has increased the difficulty faced by modern parents (Small, 1998). The study presents itself as an intervention to provide

caregivers—parents and medical professionals—with the necessary abilities to appropriately interpret cries because they are crucial to an infant's emotional development (Cynthia A. Stifter, 2002). The possible effects on an infant's development and health highlight how urgent it is to find novel solutions.

The specific challenges of modern parenting include information overload, lack of family support, and hectic schedules that increase parental stress (Guibert, 2013). The study acknowledges these difficulties and attempts to give modern parents useful resources to help them better understand their infants.

The study explores the global perspective of baby cries, recognizing them as a universal language that fosters empathy and global connection. It highlights the importance of understanding infant cries for infants and caregivers, and its implications for family dynamics, mental health, and global communication. The research, initially focused on Sri Lankan infants, suggests the development of tools and models aligned with cultural standards. Baby cries can help caregivers from diverse cultural backgrounds communicate and build empathy globally.

This research, combining creativity, empathy, mental health, and technology, has the potential to transform lives by demonstrating human resilience and inspiring future generations to pursue scientific and humanitarian goals.

Table 1 - Summary of the literature review

| | Variable | Area | Research paper name |
|---|---|---|---|
| 1 | | Factors affecting Infant Mood | Infant bonding and attachment to the caregiver: Insights from basic and clinical science |
| 2 | | | Physical contact in parent-infant relationship and its effect on fostering a feeling of safety |
| 3 | | | Aggressive parenting behavior among grandparents providing childcare for grandchildren: A case study of Shenzhen, China. |
| 4 | | | Maternal mental health services in Sri Lanka: challenges and solutions |
| 5 | | Emotions Expressed through Infant Cries | Longitudinal Study of Maternal Beliefs About Infant Crying During the Postpartum Period: Interplay with Infant's Temperament |
| 6 | | | Defining and distinguishing infant behavioral states using acoustic cry analysis: is colic painful? |
| 7 | Predicted Infant Mood (Dependent Variable) | | A Scientometric Review of Infant Cry and Caregiver Responsiveness: Literature Trends and Research Gaps over 60 Years of Developmental Study |

| # | | | |
|---|---|---|---|
| 8 | Predicted Infant Mood (Dependent Variable) | | Maternal stress level when a baby is admitted to the neonatal intensive care unit at Teaching Hospital Jaffna and the influence of maternal and infant characteristics on this level |
| 9 | | Cross-cultural Differences in Infant Mood | Air quality and mental health: evidence, challenges and future directions |
| 10 | | | The Impact of Economic Growth and Air Pollution on Public Health in 31 Chinese Cities |
| 11 | | | National Family Planning Programme (NFPP) review |
| 12 | | | Prevalence of Major Depressive Disorder Among Spouses of Men Who Use Alcohol in a Rural Community in Central Sri Lanka |
| 13 | | Impact of Infant Mood on Caregiver-Infant Interaction | Associations between stress exposure and new mothers' brain responses to infant cry sounds |
| 14 | | | Studying caregiver-infant co-regulation in dynamic, diverse cultural contexts: A call to action |
| 15 | | | Infant and preschooler feeding behaviors in Chinese families: A systematic review |
| 16 | | | Effectiveness of a health promotion intervention to address determinants of child neglect in a disadvantaged community in Sri Lanka Open Access |
| 17 | | Technological Solutions for Infant Mood Recognition | A Low-Cost Intelligent Hardware System for Real-Time Infant Cry Detection and Classification |
| 18 | | | Infant Cry Detection System with Automatic Soothing and Video Monitoring Functions |
| 19 | | | Deep Learning for Infant Cry Recognition |
| 20 | | | A self-training automatic infant-cry detector |
| 21 | | | Automatic Detection of Cry Sounds in Neonatal Intensive Care Units by Using Deep Learning and Acoustic Scene Simulation |
| 22 | | | Infant cry classification using CNN – RNN |
| 23 | | | Baby Cry Detection in Domestic Environment using Deep Learning |
| 24 | | Pitch Variations | Newborn Cry Acoustics in the Assessment of Neonatal Opioid Withdrawal Syndrome Using Machine Learning |
| 25 | | | Cry Features Reflect Pain Intensity in Term Newborns: An Alarm Threshold |

| 26 | INDEPENDENT VARIABLES | | Impact of the Cry of the Infant at Risk on Psychosocial Development |
|----|----|----|----|
| 27 | | Intensity Fluctuations | Maternal Mood and Perception of Infant Temperament at Three Months Predict Depressive Symptoms Scores in Mothers of Preterm Infants at Six Months |
| 28 | | | Cry features reflect pain intensity in term newborns: an alarm threshold |
| 29 | | | Cry features reflect pain intensity in term newborns: an alarm threshold |
| 30 | | Temporal Patterns | Temporal Patterns of Infant Regulatory Behaviors in Relation to Maternal Mood and Soothing Strategies |
| 31 | | | Analyzing temporal patterns of infant sleep and negative affective behavior: A comparison between different statistical models |
| 32 | | | Fundamental Frequency Variation of Neonatal Spontaneous Crying Predicts Language Acquisition in Preterm and Term Infants |

In the context of the infant mood prediction and recommendation system, the conceptual framework clarifies the links between important independent and dependent variables. The concept aims to clarify why changes in an infant's cry patterns (an independent variable) could affect the capacity to accurately predict their emotional states (a dependent variable), ultimately resulting in the creation of caregiver recommendations.
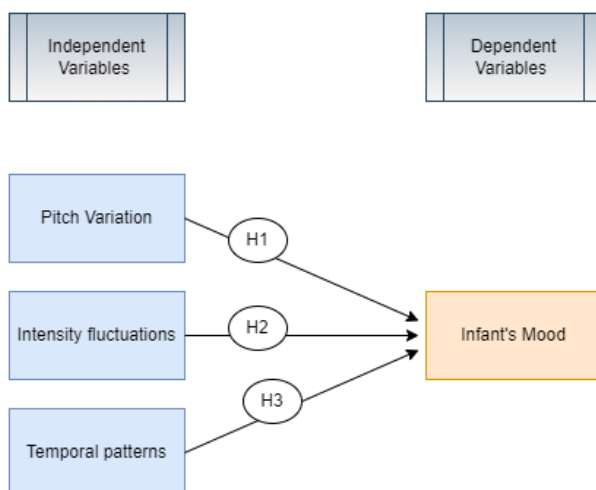


*Figure 1 - Conceptual Framework*

***Hypothesis***

**H1₀ -** There is no significant relationship between pitch variations in infant crying and the infant's mood.

**H1$_1$ -** There is a significant relationship between pitch variations in infant crying and the infant's mood.

**H2$_0$ -** There is no significant relationship between intensity fluctuations in infant crying and the infant's mood.

**H2$_1$ -** There is a significant relationship between intensity fluctuations in infant crying and the infant's mood.

**H3$_0$ -** There is no significant relationship between temporal patterns in infant crying and the infant's mood.

**H3$_1$ -** There is a significant relationship between temporal patterns in infant crying and the infant's mood.

**Methodology**

Face-to-face interviews with medical professionals, including doctors and midwives, were chosen as the primary method for fact gathering in this project, as they offer detailed insights into infant care methods, caregiver experiences, and the identification of emotional states in infants.
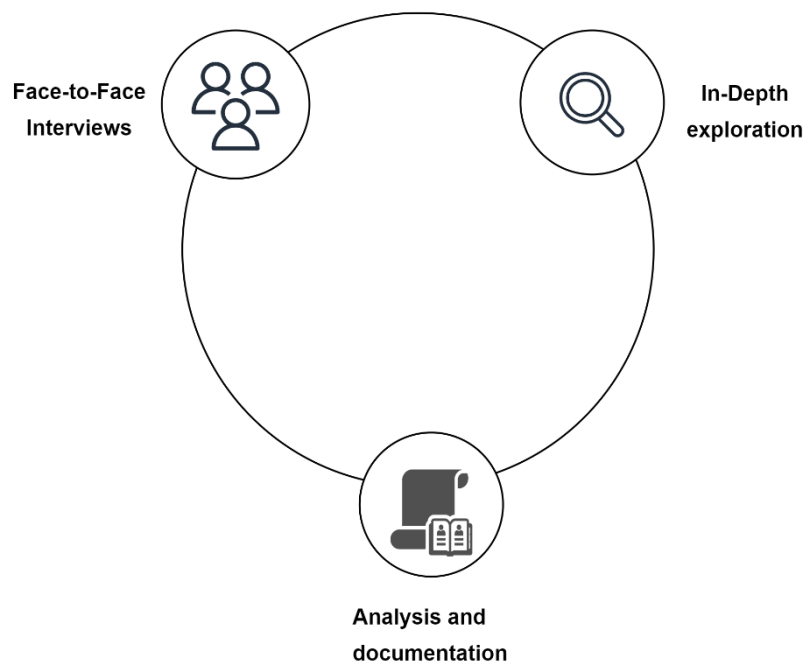


*Figure 2 - Fact gathering cycle*

*Research approach*

This study's research approach combines quantitative and qualitative approaches in order to gain a full understanding of infant cry patterns, caregiver responses, and the design and development of a machine-learning model for mood prediction. The multifaceted character of the research issues needs a wide range of data gathering and analysis methodologies to ensure a comprehensive investigation of the subject.

## *Qualitative Research*

### *1. In-Depth Interviews*

**Rationale:** In-depth interviews with Sri Lankan doctors, midwives, and infant caregivers will gather qualitative data on infant cry-out patterns, caregiver behaviors, and clinical considerations.

**Impact:** By identifying and classifying recurrent themes in interview data, thematic analysis provides a greater understanding of emotional dynamics and therapeutic considerations. The overall understanding of the study's conclusions is enhanced by these qualitative data.

### *2. Thematic Analysis*

**Rationale:** Thematic analysis will be used to identify and categorize themes in interviews, providing insights into emotional dynamics of caregiver-infant relationships and clinical features of infant crying.

**Impact:** Thematic analysis uncovers delicate insights from qualitative data, which enriches data interpretation, guides model development, and impacts caregiver recommendations.

## *Quantitative Research*

### *1. Acoustic Data Collection*

**Rationale:** Acoustic data collection will involve collecting quantitative infant cry recordings, capturing pitch variations, intensity fluctuations, and temporal patterns, using mobile devices for machine learning model creation.

**Impact:** By providing the model with a scientific basis derived from this data, the model is able to learn from a wide range of acoustic characteristics linked to different emotional expressions in baby cries.

### *2. Statistical Analysis*

**Rationale:** The study used statistical analysis to analyze acoustic recordings, focusing on correlations between auditory parameters, caregiver practices, and expected emotions.

**Impact:** The machine-learning model's development and caregiver recommendations are guided by statistical findings that provide light on the correlation between particular caregiver actions and unique Acoustical characteristics.
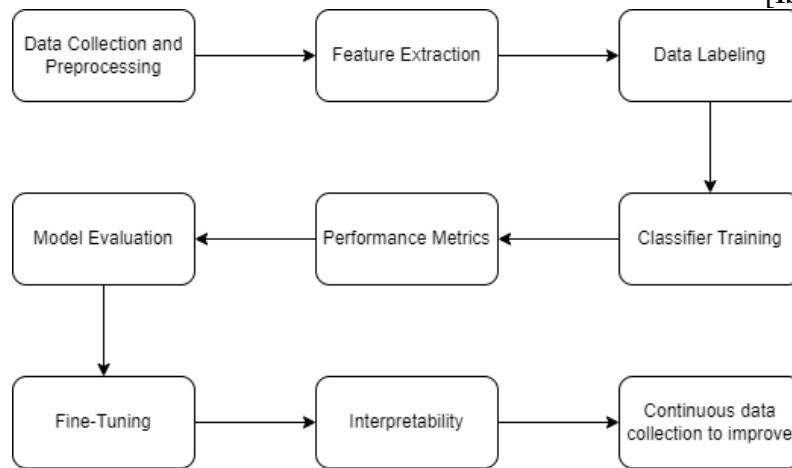
*Figure 3 - Data Analysis flow*

### *Machine Learning Model Development*

1. *Data Preprocessing*

   **Rationale:** The mobile app's acoustic data will undergo preprocessing stages like noise reduction and feature extraction to prepare it for machine learning model training.

   **Impact:** Clear and organized data enhances the machine-learning model's performance, leading to more precise mood forecasts.

2. *Model Training*

   **Rationale:** Machine-learning algorithms like CNNs and RNNs will be used to train a mood prediction model based on the acoustic characteristics of infant cries.

   **Impact:** The success of this training step determines the model's overall performance and determines how well it can predict emotions.

3. *Cross-Validation and Evaluation*

   **Rationale:** The machine-learning model's performance will be assessed through cross-validation techniques and metrics like accuracy, precision, recall, and F1-score to ensure its correctness and generalizability.

   **Impact:** Strong evaluation criteria verify the machine-learning model's dependability, instilling confidence in its practical application for real-time mood forecasts.

4. *Integration with Mobile App*

   **Rationale:** The machine-learning model will be integrated into a mobile app, providing real-time mood forecasts for newborns based on cry analysis.

   **Impact:** By integrating the model, it becomes more accessible and user-friendly and is in line with the ultimate objective to encourage infant well-being through creative use of technology.

## Interview questions and guidelines

Questions for doctors:

- What are the different types of cries that infants make?
- What emotions do these cries express?
- What are the challenges that parents and caregivers face in understanding their infant's cries?
- How can a technology-assisted solution help parents and caregivers understand their infant's cries?
- What features would be important in such a solution?

Questions for midwives:

- How do midwives typically help parents and caregivers understand their infant's cries?
- What techniques do midwives use to soothe infants?
- How can a technology-assisted solution complement the techniques that midwives use?
- What are the challenges that midwives face in helping parents and caregivers understand their infant's cries?
- What are the ethical considerations of using a technology-assisted solution to help parents and caregivers understand their infant's cries?

*Figure 4 - Interview Questions*

## Results
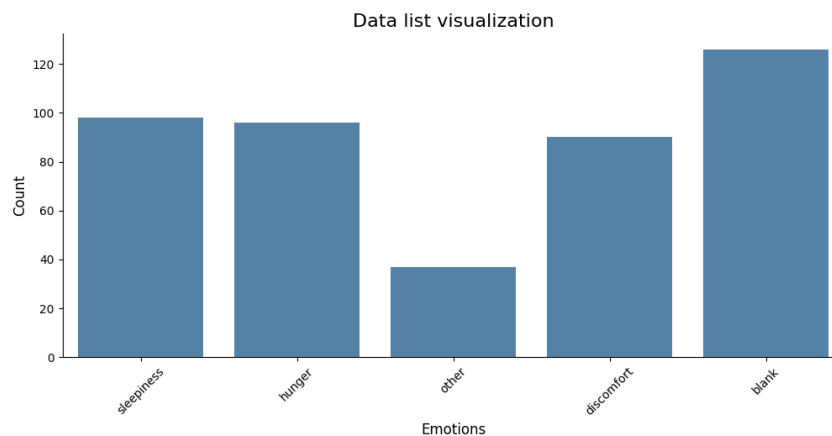


*Figure 5 - Data list visualization*

The model was trained by organizing audio files into distinct folders based on detected patterns and including blank files to differentiate between cry and non-cry audio. This process improved the model's accuracy in classifying newborn moods, enhancing its performance.

126 audio tracks were added to the 'blank' folder, 96 to 'hunger,' 90 to 'discomfort,' 95 to 'sleepiness,' and 37 to the 'other' folder throughout this process. These categorized audio samples will help the model improve its performance and accuracy in classifying newborn moods.

*Intensity fluctuation –*
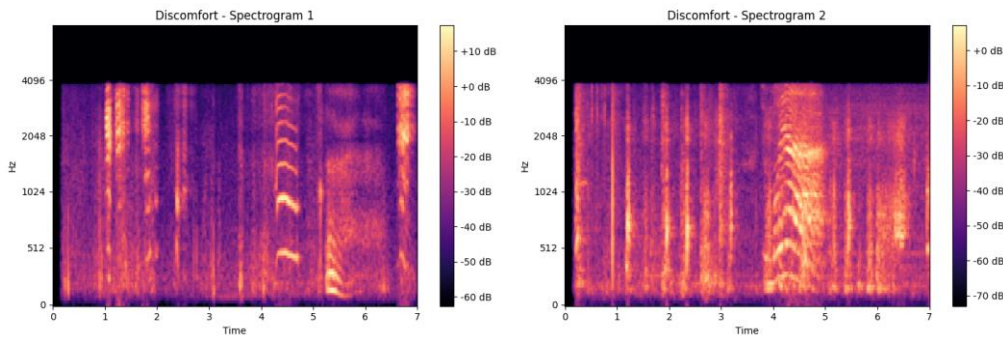


*Figure 6 - Discomfort spectrogram*

The chart demonstrates intensity fluctuations in two distinct cry patterns, 'Discomfort - Spectrogram 1' and 'Discomfort - Spectrogram 2,' providing a quantitative view of these fluctuations. Spectrograms aid in comparing cry patterns, particularly in newborn mood sensing and emotional well-being assessment applications.
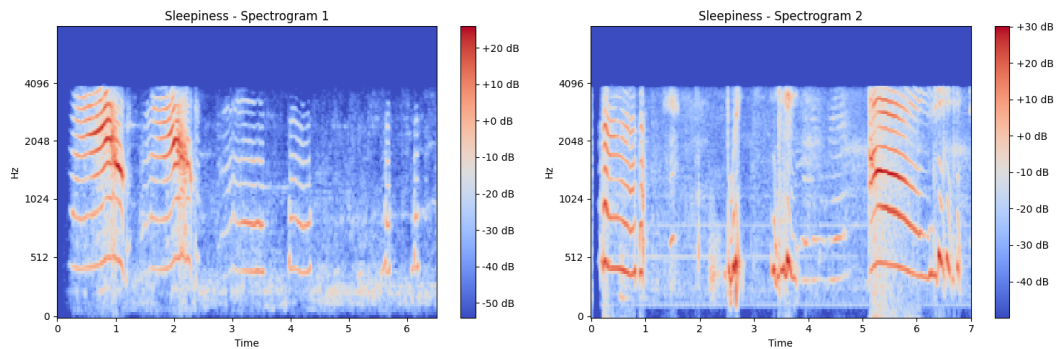


*Figure 7 - Sleepiness spectrogram*
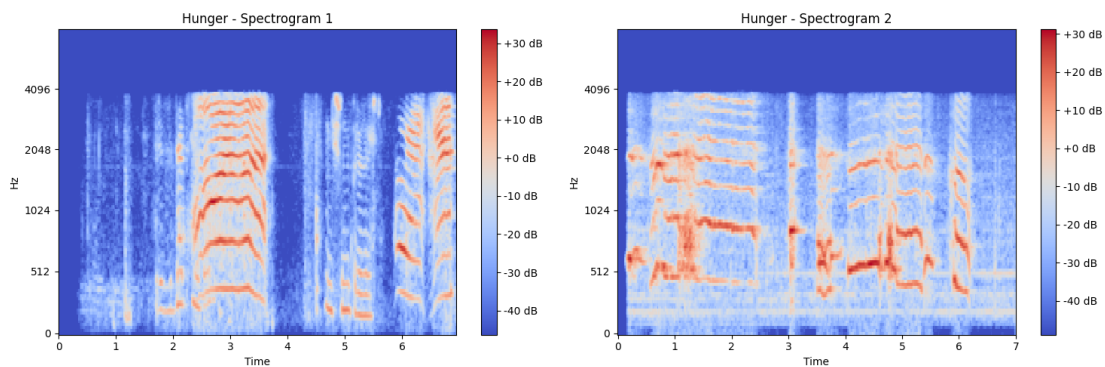


*Figure 8 - Hunger spectrogram*

*Pitch variation*
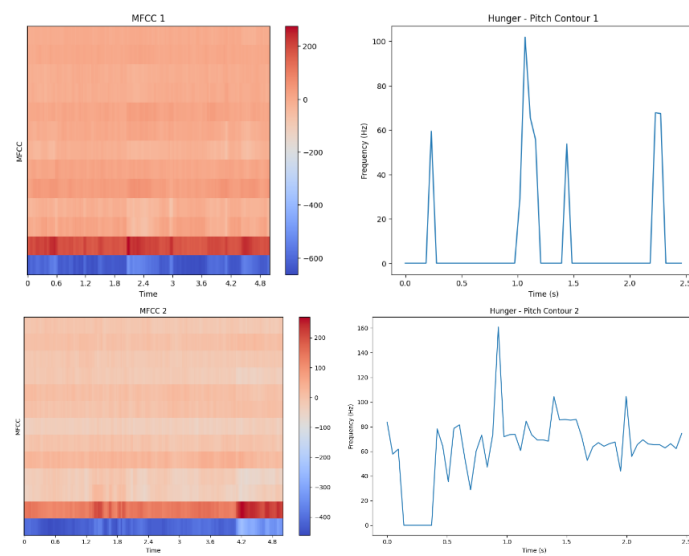


*Figure 9 - Hunger pitch contour*

As you can see when an infant is hungry, their cry pattern will be instantly gone for a high pitch and then lower again.
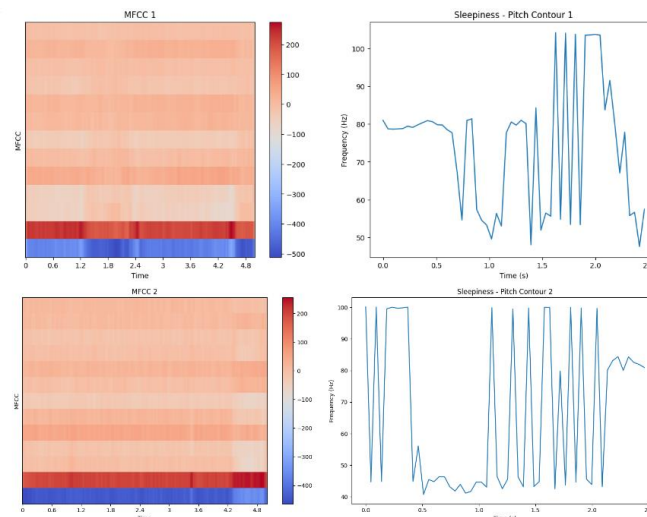


*Figure 10 - Sleepiness Pitch contour*

However, the things are different when the baby is sleepy or tired; the pitch of the cry pattern will go up and down more frequently because infant maybe in a confused state.
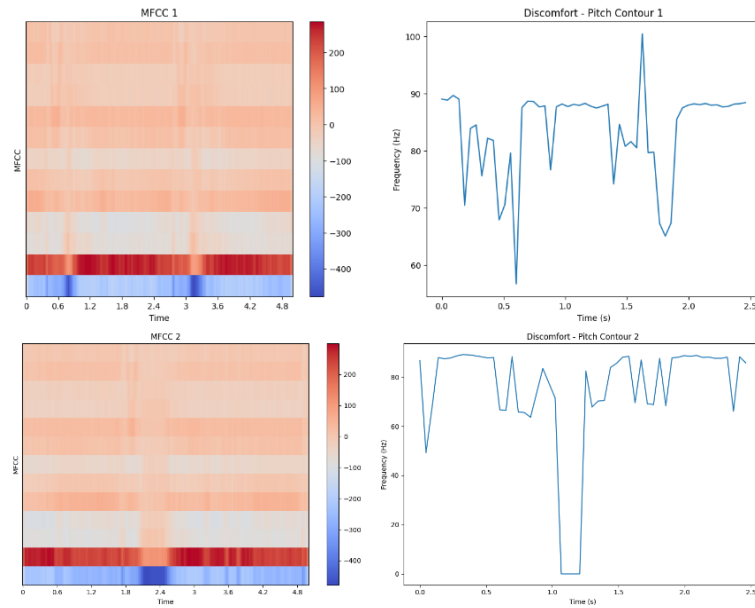
*Figure 11 - Discomfort Pitch contour*

The pitch of the cry pattern will go lower instantly and then it will stay in a same line for a particular time when the infant is in a discomfort mood.

*Temporal pattern*
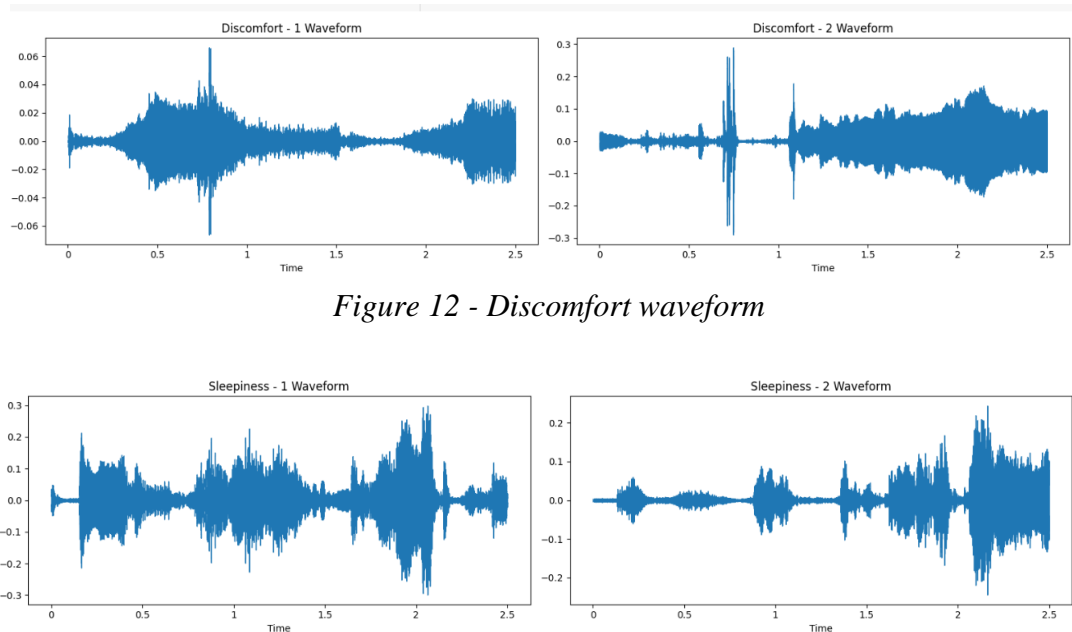


*Figure 12 - Discomfort waveform*
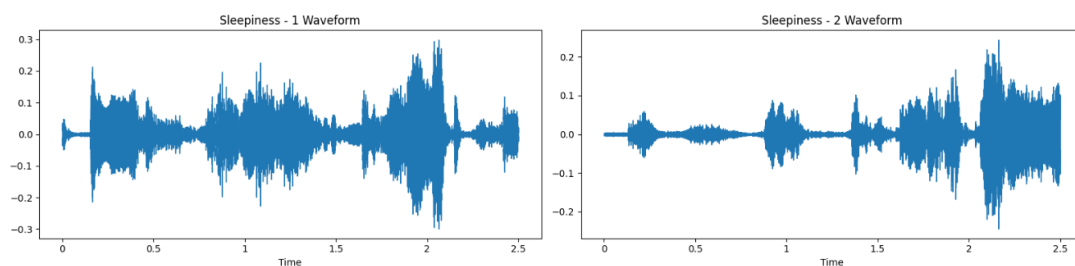


*Figure 13 - Sleepiness waveform*
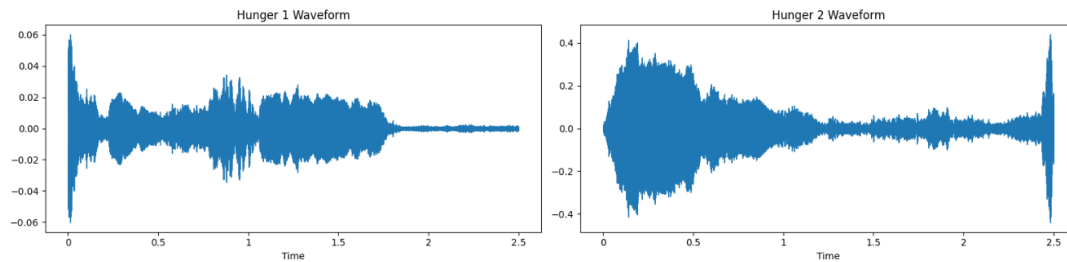
*Figure 14 - Hunger waveform*

We can see a constant and noticeable pattern throughout these three moods when we examine the temporal patterns in each image. These patterns represent distinct auditory elements that define each mood group. This discovery strengthens my infant mood classification algorithm by confirming the presence of mood-specific acoustic features in audio data.
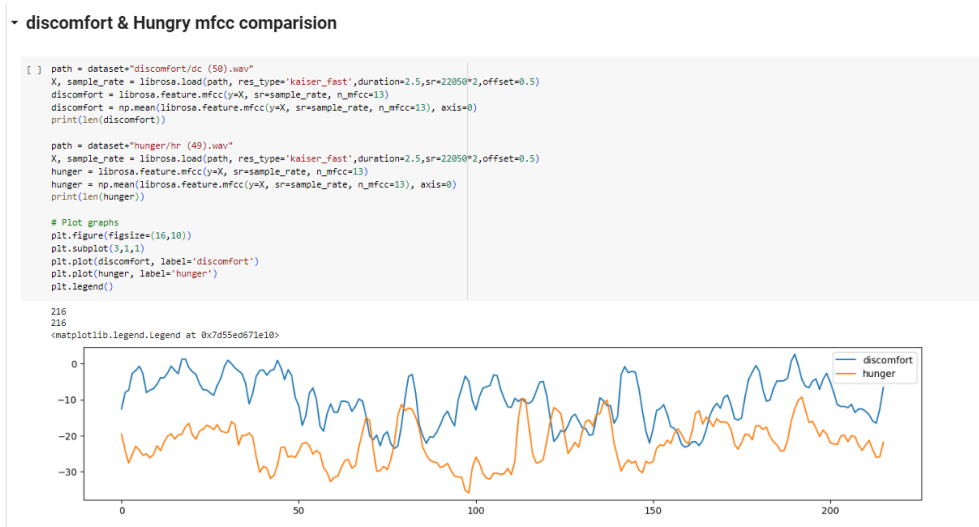


*Figure 15 - Discomfort and Hunger comparison*

The implementation compares the acoustic properties of audio recordings representing two infant moods, 'discomfort' and 'hunger', using Mel-Frequency Cepstral Coefficients (MFCC) characteristics. The code loads data, computes MFCC features, and displays mean values in feature vectors, improving mood classification accuracy.

**Actual User Input Interface Designs**

| Login screen | Register Screen | Dashboard |
|---|---|---|
|   *Figure 16 - Login screen* |   *Figure 17 - Registration screen* |   *Figure 18 - Dashboard* |

| Recommendations screen (Validate) |
|---|
|   *Figure 19 - Validate recommendations* |
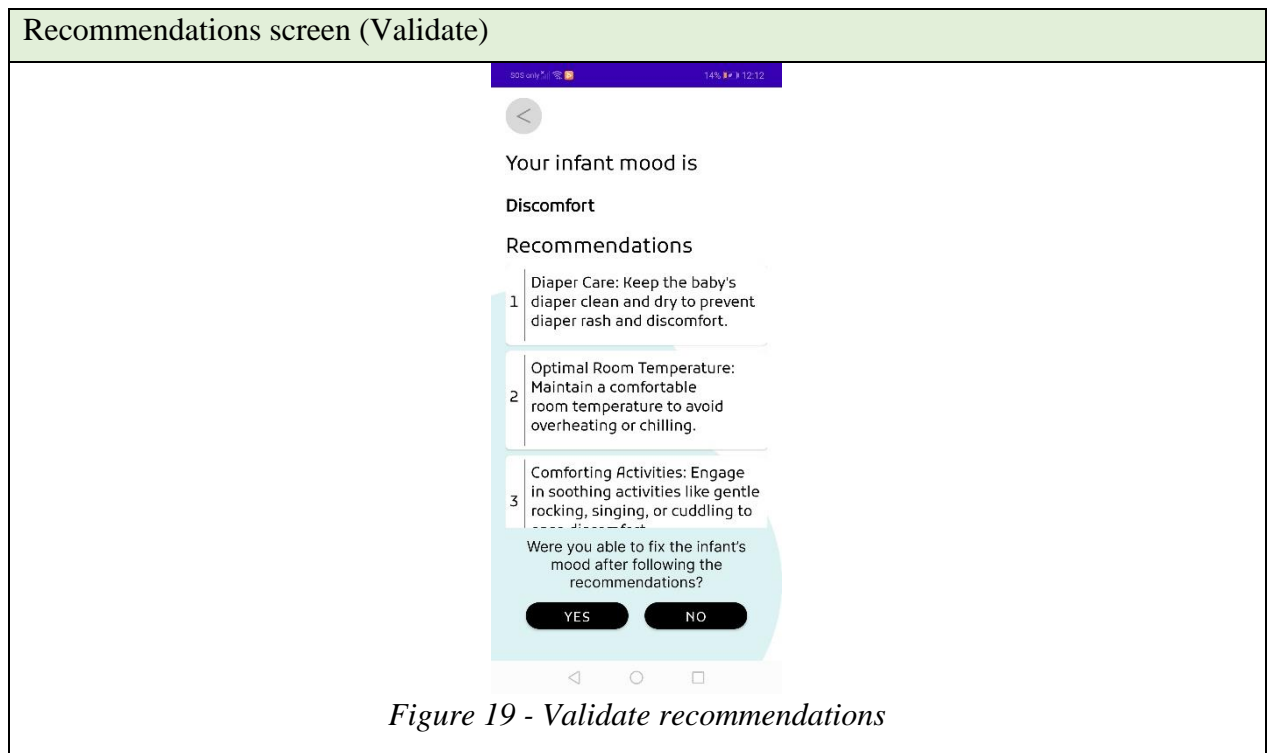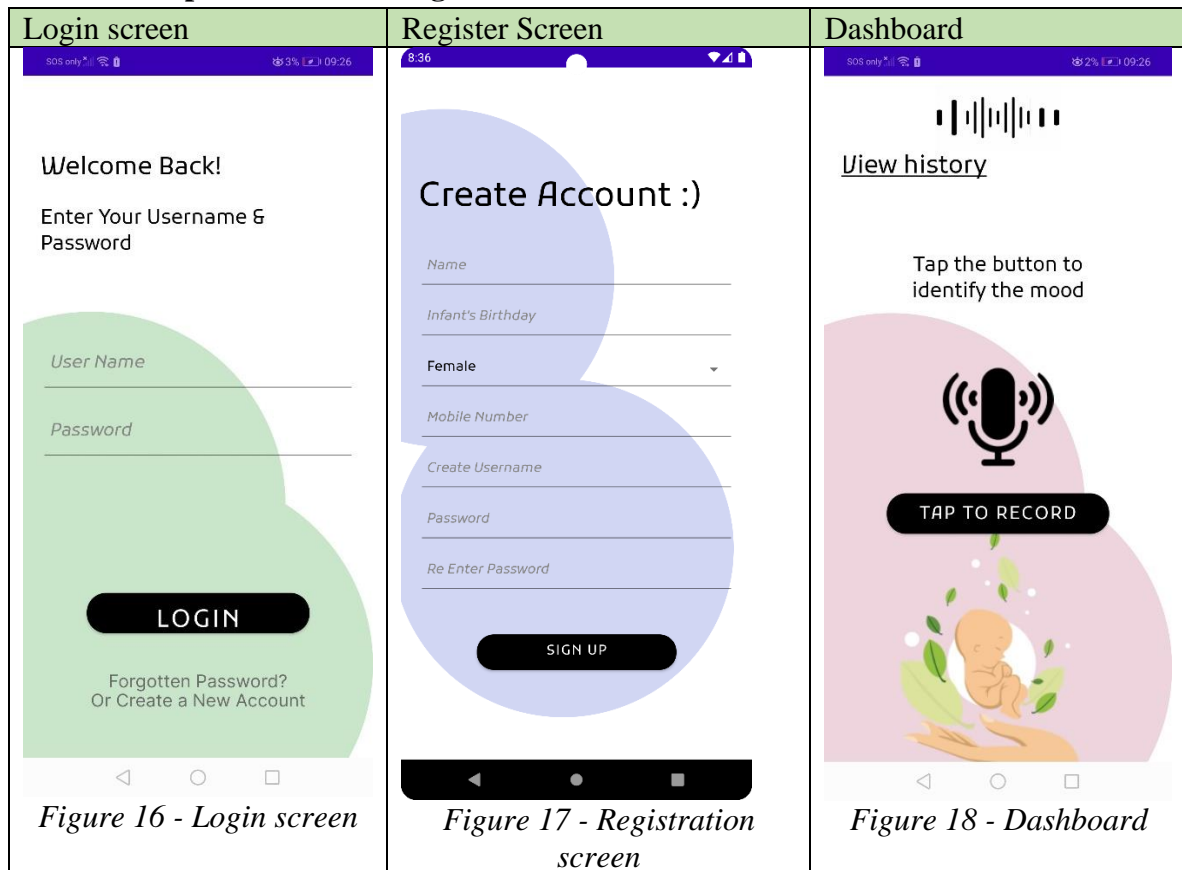
**Actual User Output Interface Designs**

| Hunger | Sleepiness | Discomfort |
|---|---|---|
|  |  |  |
| *Figure 20 - Hunger recommendations* | *Figure 21 - Sleepiness recommendations* | *Figure 22 - Discomfort recommendations* |
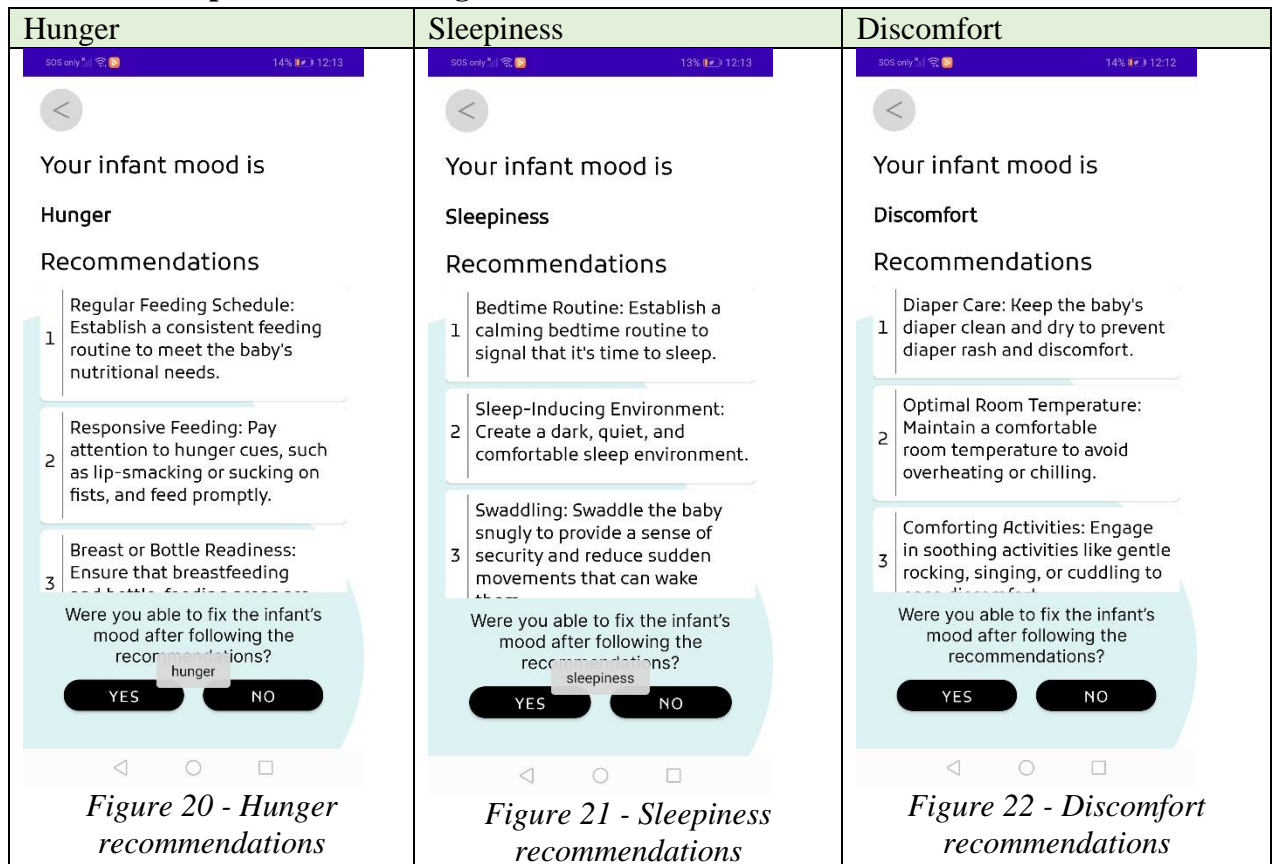
**Discussion**

The InfantMoodSense application is a significant advancement in pediatrics and parenting, detecting cry patterns in infants to assess their mood. It aids parents in improving infants' mental and physical health and bridges the gap between theoretical understanding and practical application.

The project has successfully met its stated objectives, delivering an innovative system with a Hybrid Convolutional-LSTM Neural Network achieving a noteworthy 72% accuracy in predicting infant moods through audio analysis. The technical discussions, emphasizing the MVVM architectural pattern and Python-based audio data processing, reflect the project's thorough methodology. Despite commendable achievements, constraints such as noise sensitivity, data variability, limited emotional states, and privacy concerns necessitate ongoing monitoring.

The project aims to advance childcare through cutting-edge technology, with InfantMoodSense showing potential for positive impacts on childcare practices and pediatric research. With a 72% accuracy, it lays the groundwork for future advancements and emphasizes the commitment to improving childcare through advanced technology and efficient analysis of infant moods.

**Conclusion**

The project achieved its goal, predicting infant moods with a commendable 72% accuracy using a Hybrid Convolutional-LSTM Neural Network and efficient audio data processing.

InfantMoodSense has benefits for early-stage infant care despite drawbacks including limited emotional states and noise sensitivity. With the use of larger datasets, it represents a major advancement in pediatric research and opens the door to further advancements. It is a big advance in utilizing technology to improve childcare, and it has a direct impact on childcare practices. It also paves the way for continuous innovation in baby well-being. With a 72% accuracy rate, InfantMoodSense highlights its significance in the early childhood care area and provides a foundation for future developments in forecasting infant moods.

## Recommendations

The InfantMoodSense project lays a solid foundation for future enhancements and improvements. As the system evolves, several key areas are ripe for development and innovation.

### *Utilizing Live Recordings*

The system's future development can improve mood recognition by utilizing live recordings and real-time mood predictions. This adaptive learning strategy allows the system to adapt to individual variances in infant vocalizations and environmental variables.

### *Expanding Mood Categories*

The InfantMoodSense project categorizes newborn moods into discomfort, hunger, and sleepiness, with future expansion to include a wider range of emotions, enabling more personalized caregiving.

### *Seamless Mobile Application Integration*

InfantMoodSense mobile application is being developed to provide caregivers with real-time mood predictions and historical data, with a user-friendly interface and push notifications for engagement.

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# FACTORS AFFECTING CUSTOMER SATISFACTION WITH THE PRESENCE OF INTEGRATED QUALITY MANAGEMENT SYSTEM IN FOOD ENTERPRISES

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**Abstract**

This study evaluates the significant factors influencing customer satisfaction with having an integrated quality management system in food enterprises and to identify the benefits from establishing quality standards and practice of IQMS principles in food industry. Used five main factors of SERVQUAL model. Using random sampling technique 50 participants of the target population were selected as MR and 50 participants from the customer based were selected from the total population of 100 based on Krejcie and Morgan table. In conducting this study, the required data is obtained through structured questionnaire. In the analysis descriptive statistics, correlation analysis, and multiple regression analysis was performed and used SPSS 20 was used. There for SERVQUAL model is accepted in this study. 99.8 % adjusted R Squared value shows the all-independent variables that have selected together doesn't come to 100%. So still there are other variables which will affected to the customer satisfaction.

**Key Words**: Customer Satisfaction, Integrated Quality Management System, SERVQUAL model

## Introduction

### *Background of the study*

The competition and globalization in our environment are growing (Malekpour, Yazdani and Rezvani, 2022). The concept of quality is elusive and restricted. More than ever, consumers now prefer high quality. For businesses to satisfy customers, they need to deliver quality. (Veselova, 2018). Certificates make it easier to select and make purchases by lowering the confusion that can develop when evaluating a product's quality before purchasing. To ensure marketing claims for unobservable quality features, certification programs are utilized (Kaczorowska *et al.*, 2021).

Customers are the lifeblood of any business. IQMS development is a modern, innovative project intended to improve the effectiveness of general management of a business (Akhmetova, Baibolova and Serikkyzy, 2019). IQMS has a great impact than implementing only ISO 9001 on business performance, improving employee awareness, company image, product quality and safety, customer satisfaction, market share growth (due to access to new markets and customers), internal organization and communication, productivity caused, and the quantity of nonconforming products (Agus *et al*., 2020).

Integration has advantages in cost-cutting, enhancing the company's external image, maximizing resources, enhancing internal communication, delivering effectiveness in operations, and enhancing customer satisfaction (Zhu, Habibah and Talib, 2022).

Food businesses want to dominate the world market by exporting their goods. The effects of export activities on businesses and the national economy are significant. One strategy to do this is to implement an integrated management system, specifically ISO 9001 for quality management, ISO 45001 for safety management, ISO 14000 for environmental management, and ISO 22000 for food safety and GFSI for food quality, safety and it offers passport for global market (Purwanto, Budi Santoso and Asbari, 2020).

There are some limitations when implementing only ISO 9001: 2015 in food enterprises. But IQMS is capable of meeting food safety and quality requirements for customer satisfaction. It can also meet the needs of export market customers. The business can expand their customer base.

*Objectives of the Study*

The purposes of this study are,

- To evaluate the significant factors influencing customer satisfaction with having an integrated quality management system in food enterprises
- To identify benefits from establishing quality standards and practice of IQMS principles in food industry

*Significance of the Study*

The goal behind the IQMS concept is for an organization to work as hard as possible and to manage all of its activities through an Integrated Management System (Akhmetova, Baibolova and Serikkyzy, 2019).

Significance of the study are to justify the significant factors influencing customer satisfaction with having an integrated quality management system in food enterprises and to identify benefits from the establishing quality standards and practice of IQMS principles in food industry.

The SERVQUAL model has five aspects, and by comprehending them, one may start to modify the company's operations to better meet the needs of customers. Market researchers developed the SERVQUAL model in the beginning to increase customer satisfaction in the retail and service sectors (Commbox, 2020).
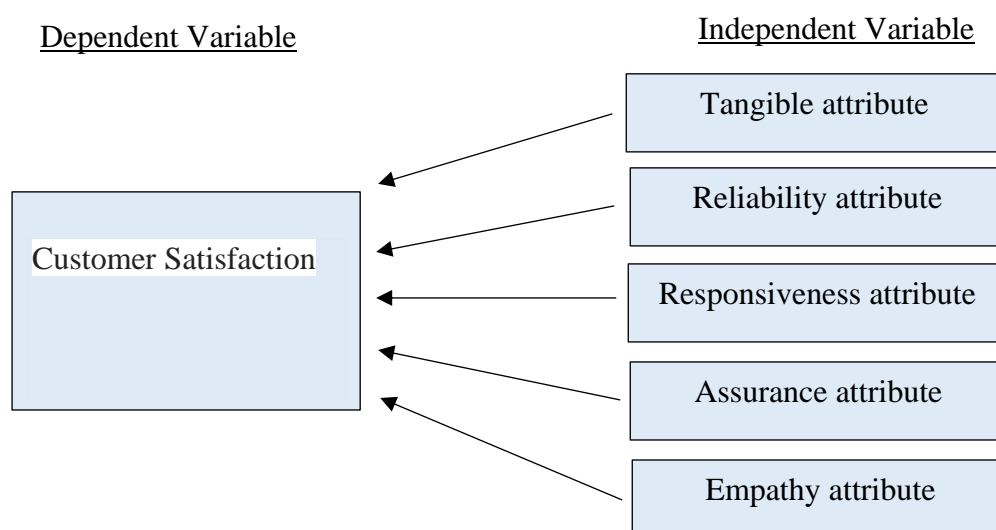


*Figure 1 : Conceptual Framework of the Study (Source: Usman et al., 2019)*

**Methodology**

For this study, quantitative data was collected through a survey based on a questionnaire. The target population was food products consumers and management representatives of food businesses will be organized and analyzed through the questionnaire from 100 responses. Sample calculated through the Morgan table under the 95% confidence level. If the respondent in this study is not a management representative of the QMS then they are considered as customers. Designed to offer a methodical justification of how the research questions are handled in a quantitative study.

Data collection was done by distributing the structured questionnaire according to the simple random way. IBM SPSS Statistics 20.0.0 was used as the tool for data analysis. Descriptive analysis was done on the respondents' demographic data. A descriptive analysis of the summery of the data was conducted. The strength and link between a few independent factors and dependent variable were examine using five-point Likert scale.

The construct of hypothesis development is another outcome of this review to evaluate the significant factors influencing customer satisfaction with having an integrated quality management system in food enterprises.

SERVQUAL model in with 19 indicators. The distribution is indicators for Tangible and Reliability such as technology and equipment used, material quality, packing quality, physical appearance product delivered and fitness and safety. Responsiveness dimension such as; Assurance dimensions such as quick responsive, resolve queries, customer support and no late reply. Empathy dimensions such as; trustable workforce, confidentiality in dealings, competent workforce and friendly workforce.

**Results**

*Demographic Characteristics of Respondents*

The participant's demographic data is provided for analysis in this section of the questionnaire. The analysis aims to provide details about the respondent age, educational background, types of project handling, country they work for, and whether or not they are MR of QMS.

According to the respondents it proves the important of having IQMS in food industry. Majority of respondent's opinion was IQMS can gave high quality safe product. Second largest impotence has chosen as IQMS can meet customer requirements. Below table (Table 1) shows the response rate for the benefits can achieve with the presence IQMS in food enterprises.

Table 1: Response rate for the benefits can achieve with the presence IQMS in food enterprises

| The benefits of presence of IQMS | Rate of respondents |
|---|---|
| Compliance with relevant legislation | 62.6% |
| Meet customer requirements/ customer satisfaction | 79.1% |
| High quality safe product | 85.7% |
| Improvement of brand image | 63.7% |
| Cost savings | 48.4% |
| Avoid duplication between procedures of systems | 49.5% |
| Reduction of hazardous waste generation | 60.4% |

| Reduction of production losses/ Improve operational efficiency | 59.3% |
|---|---|
| Competitive advantage | 54.9% |
| Employee satisfaction | 53.8% |
| Leadership engagement | 42.9% |
| Expand the market size/ To meet the international market | 50.5% |
| Reduce the number of third-party food safety audits | 37.4% |
| Drive continuous business improvement | 44.0% |

*Descriptive Statistics*

| | Customer satisfaction | Tangible | Reliability | Responsiveness | Assurance | Empathy |
|---|---|---|---|---|---|---|
| *Mean* | 4.0656 | 4.1911 | 4.0267 | 3.9711 | 4.1056 | 4.0056 |
| *Std. Deviation* | 0.61684 | 0.68821 | 0.64942 | 0.77652 | 0.71890 | 0.81762 |

Reliability has the highest mean value and assurance has the lowest mean value indicating that, on average, customers rated assurance slightly lower than the other dimensions.
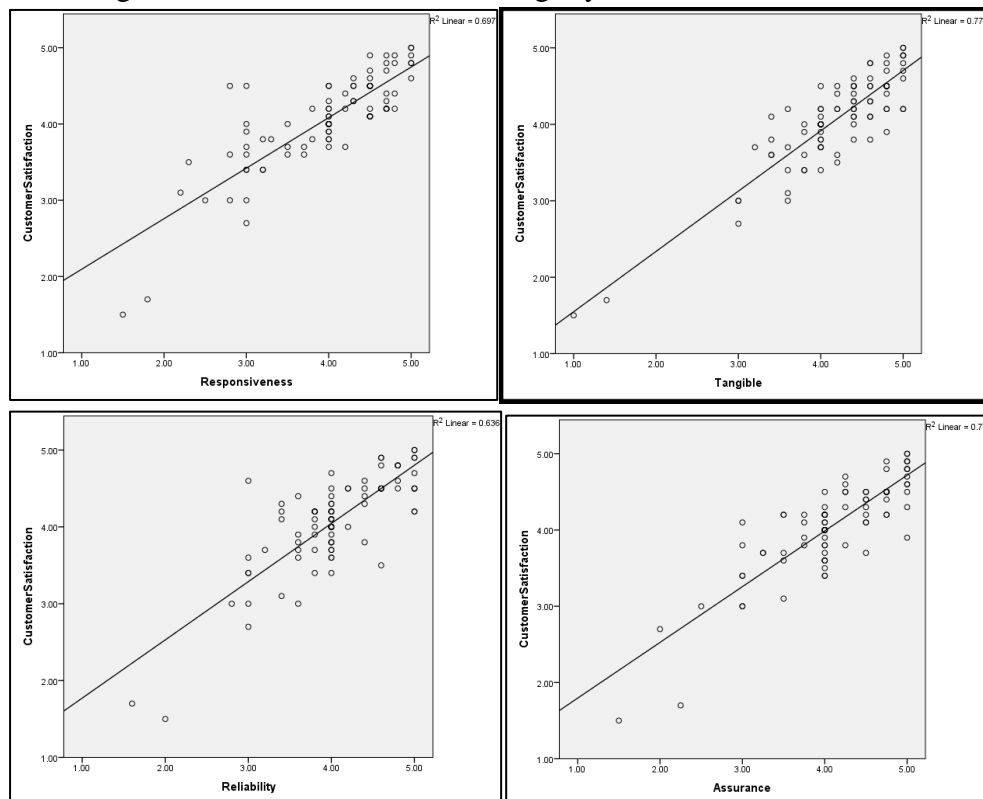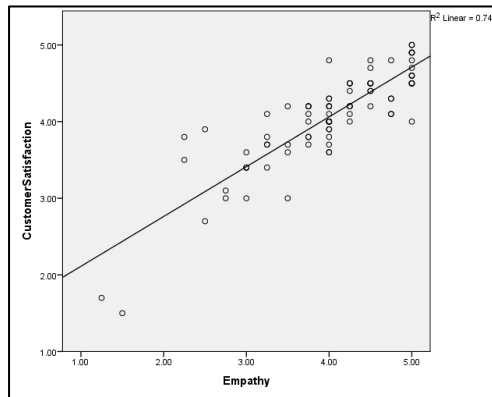
*Correlation*

Tangible has strong positive relationship towards the customer satisfaction. Since the Pearson correlation is 0.880 it's greater than 0.06.

According to the significance value (0.000) is lower than the 0.05 accept the alternative hypothesis and rejected the null hypothesis.

|  |  | Tangible | Customer Satisfaction |
|---|---|---|---|
| Tangible | Pearson Correlation | 1 | .880** |
|  | Sig. (2-tailed) |  | .000 |
|  | N | 90 | 90 |
| Customer Satisfaction | Pearson Correlation | .880** | 1 |
|  | Sig. (2-tailed) | .000 |  |
|  | N | 90 | 90 |

Therefore, r (Pearson correlation) equals to 0.798 and this value is greater than 0.06. So, reliability factor has strong positive relationship towards the customer satisfaction. Due to significance value is below than the 0.05, accepted the alternative hypothesis.

|  |  | Customer Satisfaction | Reliability |
|---|---|---|---|
| Customer Satisfaction | Pearson Correlation | 1 | .798** |
|  | Sig. (2-tailed) |  | .000 |
|  | N | 90 | 90 |
| Reliability | Pearson Correlation | .798** | 1 |
|  | Sig. (2-tailed) | .000 |  |
|  | N | 90 | 90 |

So, the Pearson correlation is 0.835, it is more than 0.06. There is strong positive relationship between responsiveness to customer satisfaction. p value =0.000, since p value is less than 0.05 accepted the alternative hypothesis and rejected the null hypothesis

|  |  | Customer Satisfaction | Responsiveness |
|---|---|---|---|
| Customer Satisfaction | Pearson Correlation | 1 | .835** |
|  | Sig. (2-tailed) |  | .000 |
|  | N | 90 | 90 |
| Responsiveness | Pearson Correlation | .835** | 1 |
|  | Sig. (2-tailed) | .000 |  |
|  | N | 90 | 90 |

According to below table significance value is less than 0.05. Therefore, alternative hypothesis is accepted.

Pearson correlation = 0.852

Assurance has strong positive relationship towards the customer satisfaction.

|  |  | Customer Satisfaction | Assurance |
|---|---|---|---|
| Customer Satisfaction | Pearson Correlation | 1 | .852** |
|  | Sig. (2-tailed) |  | .000 |
|  | N | 90 | 90 |
| Assurance | Pearson Correlation | .852** | 1 |
|  | Sig. (2-tailed) | .000 |  |
|  | N | 90 | 90 |

p value = 0.000,

p value is greater than 0.05,

Therefore, accepted the alternative hypothesis.

Pearson correlation = 0.861

Since it is greater than 0.06, empathy factor has strong positive relationship towards the customer satisfaction.

|  |  | Customer Satisfaction | Empathy |
|---|---|---|---|
| Customer Satisfaction | Pearson Correlation | 1 | .861** |
|  | Sig. (2-tailed) |  | .000 |
|  | N | 90 | 90 |
| Empathy | Pearson Correlation | .861** | 1 |
|  | Sig. (2-tailed) | .000 |  |
|  | N | 90 | 90 |

*Multiple Regression Analysis*

**Model Summary**

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate |
|---|---|---|---|---|
| 1 | .999ᵃ | .998 | .998 | .02833 |

According to above table, strongly positive relationship to all independent variable together because Pearson correlation is 0.999. But,
Adjusted R Square = 99.8%.

**ANOVAᵃ**

| Model |  | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| 1 | Regression | 33.796 | 5 | 6.759 | 8423.193 | .000ᵇ |
|  | Residual | .067 | 84 | .001 |  |  |
|  | Total | 33.863 | 89 |  |  |  |

According to the ANOVA table,
Significant value = 0.000
So, the null hypothesis is rejected.

**Discussion**

The significance value (p Value) of relationship, as indicated by the tabulated data above, is 0.000 (0.000<0.05), which shows that for all predictors, the alternative hypothesis is accepted and the null hypothesis is rejected. There for all predictor influenced on customer satisfaction with the presence of IQMS in food enterprises. There for SERVQUAL model is accepted in this study.

A strong positive relationship exists between the independent variables and the dependent variable as the Pearson correlation of the variables is greater than 0.06.

According to the model summary, strongly positive relationship to all independent variable together because Pearson correlation is 0.999. But, Adjusted R Square value is 99.8%. It means, even all independent variables that have selected together doesn't come to 100%. So still there are other variables which will affected to the customer satisfaction. There are 0.2% of other variables which will affected to customer satisfaction.

**Conclusion**

According to the analysis main five factors of SERVQUAL model are significant factors affecting for the customer satisfaction with the presence of IQMS in food industry. Among tangible, reliability, responsiveness, assurance and empathy factors of SERVQUAL model, tangible factor has highest mean score. Otherwise, all of these five factors have overall 99.8% of score and highly impact on customer satisfaction. But still there are other variables which will affected to the customer satisfaction. So, IQMS has a great impact than implementing only ISO 9001 on food business.

Table 1 lists the advantages of using IQMS in food business. Additionally, it proves that the existence of IQMS in the food industry can be used to achieve consumer requirements or satisfaction among recognized benefits because of it has higher rate of respondents.

*Recommendation*

According to the research findings five factors of SERVQUAL model is an effective model for measure the customer satisfaction. Tangible, reliability, responsiveness, assurance and empathy factors has strong positive impact on customer satisfaction with the presence of IQMS in food enterprises.

IQMS has a great impact than implementing only ISO 9001 on to meet customer requirements/ customer satisfaction, provide high quality safe product, compliance with relevant legislation, improvement of brand image, Avoid duplication between procedures of systems, expand the market size/ to meet the international market, reduce the number of third-party food safety audits, reduce the number of third-party food safety audits, employee satisfaction, reduction of hazardous waste generation, and drive continuous business improvement.

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**Annexture 01**
**List of Abbreviation**

| | |
|---|---|
| QMS | Quality Management System |
| IMS | Integrated Management System |
| IQMS | Integrated Quality Management System |
| ISO | International Organization for Standardization |
| MR | Management Representative |

# FACTORS INFLUENCING THE SUCCESS OF USER-FRIENDLY MOBILE APPLICATIONS FOR SENIOR CITIZENS WITH LIMITED DIGITAL LITERACY IN THE COLOMBO DISTRICT

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**Abstract**

As mobile applications become integrated to modern daily life, ensuring their usability for all user groups including senior citizens is essential. This study aims to investigate the factors influencing the success of user-friendly mobile applications targeting Colombo District, Sri Lanka. A quantitative research approach is used, and data is collected using a survey as the primary data collection method. The study involved 383 participants based in Colombo District, including both male and female participants. Main factors including typography and colors have been identified as successful factors when designing mobile applications for senior citizens. The results provide insights into the enhancements and design patterns catering to the requirement of the targeted population which ensures the accessibility and usability of mobile applications for senior citizens.

**Keywords:** Mobile Applications, Senior Citizens, User-friendly

**Introduction**

Mobile applications can consider an application software designed to use on smartphones, boosts lifestyle, and provides services. Despite the proven success and benefits that mobile applications offer, some individuals, especially those in older age groups, remain hesitant to adopt them.

Product development and marketing often overlook the senior demographic, despite the fact that this age group is consistently emergent in most developed societies. Understanding the factors contributing to their reluctance to embrace modern technology is essential. Simultaneously, identifying the key drivers for successful mobile applications tailored to senior citizens can enrich their knowledge and enhance their quality of life across various domains, including health management, social connectivity, and reservations.

A significant number of mobile users in Sri Lanka are elderly with limited digital skills. However, many mobile apps do not cater to their needs, often featuring small text and complex navigation. To bridge the gap between seniors and others, mobile apps for seniors should have unique considerations.

The aim of this study is to define the key components of effective mobile applications for Sri Lanka's senior citizen population.

The objective of this study as follows,

- Identify the key factors for a successful mobile application designed for senior citizens
- Identify the limitations of senior citizen community.
- Identify the appropriate design patterns of mobile interfaces

- The identification of the limitations of senior citizens in the perspective of district level
- Provide a basement for future researchers

**Methodology**

This research employs an empirical and qualitative approach to investigate the success criteria of mobile applications designed for senior citizens. Utilizing correlation and regression analysis, it aims to understand the relationship between independent and dependent variables. Focused on the senior citizen population in Colombo district, Sri Lanka, the study justifies the use of non-probability sampling for its clear target demographic. The sample size of 383 participants is determined through the Survey System website, enhancing methodological consistency. This comprehensive approach aligns with the research objectives, ensuring relevance and credibility in exploring mobile application success factors for senior citizens in Colombo.

*Related Research*

Previous studies have been referred in order to identify the research gap and to identify the relevant variables for the research.

The study (Zahida, et al., 2021) has identified the following as some of the common issues with mobile application interfaces designed for elder population.

- Smaller text
- Complex Navigation
- Usage of lighter colors
- Complex Layout
- Higher usage of text entry

According to Stuen and his team (Stuen & Faye, 2016) reasons for the issues encountered by aged population are,

- Vision impairment
- Cognitive Decline
- Weak Motor functionalities
- Memory loss
- Sensory Impairments
- Concentration Issues

According to the available research studies, the recommendations are as follows

- Use less navigation methods in the mobile application (Liu, et al., 2021)
- Include contrasting colours in the design to give a clear vision for the appropriate elements (Husain & Ibrahimb, 2020)
- Instead of using text entry, the usage of touch screen is more accessible for senior citizens (Caprani, et al., 2019)
- Use larger font sizes, especially from size 36 to 48 (Goumopoulos, et al., 2017)

After analysing all the factors identified in literature review related to the success of user-friendly mobile applications, five factors have been identified as the factors which greatly affect the success criteria when developing mobile applications for senior citizens. The selected factors are,

- Text

- Colour
- Navigation
- Use guidelines and instructions
- Gestures

An empirical study is used in this research and a quantitative research approach is used. To analyse the relationship between independent variables and the dependent variable, correlation and regression analysis techniques are used.

The population implemented in this study is senior citizens in Colombo district, Sri Lanka. The non-probability sampling called purposive sampling method is used based on 383 participants from senior citizens living in Colombo district. In order to collect data for this study a research questionnaire is used.

**Results**

Typography Over User-Friendly Mobile Applications

Question from Q-1.1 to Q-1.5 in the survey evaluate the indicators related to "Typography" and the overview of the responses for each question is illustrated in the below figure 4.14.

**Typography**

| | Q1.1 | Q1.2 | Q1.3 | Q1.4 | Q1.5 |
|---|---|---|---|---|---|
| Strongly Disagree | 34.7% | 29.8% | 29.8% | 24.8% | 49.9% |
| Disagree | 40.2% | 39.9% | 45.4% | 40.2% | 50.1% |
| Neutral | 25.1% | 30.3% | 24.8% | 35.0% | 0.0% |
| Agree | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| Strongly Agree | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
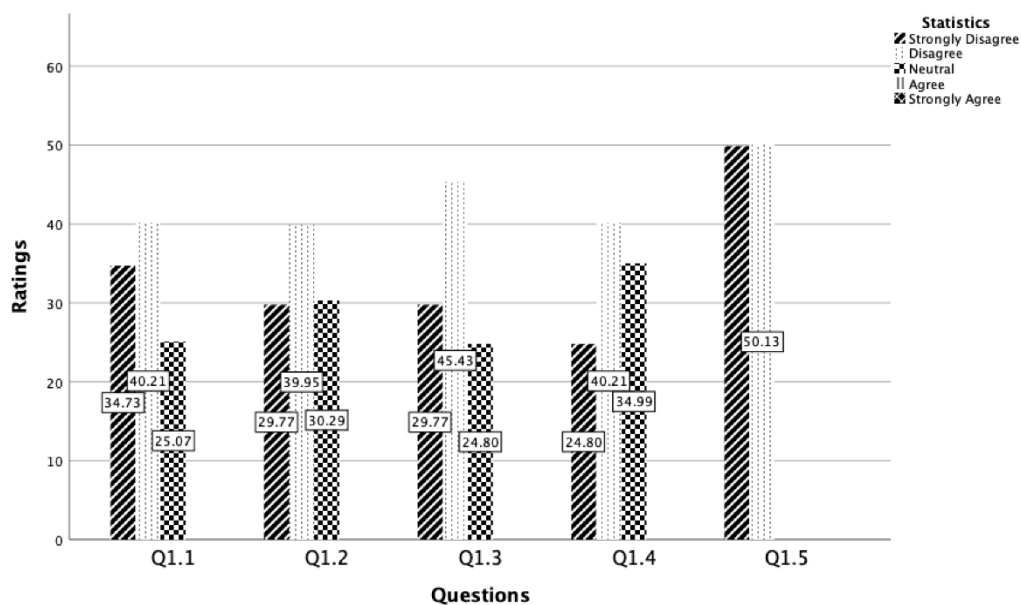


*Figure I - Response Summary Graph for "Typography"*

Following are the mainly identified factors related to each indicator of "Typography"

Table I - Indications of Response Analysis for "Typography"

| Indicator Assessed | Qu. No. | Observations |
|---|---|---|
| Level of Readability | 1.1 | Based on the survey results a majority of respondents (74.9% of total) have not given a positive rating towards the readability of fonts in mobile applications. |
| Assess whether the default font size is acceptable | 1.2 | A significant number of respondents find it difficult to read text available in mobile applications. |
| Rate of Clear Text Presentation | 1.3 | The research observation indicates that a majority of respondents, 29.8% strongly disagreeing and 45.4% disagreeing, do not believe that the usability of mobile applications for senior users is significantly enhanced when information is not presented in a concise and clear text format. |

**GGraph**
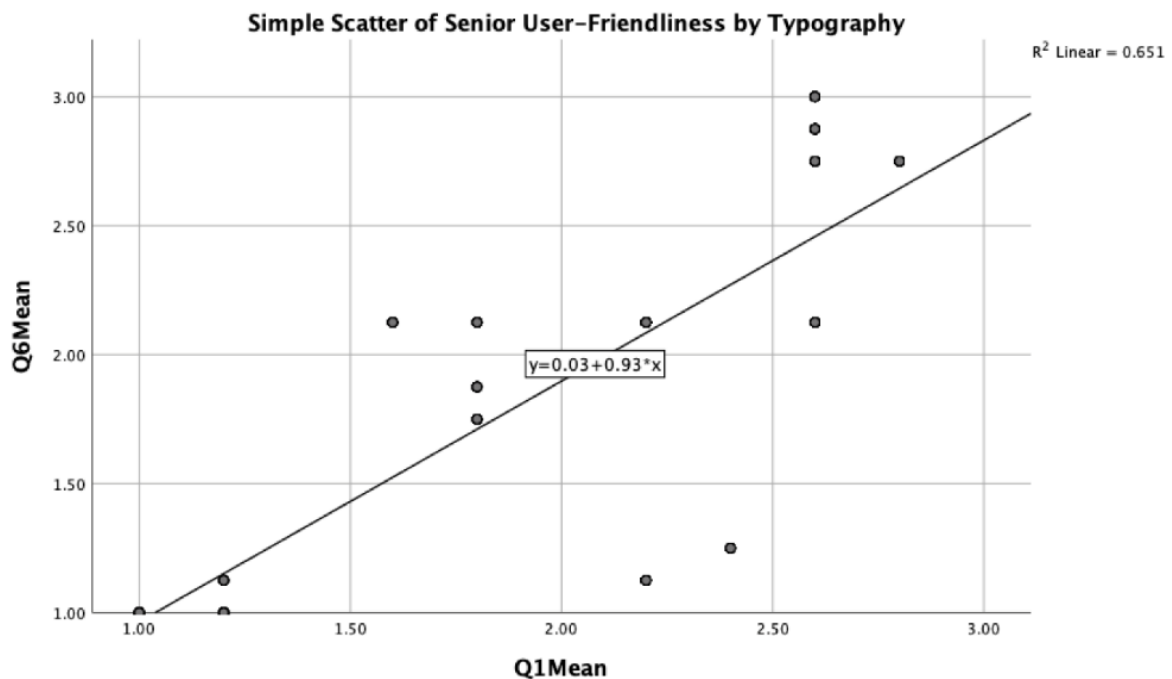


*Figure II - Scatter plot of "User-Friendliness of Mobile Applications" for "Typography"*

## Correlations

### Descriptive Statistics

|  | Mean | Std. Deviation | N |
|---|---|---|---|
| Q1Mean | 1.8924 | .59132 | 383 |
| Q6Mean | 1.7973 | .68400 | 383 |

### Correlations

|  |  | Q1Mean | Q6Mean |
|---|---|---|---|
| Q1Mean | Pearson Correlation | 1 | .807** |
|  | Sig. (2–tailed) |  | .000 |
|  | N | 383 | 383 |
| Q6Mean | Pearson Correlation | .807** | 1 |
|  | Sig. (2–tailed) | .000 |  |
|  | N | 383 | 383 |

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

*Figure III - Pearson Correlation Results for "User-Friendliness of Mobile Applications" by "Typography"*

According to the above-mentioned scatter plot and correlation analysis,

- Pearson correlation value related to "Typography" is, R = 0.807. Therefore, it indicates that the independent variable "Typography" has a positive strong relationship with "User-friendliness of mobile applications" according to the correlation theory.
- R squared coefficient value is $R^2$ Linear – 0.651 It indicates that the contribution from "Typography" to the dependent variable "User-friendliness of mobile applications" is 65% and the contribution from other independent factors and variables are 35%
- Two tailored significant value is p <0.001. As the 2 tailed sig. value is below the alpha value, for the independent variable "Typography", alternative hypothesis ($H1_a$) is accepted, and the null hypothesis is rejected by the researcher.
- The relationship between the IV and DV is denoted by the equation,
  - y = 0.03 + 0.93*X

In the same manner, other variables have been analysed to identify the relationship between independent variables and dependent variable.

**Discussion**

The hypothesis test outcomes, derived from the analysis of coefficients, can be summarized as follows,

Table II - Summary Table of Hypothesis Summary

| Independent Variable | Hypothesis Accepted | Type of Relation to Dependent Variable | Strength of the Relationship |
|---|---|---|---|
|  |  |  |  |

| | | | (Pearson Correlation Value) |
|---|---|---|---|
| Typography | H1ₐ | Positive - Strong | 0.807 |
| Colours | H2ₐ | Positive - Strong | 0.725 |
| Navigations | H3ₐ | Positive - Strong | 0.878 |
| Guidelines and Instructions | H4ₐ | Positive - Strong | 0.980 |
| Gestures | H5ₐ | Positive - Strong | 0.966 |

*Model Summary*

With the usage of Regression analysis functionality in SPSS software tool, a model summary is generated.

**Model Summary**

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate |
|---|---|---|---|---|
| 1 | .992ᵃ | .983 | .983 | .08923 |

a. Predictors: (Constant), Q5Mean, Q2Mean, Q3Mean, Q4Mean, Q1Mean

*Figure IV - SPSS Model Summary for IV – DV*

According to the above model summary, it indicates that adjusted R Square value is 0.983. Therefore, it shows that all the selected five independent variables have contributed 98.3% towards the dependent variable. Further, 1.3% of other factors, which have not mentioned in the conceptual model have contributed for the user friendliness of mobile applications.

**Conclusion and Recommendations**

Based on the quantitative analysis the major aspects affecting the user-friendliness of mobile applications designed for senior citizens have been identified. They are,

- Typography: The choice of fonts and text size in the application significantly impacts readability and comprehension for senior users.
- Guidelines and Instructions: Clear and concise instructions and guidance within the mobile application is crucial to help senior citizens navigate and utilize its functionalities effectively.
- Navigation: Straightforward and intuitive navigation systems are essential for ease of use and ensuring that seniors can move around the app without confusion.
- Colours: The colour schemes used in the app should be designed by considering on the visibility and legibility, as age-related visual impairments can affect it.
- Gestures: The development of touch and gesture controls needs to be designed with sensitivity to the motor skills and dexterity of senior citizens to ensure they can interact with the mobile application smoothly.

*Recommendations*

- Having larger font sizes and clear font faces enhances the readability of the text available in mobile applications rather than having fancy and unclear font faces.
- In the perspective of colours, high contrast colour combinations such as back text on white background are recommended to enhance the optimal readability of senior citizens.
- When implementing gestures in mobile applications, it is needed to identify the physical barriers of senior citizens.
- Simple, step-by-step guidance within the mobile application including plain language and avoiding technical jargons make it easy for the senior citizens to comprehend.
- It is recommendable to prioritize a user-centric and intuitive navigation structure with large and labelled buttons.

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# ADOPTION OF ARTIFICIAL INTELLIGENCE IN BUSINESSES: IMPACTS ON DECISION-MAKING PROCESSES AND PERFORMANCE IN SRI LANKA

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**Abstract**

Artificial Intelligence (AI) is emerging as an essential component of changing operational strategies and outcomes in the rapidly changing business world. This study investigates the transformative function of Artificial Intelligence (AI) in business, with an emphasis on its impact on decision-making processes and overall corporate performance in the context of Sri Lanka. The research categorizes prominent AI applications and identifies sectors most influenced by these technologies. A survey was used to collect empirical data, highlighting the real-world influence of technological improvements on business performance and decision-making. Preliminary studies suggest that while AI significantly improves performance and decision-making capabilities, its integration creates challenges for businesses. The study provides a comprehensive overview of AI adoption in businesses, highlighting its potential and challenges. It offers valuable insights into the benefits and challenges of AI, enhancing our understanding of its role in modern business.

**Keywords:** Artificial Intelligence, Businesses, Decision-making, Performance

**Introduction**

The digital business era is undergoing a transformation due to artificial intelligence (AI), which is changing operational processes, strategic planning, and decision-making. Computer vision, robotics, natural language processing, and machine learning are some of its uses. Adoption of AI is nevertheless hampered by issues with labor competency, data protection, and ethics. Due to human limits and the complexity of data, businesses find it difficult to make decisions in real time in today's fast-paced market. AI provides a solution by analyzing massive datasets for strategic decision-making, especially using machine learning algorithms. However, there are many obstacles in the way of adopting and integrating AI, such as a lack of resources, knowledge gaps, out-of-date technology, and problems with business culture.

In order to overcome the obstacles to AI adoption and integration, this research attempts to investigate the transformative effects of AI on corporate operations and strategy across industries. The goals of this study focus on a multifaceted investigation into artificial intelligence (AI) in the business domain, recognizing the scope and influence of AI innovations such as robotic process automation, machine learning, and natural language processing. The study also looks at how technological, financial, and human-centric hurdles affect businesses decision-making and performance, and how AI might help solve these problems.

Finally, the study addresses possible risks and ethical considerations while offering practically valid empirically supported recommendations for businesses thinking about implementing AI.

Understanding AI's significance for contemporary businesses is greatly enhanced by this study, which provides information to tech developers, policymakers, and business professionals. As AI develops further, it addresses the societal and policy ramifications and helps to shape the moral and practical foundation for its application in business.

## Methodology

### *Conceptual Framework*

The study aimed to investigate the impact of artificial intelligence (AI) on business performance and decision-making processes. A questionnaire was developed to gather empirical data and understand the practical implications of AI advances. The survey aimed to identify businesses that have implemented AI technology and investigate their perceived effects on performance and decision-making processes. A pilot survey with 10 participants was conducted to evaluate the effectiveness and accuracy of the survey questions. The study's findings underscore the importance of understanding the multidimensional nature of AI's impact on businesses.
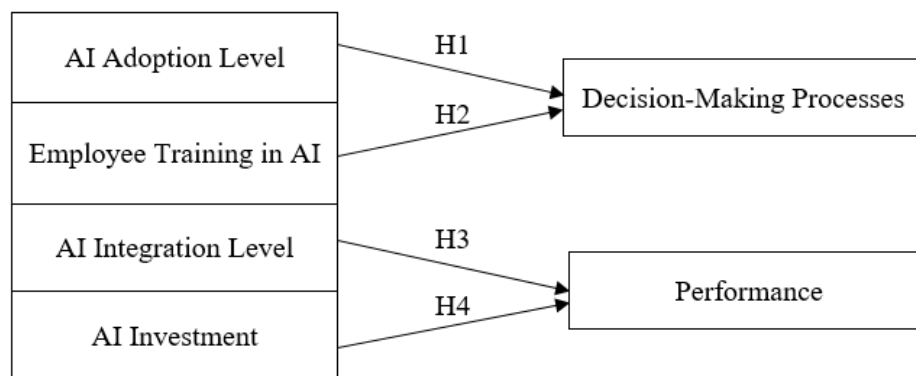


*Figure 1 : Conceptual Framework*

### *Independent and Dependent Variables*

The independent variables include AI Adoption Level, Employee Training in AI, AI Integration Level, and AI Investment each of which offers a different viewpoint on how artificial intelligence is incorporated into business contexts.

Decision-Making process and Business Performance are the dependent variables that are crucial elements that are influenced by independent variables in the context of AI adoption in businesses.

### *Development of Hypothesis*

Hypothesis Set 1: Regarding AI Adoption and Decision-Making

$H_01$: AI adoption level does not significantly impact organizational decision-making

$H_11$: AI adoption level significantly impact organizational decision-making

Hypothesis Set 2: Regarding Employee Training in AI and Decision-Making

$H_0$2: Employee training in AI does not significantly impact organizational decision-making

$H_1$2: Employee training in AI significantly impact organizational decision-making


Hypothesis Set 3: Regarding AI Integration and Organizational Performance

$H_0$3: AI integration level does not significantly impact organizational performance

$H_1$3: AI integration level significantly impact organizational performance


Hypothesis Set 4: Regarding AI Investment and Organizational Performance

$H_0$4: AI investment does not significantly impact organizational performance

$H_1$4: AI investment significantly impact organizational performance


*Sample Design and Size*

The study employed a basic random sample technique to select companies in Sri Lanka that had integrated artificial intelligence technologies. Using statistical methods, the sample size was established while taking the population size, confidence level, and margin of error into account. A final sample size of 96 participants took part in the study.


*Data Collection and Analysis*

The survey used a Likert scale questionnaire to gather data on employees' views and experiences with AI in their enterprises. Employees from a range of industries were given access to the questionnaire, and responses were gathered. The survey was limited to those directly involved in or knowledgeable about their organization's AI adoption and integration processes for accuracy and reliability.

The survey data was imported into Microsoft Excel and then exported to SPSS for a thorough analysis. SPSS's specialized features provided a robust framework for drawing actionable conclusions, enhancing the validity and integrity of the research findings.

**Results and Discussion**
*Descriptive Analysis*

*Industries Using AI*

**Statistics**

D1

| N | Valid | 96 |
|---|-------|-----|
|   | Missing | 0 |

**Industries using AI**

|       |                        | Frequency | Percent | Valid Percent | Cumulative Percent |
|-------|------------------------|-----------|---------|---------------|--------------------|
| Valid | Apparel                | 10        | 10.4    | 10.4          | 10.4               |
|       | Construction           | 7         | 7.3     | 7.3           | 17.7               |
|       | Education              | 16        | 16.7    | 16.7          | 34.4               |
|       | Finance                | 17        | 17.7    | 17.7          | 52.1               |
|       | Health                 | 5         | 5.2     | 5.2           | 57.3               |
|       | Information Technology | 39        | 40.6    | 40.6          | 97.9               |
|       | Other                  | 2         | 2.1     | 2.1           | 100.0              |
|       | Total                  | 96        | 100.0   | 100.0         |                    |

*Figure 2: Industries using AI in Sri Lanka*
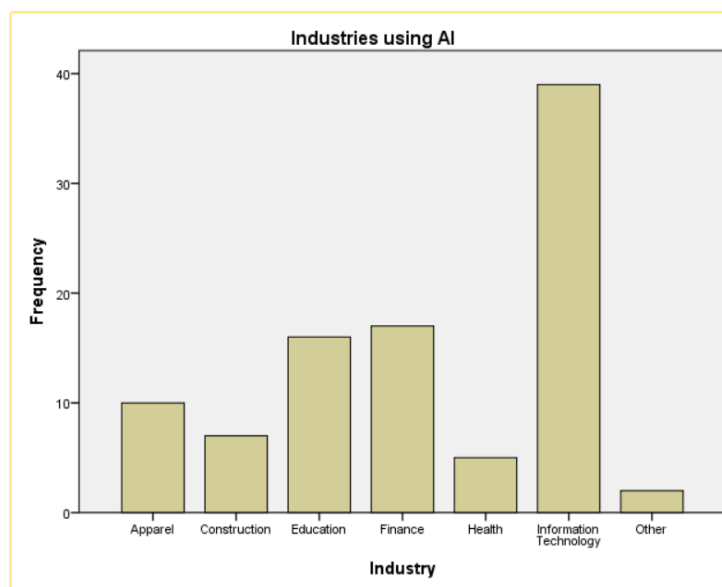


*Figure 3: Industries using AI in Sri Lanka - Bar chart*

According to the data, the IT sector has the highest adoption of AI, with 40.6% of businesses deploying AI, indicating a clear preference for the technology. With 17.7% and 16.7% adoption rates, respectively, the financial and educational sectors also exhibit considerable AI adoption. For risk analysis, fraud deetection, customer service, personalized learning environments, and administrative automation, these industries are expected to adopt AI (Dwivedi et al., 2021).

The least amount of AI adoption is in the health and other categories, with 5.2% and 2.1%, respectively, indicating potential growth or adoption barriers in these industries. Overall, the evidence shows a significant adoption trend for AI in the IT industry.

*AI Technologies Adopted by the Industries*

## Descriptives

[DataSet1]

**Descriptive Statistics**

|                      | N  | Mean | Std. Deviation | Variance |
|----------------------|----|------|----------------|----------|
| Machine_Learning     | 96 | .49  | .503           | .253     |
| Speech_Recognition   | 96 | .22  | .416           | .173     |
| Virtual_Agents       | 96 | .29  | .457           | .209     |
| Robotics             | 96 | .11  | .320           | .103     |
| Computer_Vision      | 96 | .43  | .497           | .247     |
| Other                | 96 | .16  | .365           | .133     |
| Valid N (listwise)   | 96 |      |                |          |

*Figure 4: AI Technologies adopted by the industries*

The statistics show that 49% of businesses use machine learning, with a high standard deviation indicating wide adoption. Speech recognition is used by 22% of businesses, while virtual agents are used by 29%. Robotics is used by 11%, with a low standard deviation. Computer vision is used by 43% of businesses, and other technologies are fairly variable.

## Hypothesis Testing

*How Decision-Making Affected by AI Adoption and Employee Training in AI?*

Here, the dependent variable (Mean_DV1) was created by summing the means of the overall quality of decision-making in an organization since implementing AI technologies (V1) and the extent to which the speed of decision-making has been influenced by AI technologies (V2). The mean of the current level of AI adoption in the organization (V5) and the extent of AI technology deployment across various departments (V6) were implemented to create the independent variable (Mean_IV1). The mean of the accessibility for AI training programs to employees in the organization (V7) and the extent of the AI training provided to employees is omprehensive and covers all necessary aspects (V8) that were implemented to create the independent variable (Mean_IV2).

**Descriptive Statistics**

|  | Mean | Std. Deviation | N |
|---|---|---|---|
| Mean_DV1 | 3.2448 | .87658 | 96 |
| Mean_IV1 | 3.1042 | .94567 | 96 |
| Mean_IV2 | 3.1250 | .95697 | 96 |

*Figure 5: Descriptive statistics for the variables*
Mean_DV1, Mean_IV1 and Mean_IV2
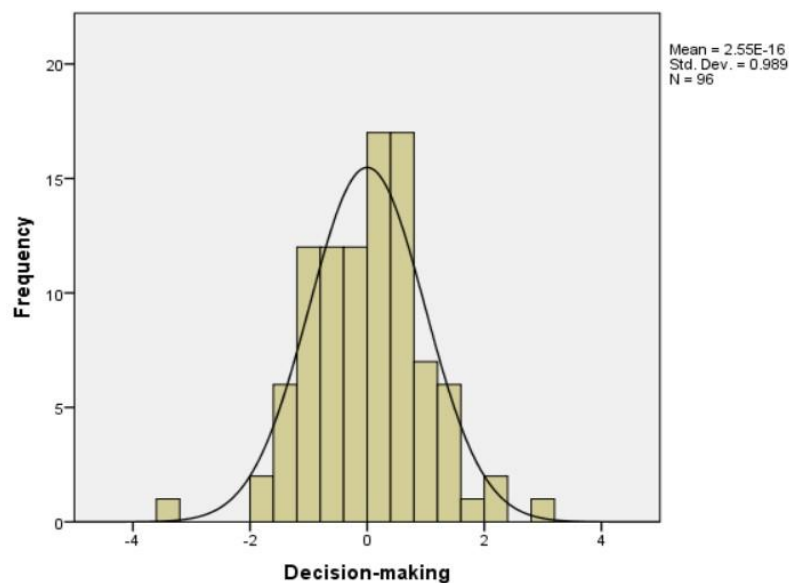


*Figure 6: Histogram for Decision-making*

**Coefficients[a]**

| Model | | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. | 95.0% Confidence Interval for B | |
|---|---|---|---|---|---|---|---|---|
| | | B | Std. Error | Beta | | | Lower Bound | Upper Bound |
| 1 | (Constant) | .962 | .222 | | 4.333 | .000 | .521 | 1.403 |
| | Mean_IV1 | .545 | .090 | .588 | 6.051 | .000 | .366 | .724 |
| | Mean_IV2 | .189 | .089 | .206 | 2.122 | .036 | .012 | .366 |

a. Dependent Variable: Mean_DV1

*Figure 7: Coefficient table for the variables taken for decision-making process*

**Model Summary[b]**

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate | Change Statistics | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | R Square Change | F Change | df1 | df2 | Sig. F Change |
| 1 | .748[a] | .560 | .551 | .58765 | .560 | 59.191 | 2 | 93 | .000 |

a. Predictors: (Constant), Mean_IV2, Mean_IV1

b. Dependent Variable: Mean_DV1

*Figure 8: Model summary table for the variables taken for decision-making process*

**ANOVA$^a$**

| Model | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| 1 | Regression | 40.881 | 2 | 20.441 | 59.191 | .000$^b$ |
| | Residual | 32.116 | 93 | .345 | | |
| | Total | 72.997 | 95 | | | |

a. Dependent Variable: Mean_DV1

b. Predictors: (Constant), Mean_IV2, Mean_IV1

*Figure 9: ANOVA Table for the variables taken for the decision-making process*

Given the strong positive correlation between Mean_IV1 (AI Adoption Level) and Mean_DV1 (Decision Making) (r = 0.734, p < 0.001), it is clear that as the level of AI adoption rises, so do the efficiency and effectiveness of decision-making. As a result, null hypothesis (H$_0$1) is rejected and the alternative hypothesis (H$_1$1) is accepted, indicating that the level of AI adoption has a considerable influence on organizational decision-making. Similar to this, a significant positive correlation between Mean_IV2 (Employee Training in AI) and Mean_DV1 (Decision Making) (r = 0.622, p < 0.001) suggests that as the accessibility and effectiveness of AI training for employees increases, so does the quality and speed of decision-making. As a result, null hypothesis (H$_0$2) is rejected and the alternative hypothesis (H$_1$2) is accepted, indicating that employee AI training has a considerable influence on business decision-making.
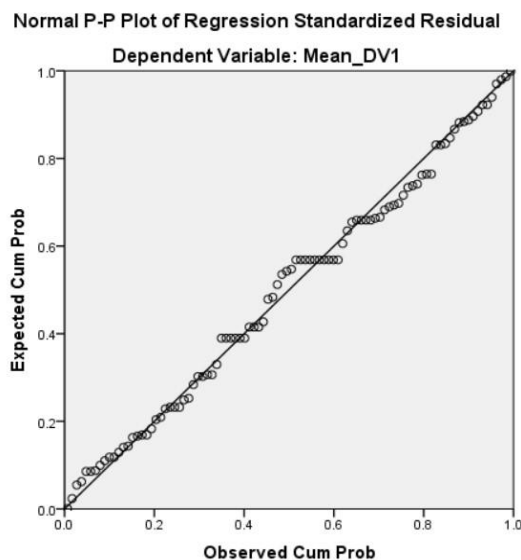


*Figure 10: Normal P-P Plot of Regression Standardized Residual for Decision - making*
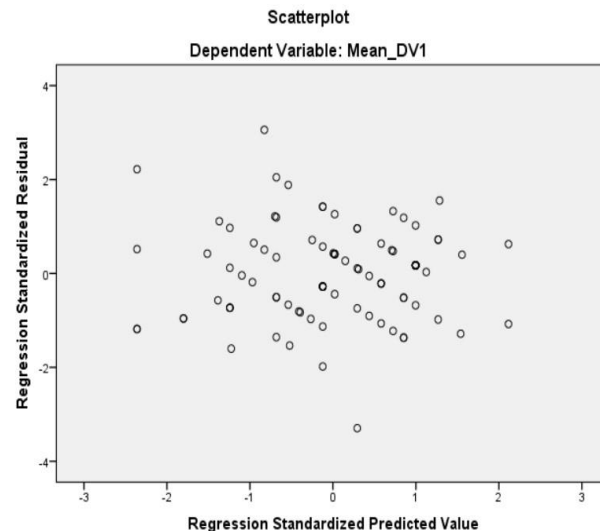


*Figure 11: Scatterplot for Decision-making*

**Descriptive Statistics**

|          | Mean   | Std. Deviation | N  |
|----------|--------|----------------|----|
| Mean_DV2 | 3.2552 | .97871         | 96 |
| Mean_IV3 | 3.2448 | .91478         | 96 |
| Mean_IV4 | 3.2344 | .95409         | 96 |

*Figure 12:  Descriptive statistics for the variables*
Mean_DV2, Mean_IV3 and Mean_IV4

### *How Business Performance affected by AI Integration Level and AI Investment?*

Here, the mean of two variables, the effect of AI technologies on the organization's overall performance (V3) and the degree to which customer satisfaction has been impacted by the adoption of AI technologies in the business (V4), was used to develop the dependent variable (Mean_DV2). For Hypothesis Set 3, the independent variable (Mean_IV3) was derived by averaging two separate variables: the seamlessness of AI technologies integration into existing processes and systems in the organization (V9) and the extent to which AI technologies support data-driven decision-making in the organization (V10). The independent variable (Mean_IV4) for Hypothesis Set 4 was developed by computing the mean of two variables: the adequacy of the organization's current investment in AI technologies (V11) and the extent to which investments in AI have provided a competitive edge to the organization (V12).
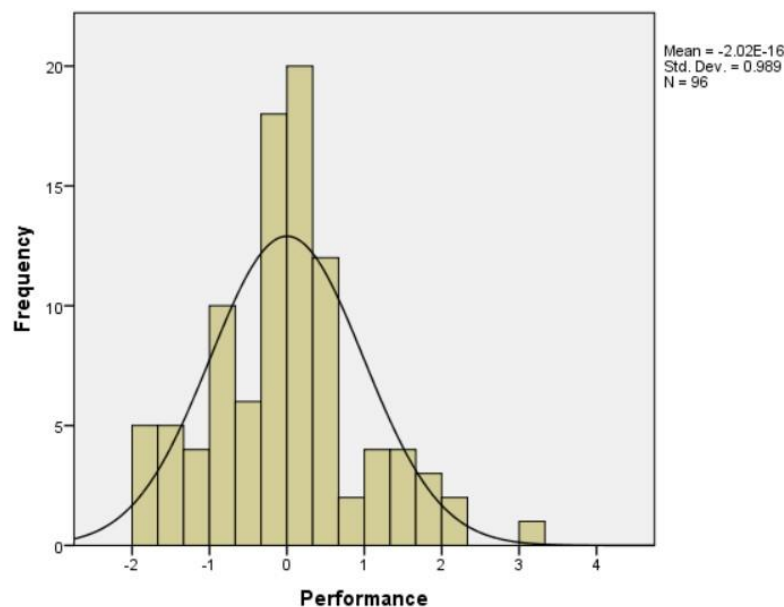


*Figure13: Histogram for Performance*

**Coefficients**[a]

| Model | | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. | 95.0% Confidence Interval for B | |
|---|---|---|---|---|---|---|---|---|
| | | B | Std. Error | Beta | | | Lower Bound | Upper Bound |
| 1 | (Constant) | .810 | .279 | | 2.901 | .005 | .255 | 1.364 |
| | Mean_IV3 | .672 | .129 | .628 | 5.216 | .000 | .416 | .928 |
| | Mean_IV4 | .082 | .124 | .080 | .661 | .510 | -.164 | .327 |

a. Dependent Variable: Mean_DV2

*Figure 14: Coefficients table for the variables taken for business performance*

**ANOVA**[a]

| Model | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| 1 | Regression | 43.644 | 2 | 21.822 | 42.857 | .000[b] |
| | Residual | 47.353 | 93 | .509 | | |
| | Total | 90.997 | 95 | | | |

a. Dependent Variable: Mean_DV2

b. Predictors: (Constant), Mean_IV4, Mean_IV3

*Figure 15 : ANOVA table for the variables taken for business performance*

**Coefficients**[a]

| Model | | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. | 95.0% Confidence Interval for B | |
|---|---|---|---|---|---|---|---|---|
| | | B | Std. Error | Beta | | | Lower Bound | Upper Bound |
| 1 | (Constant) | .810 | .279 | | 2.901 | .005 | .255 | 1.364 |
| | Mean_IV3 | .672 | .129 | .628 | 5.216 | .000 | .416 | .928 |
| | Mean_IV4 | .082 | .124 | .080 | .661 | .510 | -.164 | .327 |

a. Dependent Variable: Mean_DV2

*Figure 16: Coefficients table for the variables taken for business performance*

Given the strong positive correlation between Mean_IV3 (AI Integration Level) and Mean_DV2 (Organizational Performance) ($r = 0.691$, $p < 0.001$), it is clear that as the level of AI integration rises, so does organizational performance. As a result, null hypothesis (H03) is rejected and the alternative hypothesis (H13) is accepted, indicating that the level of AI integration has a considerable influence on organizational performance. Similarly, the relationship between Mean_IV4 (AI Investment) and Mean_DV2 (Organizational Performance) is significantly positive ($r = 0.572$, $p < 0.001$), suggesting that organizational performance rises with AI investment. As a result, null hypothesis (H04) is rejected and the alternative hypothesis (H14) is accepted, indicating that the AI Investment has a considerable influence on organizational performance.
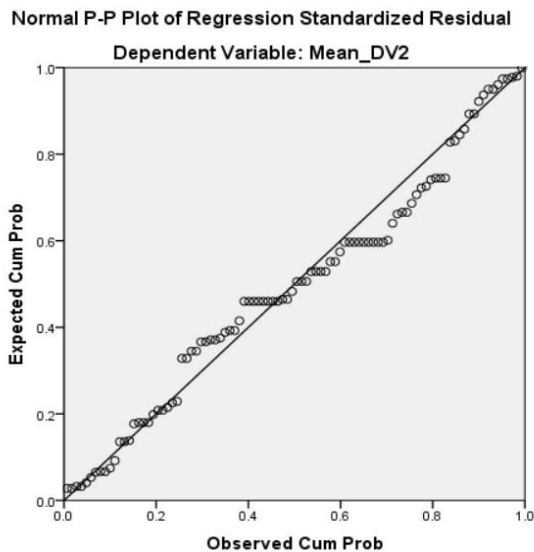
*Figure17: Normal P-P Plot of Regression Standardized Residual Performance*
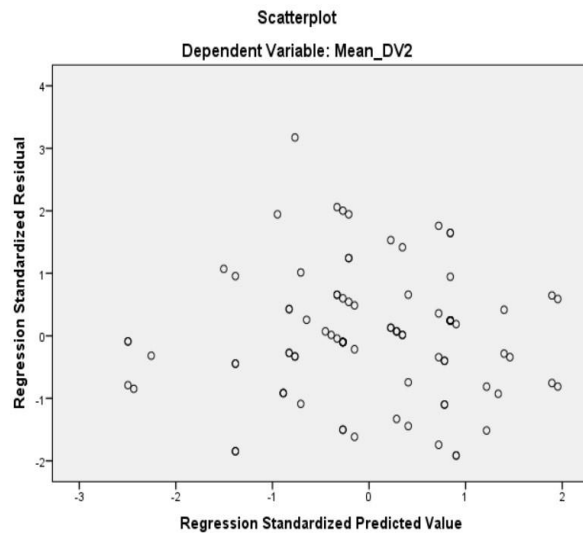


*Figure 18: Scatterplot for Performance*

**Conclusions and Recommendations**

The setting of business operations and decision-making processes has clearly changed with the arrival of artificial intelligence (AI). This research has provided the multifaceted effects of AI adoption on business performance and decision-making processes through a comprehensive study of different sectors and AI applications. It shows that although AI greatly improves efficiency and decision-making, there are certain major obstacles to its integration in organizations. The necessity of investing in AI for competitive advantage, the significance of strategic AI integration in business processes, and employee training are some of the key findings. According to the findings, different industries have different rates of AI adoption. The IT industry leads with 40.6%, followed by banking and education. Among the most popular AI technologies are computer vision, machine learning, and speech recognition; each has varying industry uses and acceptance rates.

The study highlights the necessity for businesses to incorporate AI with strategic and ethical considerations, stressing the significance of coordinating AI adoption with ethical norms and commercial goals. It is determined that training programmes that combine technical expertise with strategic application are essential for employee growth. It is advised that businesses integrate AI gradually and progressively through pilot projects in order to successfully manage the intricacies of AI. This approach also enables the development of a fundamental understanding of AI technology, its real-world applications, and business implications. Utilizing metrics and KPIs to measure performance and impact, regular monitoring and assessment of AI systems is crucial. Finally, the study contributes to the larger conversation on AI's role in business by bridging the theoretical and practical aspects of AI in business and providing insights for strategy formulation, policy-making, and ethical issues.

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# VISUAL IMPACT ON EFFICIENCY: A COMPREHENSIVE ANALYSIS ON HOW HCI IMPACT ON EMPLOYEE PRODUCTIVITY AND PERFORMANCE THROUGH GRAPHICAL USER INTERFACE IN ORGANIZATIONS

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## Abstract

Purpose of the study was to understand the positive impact of the Graphical User Interface (GUI) of software applications to the productivity of employees who are working under different industries with different forms of experiences and knowledge which is a HCI factor. Research was carried out to test whether if there is a significant positive impact of the appearance and the complexity of the GUI for the employee productivity. There are several research studies which were conducted to check what impacts the employee productivity and issues in GUI. But there were not any specific studies carried out to research on the impact of GUI in terns of HCI for the users. To make the study more meaningful, the research was conducted considering employees who deals with computers every day and still having issues in meeting deadlines. The study was carried out to a specific population by creating a sample design in concern of the analysis conducted which is a quantitative analysis. The data was gathered through an online questionnaire testing the defined variables. According to the analysis, it was found that there is a positive impact of the complexity of the GUI towards the employee productivity but there's less slight impact of appearance of GUI to the productivity of the Employee compared to the complexity.

**Keywords**: GUI – Graphical User Interface, HCI- Human Computer Interactions

## Introduction

HCI is a trending topic in information technology world and in Information Systems area at present. The reason behind this is due to the large amount of computer usage and the dependency of the people on computer-based devices with related to personal and organizational work. People and organizations transforming from paper based to digitalized environments in every aspect from education, health, banking and much more.

Among all the factors, this paper will be researching on the user interface component which is highly contributing fact in HCI. According to (Myers, 1993) the users of the software applications expect to have proper systems which can be used without any frustration. They seek more usability of the application which means the human computer interaction should be high. And the usability will be completely depending on the GUI of the applications.

In terms of the HCI, the usability and effectiveness considered very important as the usability explains how far the specific system can be used and have HCI while the effectiveness in HCI explains how for the system is effective in completing day today tasks. Considering both effectiveness and the usability, the parameter that can be measured from a user is the

productivity. In terms of the HCI if there is a proper usability and the effectiveness then it can be considered as there is a proper productivity of the user by using the same application.

Employee productivity is vital to an organization as it is the main aspect of achieving goals of and objectives of the organization. Productivity means the employee should be able to complete the given task within a short time period but by providing the best possible output. Currently the organizations are working on increasing the productivity of the user by making sure that the employee should be able to complete the given tasks within a given time period by converting the entire process into the computerized manner. According to (Rahmanian & Davis, 2016), the productivity can be measures as follow, the ability in measuring the improvement of the data and information availability through the system and being able to measure the improvement of being able to use it and complete the respective task within the organization.

Considering the software applications and the employee productivity both scenarios can be used to emphasize how the GUI of software applications has an impact to the employee productivity. Because if the data and information can be made available through a system shows how the employee can make the data available to the other users, customers and much more. And, the way the employee handling the same data with the system to complete the tasks also can be taken to measure the productivity of the employee which is again the usability of the system.

Considering the employee productivity and how it can get affected through the User Interface (UI) due to its complexity. According to (Rahmanian & Davis, 2016) the complexity of the UI design has an impact the efficiency and the productivity of the employees. Due to the complexity of the GUI it takes a lengthy curve to learn and understand initially how the application or the software works for the user even before they understands the exact work they have to complete and cover up through the system they use. This will cause to lessen the maximum productivity an user can provide in completing a task especially at their organization. According to a study by (Jiang & Fang, 2020), in three levels to observe how the users reacts to the same game with different UI and Blocks designed. The study has concluded that if the practice exist the performance is high but compared to the type of interface or if the complexity of the user interface is less the performance is even higher (Jiang & Fang, 2020). Accordingly, the research observations have proved the argument there is an impact of the user interface to the user performance and again the argument on user experience also being proved to a certain extent.

Considering the study carried out regarding Voice User Interface (VUI) by (Myers, et al., 2019) states that users with prior experience in programming did not have an impact with the performance in using UI and the users who had technical confidence exhibited trial and error approach while users who desired to have proper visual guidance had more performance metrics.

The purpose of this study was to research on what kind of factors affect to the productivity of the employees in organizations as there is a research gap to the same area of the study which has not clearly defined what factors are causing positive impact towards the employee performance.

**Methodology**

The study was carried out as a quantitative analysis and the population was selected as 77, 704 and the error margin for the population selected is considered as 10% and the confidence level was considered as 90%.

Considering the demographics of the study population, since the research study is more narrowed down towards studying the productivity of the employees, the working population from age between 20 – 60 was considered and the study specifically carried out without any gender barrier. Most of the respondents were between 25 – 40 which supported to understand the how UI can impact with a generation who has a proper idea of how to handle and use automated systems in the new tech era (Dong, et al., 2016).

Population is a vast group of people which can be considered coming under a specific conclusion which will be drawn to a specific topic. Sampling means the selecting the group of participants to collect data on the specific study carried out. The selected sample is representing the rest of the population equally. Since the research carried out using quantitative method to study the relationship and the impact between the UI and the productivity, the sampling method to conduct the research is a probability sampling method. In the probability method there will be an equal chance is offered to be included in the study (McCombes, 2019).

There are different methods under the probability sampling. Out of them the convenience sampling method was selected for this research since, it is more convenient as the method consider that every population has the same equal probability. And this method doesn't require any specific knowledge to do the sampling since it is not complex compared to other sampling sub types in probability sampling method (Taherdoost, 2016). Hence the simple random sampling method under the probability method was selected.

Considering the study population, 58 participants were take part in the study and out of the 58 participants, only 53 responses were able to consider for the study which gives 91.38% completed response rate.

Data was gathered using questionnaires distributed through online platform and analysed using the regression method as the research is carried out to study on the impact of the chosen variables.

***Conceptual Framework and Hypotheses***
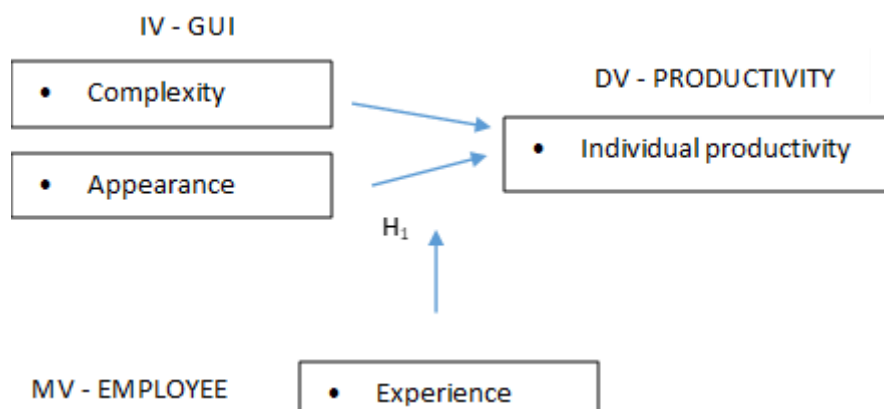


*Figure 1 – Conceptual Framework*

**Results**

*Independent Variables*

*Complexity*

The friendliness of an application initially will be measured through the user interface, since the way the interface support in understanding and helping to process the instructions to be performed and carried out. If there is proper instructions provided for easy navigation and able to clearly identify and understand how to process the next steps to complete the task will help to have proper productivity among the users.

*Appearance*

Appearance also supporting to have less complexity and more user-friendly environment within the application. If the proper colours, icons, messages with proper guidance and use of clear colours will help in understanding and getting used to the environment of the UI easily to the users.

*Moderating Variable*

*Experience*

If there is less complexity and if the appearance of the system is attractive and user friendly the understand ability and experience of using the application will be high. More the understanding of the system more the experience users likely to get. Proper experience can has an impact on the productivity, since proper experiences can increase the productivity, because users can easily gain experience with the relevant system.

*Dependent Variable*

*User Productivity*

In terms of the GUI, the independent variables such as the appearance and the complexity can have an impact to the productivity of the user. And the experience can have a significant moderation made to the user productivity increasing the ability to understand the GUI appearance and lessen the complexity the same.

*Development of Hypotheses*

It is expected to study and research on what is the relationship between above mentioned independent variables, the complexity and appearance can have an impact to the employee productivity considering the individual productivity. And the appearance as an independent variable how it moderates the other independent variables as well. Following are the developed hypotheses to the developed conceptual framework.

$H_1$: The individual productivity of the employee has a positive impact from the appearance of the UI

$H_2$: the experience moderates the relationship between the productivity and appearance of UI

$H_3$: The individual productivity of the employee has a positive impact from the complexity of UI

$H_4$: the experience moderates the relationship between the productivity and complexity of UI

*Analysing the GUI appearance and GUI complexity with user productivity*

Table 1- Multi – Regression Model Summary

| Model Summary | | | | |
|---|---|---|---|---|
| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate |
| 1 | .881ᵃ | .776 | .767 | .42673 |
| a. Predictors: (Constant), GUICom Av, GUIApp av | | | | |

Considering the hypotheses developed using the conceptual model are testing the impact of each variable to the dependent variable the most suitable analysis to be conducted is regression analysis. According to Table-01, the R Square is 0.776 which means 77.67% there are variations in the dependent variable- GUI Complexity, GUI Appearance. Considering the existing variables, a multi regression analysis was conducted as follow.

Table 2- ANOVA - Multi Regression

| ANOVAᵃ | | | | | | |
|---|---|---|---|---|---|---|
| Model | | Sum of Squares | df | Mean Square | F | Sig. |
| 1 | Regression | 30.938 | 2 | 15.469 | 84.947 | .000ᵇ |
| | Residual | 8.923 | 49 | .182 | | |
| | Total | 39.861 | 51 | | | |
| a. Dependent Variable: Prod Av | | | | | | |
| b. Predictors: (Constant), GUICom Av, GUIApp av | | | | | | |

According to the ANOVA p-value is less than 0.05. Therefore, the group of independent variable shows a significant relationship with the dependent variable. Therefore, regression model significantly predicts the GUI Complexity.

Table 3- Coefficients Multi Regression Analysis

| Coefficientsᵃ | | | | | | |
|---|---|---|---|---|---|---|
| Model | | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. |
| | | B | Std. Error | Beta | | |
| 1 | (Constant) | .382 | .214 | | 1.781 | .081 |
| | GUIApp av | .212 | .168 | .223 | 1.259 | .214 |
| | GUICom Av | .609 | .160 | .671 | 3.797 | .000 |
| a. Dependent Variable: Prod Av | | | | | | |

According to the regression analysis GUI appearance p – value is 0.214 which means, p-value > 0.05. It indicates that there is no significant relationship between GUI appearances has a positive impact on employee productivity.

> H1: The individual productivity of the employee has a positive impact from the appearance of the UI

The hypotheses will be rejected.

But considering the significance value of the GUI Complexity, p – value is 0.00 which means p – value < 0.05. It indicates that there is a significant relationship between the GUI complexity and the employee productivity. Hence,

> H3: The individual productivity of the employee has a positive impact from the complexity of UI

The hypotheses will be accepted.

Hence it clears out that the Human Computer Interaction has an impact in using GUI with its complexity.

***Analysing the moderate relationship – GUI appearance with user experience of GUI***

Considering the hypotheses, a regression analysis should be conducted as follow to identify whether if the user experience with the GUI moderates the relationship between dependent and independent variable.

Table 4- Moderate variable analysis

| **Model Summary** | | | | |
|---|---|---|---|---|
| e | R | R Square | justed R Square | td. Error of the Estimate |
| | .843ᵃ | .711 | .699 | .48528 |
| a. Predictors: (Constant), INT, GUIApp av | | | | |

According to the Table – 4, R square value is 0.711 which means independent variable can be explained 71% variation in the dependent variable.

Table 5- ANOVA analysis

| **ANOVAᵃ** | | | | | | |
|---|---|---|---|---|---|---|
| Model | | Sum of Squares | Df | Mean Square | F | Sig. |
| 1 | Regression | 28.321 | 2 | 14.161 | 60.130 | .000ᵇ |
| | Residual | 11.539 | 49 | .235 | | |
| | Total | 39.861 | 51 | | | |
| a. Dependent Variable: Prod Av | | | | | | |
| b. Predictors: (Constant), INT, GUIApp av | | | | | | |

According to the one-way ANOVA, it shows that there is a 0.00 significance. there is a strong casual effect between the dependent variable Employee productivity since p – value (0.00) < 0.05.

Table 6- Coefficients

| Coefficients[a] | | | | | | |
|---|---|---|---|---|---|---|
| Model | | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. |
| | | B | Std. Error | Beta | | |
| 1 | (Constant) | .347 | .244 | | 1.425 | .160 |
| | GUIApp av | .800 | .075 | .839 | 10.603 | .000 |
| | INT | .015 | .078 | .015 | .189 | .851 |
| a. Dependent Variable: Prod Av | | | | | | |

According to the Table – 06, INT (interaction term) has a p – value of 0.851 which is p – value > 0.05. This indicates that the moderator variable Experience doesn't influences the relationship between the independent and the dependent variable.

Hence the hypotheses 4 is rejected.

> H4: the experience moderates the relationship between the productivity and appearance of UI

***Analysing the moderate relationship – GUI complexity with user experience***

Considering the hypotheses, a regression analysis should be conducted as follow to identify whether if the user experience with the GUI moderates the relationship between dependent and independent variable.

Table 7- GUI Complexity with User Experience Model Summary

| Model Summary | | | | |
|---|---|---|---|---|
| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate |
| 1 | .881[a] | .776 | .767 | .42644 |
| a. Predictors: (Constant), GUICom Av, INT | | | | |

According to the Table – 07, R square value is 0.776 which means independent variable can be explained 77% variation in the dependent variable.

Table 8- One Way ANOVA test

| ANOVAᵃ | | | | | | |
|---|---|---|---|---|---|---|
| Model | | Sum of Squares | Df | Mean Square | F | Sig. |
| 1 | Regression | 30.950 | 2 | 15.475 | 85.096 | .000ᵇ |
| | Residual | 8.911 | 49 | .182 | | |
| | Total | 39.861 | 51 | | | |
| a. Dependent Variable: Prod Av | | | | | | |
| b. Predictors: (Constant), GUICom Av, INT | | | | | | |

According to the one-way ANOVA, it shows that there is a 0.00 significance. There is a strong casual effect between the dependent variable Employee productivity since p – value (0.00) < 0.05.

Table 9- Coefficient

| Coefficientsᵃ | | | | | | |
|---|---|---|---|---|---|---|
| Model | | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. |
| | | B | Std. Error | Beta | | |
| 1 | (Constant) | .469 | .196 | | 2.386 | .021 |
| | INT | .095 | .074 | .088 | 1.286 | .204 |
| | GUICom Av | .782 | .062 | .862 | 12.587 | .000 |
| a. Dependent Variable: Prod Av | | | | | | |

According to the Table – 14, INT (interaction term) has a p – value of 0.204 which is p – value > 0.05. This indicates that the moderator variable Experience doesn't has an effect on the relationship between the independent and the dependent variable.
Hence the hypotheses 2 is rejected.

$H_2$: the experience moderates the relationship between the productivity and complexity of UI

**Discussion**

Considering the above analysis conducted, the GUI Appearance is not causing any positive impact towards the productivity of the employees. And the experience of the GUI doesn't moderate the relationship between the GUI appearance and employee productivity also experience of the GUI doesn't moderate the relationship between the GUI complexity and employee productivity.

But considering the GUI complexity, it has a significant positive impact towards the employee productivity. Accordingly, there is a significant relationship between the user productivity to increase or decrease depending on the level of complexity of the system user interface they are using at the organization. According to the study conducted, there were users using different applications compared to one another. But commonly they have mentioned that the complexity of the application is comparatively high. According to (Rahmanian & Davis, 2016) the complexity of the UI design has an impact the efficiency and the productivity of the employees. Due to the complexity of the GUI, it takes a lengthy curve to learn and understand initially how the application or the software works for the user even before they understand the exact work they must complete and cover up through the system they use. This will cause to lessen the maximum productivity and user can provide in completing a task especially at their organization.

Such complexity can be reduced by further identifying what exactly has made it hard for the users to consider it to be complex and cause an impact to their productivity. Users tend to seek support in new environments to complete tasks. Considering computer systems non-technical users who uses the systems for day today needs proper guidance. Hence such GUI can be designed to provide proper support to the user to easily understand how to proceed with each task and making the GUI designed with more user friendly to the user to manage. The user feedback can be collected by the colleagues by introducing a prototype or a sample and ask them to provide their opinion on how it should be further enhanced.

Further the users can be given proper training through training sessions, workshops to have a better understanding of the system they supposed to work with and what to be done if they come across any issue while using the system. The training should not only provide to understand how the system works. Also, the users have to give training on how to work on cognitive skills to increase the learning ability, increase the ability of understanding, practicing and further experiencing new systems and ways to improve the working methods in the modern world. Because if the cognitive skills are improved of a person it helps in improving the other aspects of the same person to learn, understand and put the experiences in practice.

And the GUI should be designed to provide the freedom to be utilized to work by customizing it according to the user interest. According to the human nature, people have higher productivity if they can get adopted the environment very easily. Considering the computer systems, it is completely new environment, mostly to the non-technical employees working in organization. If they have the adaptability to the systems by rearranging and customizing according to their own preferences the productivity can be increased to have a higher percentage. The same has been mentioned by Schneiderman (B., et al., 2016).

**Conclusion**

According to the analysis conducted, the complexity of the Graphical User Interface has a positive impact on employee productivity. This indicates that there is an impact of HCI to the employee productivity which can be understood that the complexity of the GUI and less understandability has a significant positive relationship with the employee productivity.

The study was conducted with the employees who have a good amount of knowledge regarding the changes which have taken place in technology. And this population has at least a slight idea

how to manage the work and convert them to automated methods and systems. Even in this type of scenario, if the GUI is complex and hard to understand, there might be a barrier between the UI design and the user.

This barrier can be removed by educating both UI designer and the UI user to cope with the current trends and changes. And frequent studies can be carried out to check whether the changes of the UI designs have any sort of impact on the users. Getting frequent feedback whenever the UI is changed is vital to understand whether the user is learning and understanding how to work with UI designs because there is a significant amount of impact towards the UI complexity and productivity.

Providing a brief idea by sharing the new UI designs to the work applications before implementing is another method the designers can do to reduce the complexity of the UI and improve the productivity of the users.

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# TECHNOLOGICAL INTERVENTION FOR INFANT (BIRTH) WEIGHT ANALYSIS AT PERADENIYA HOSPITAL USING GIS MAPPING.

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## Abstract

Study that focuses on the weight and general health of infants as well as the health of mom's offspring. The research makes use of statistical analysis and Geographic Information Systems (GIS) technologies to gain a deeper understanding of the multifaceted factors affecting birth weight. The importance of placing this data in an applicable context is emphasized to enable well-informed decision-making on public health. GIS technology helps policymakers and healthcare professionals create plans that are specific to a region by visualizing complex interactions. Geographic information systems (GIS) are being used in public health research to address urgent public health issues from new angles and perhaps with data-driven, more effective solutions. This is revolutionizing the profession.

**Keywords:** GIS (Geographic Information System) Technology, Infant Weight, Low Birth Weight (LBW), Marital Status, Maternal Age, Maternal Weight, Mode Of Birth

## Introduction

This study begins a thorough investigation of the relationship between maternal variables such maternal age, mode of birth, marital status, maternal weight, and access to healthcare facilities and infant birth weight (Nina H. van Mil, 2015). The study, which is taking place in the Sri Lankan Peradeniya area, aims to clarify the intricate interactions between these factors and their possible effects on babies, offering a priceless chance to improve mother and infant health outcomes. All the locations were from Kandy Divisional sectors in Sri Lanka. There are 20 divisional sectors in the Kandy District. Since this research is focused on Peradeniya hospital 8 divisional sectors were chosen. This research is focused on Yatinuwara, Doluwa, Deltota, Udunuwara, Kandy Four Gravets, Akurana, Harispattuwa and Patadumbara. All the birth data was taken from Peradeniya hospital. For this GIS technology will be used to get a better understanding of location vise. The result will help the decisions makers and policy makers, doctors, and all health care professionals. It will help them to make more impactful decisions. It is crucial for pinpointing regions where knowledge deficiencies exist, hindering the ability to ensure optimal infant health. By identifying this, the study provides valuable insights that can serve as a foundation for targeted interventions and improvements in healthcare strategies, ultimately contributing to enhanced infant health outcomes in the identified areas.

**Methodology**

This research is quantitative research. Secondary data collection done from Peradeniya hospital. The selection of records spans from January 2023 to March 2023 because the records for the remaining months of 2023 have not yet been finalized by the hospital. Out of 1100 records 710 records were chosen due to since these records are on paper some of the entries were faded and some of the records were not part of the selected areas for this research. Those patient records were not selected.

*Overall Workflow Diagram*
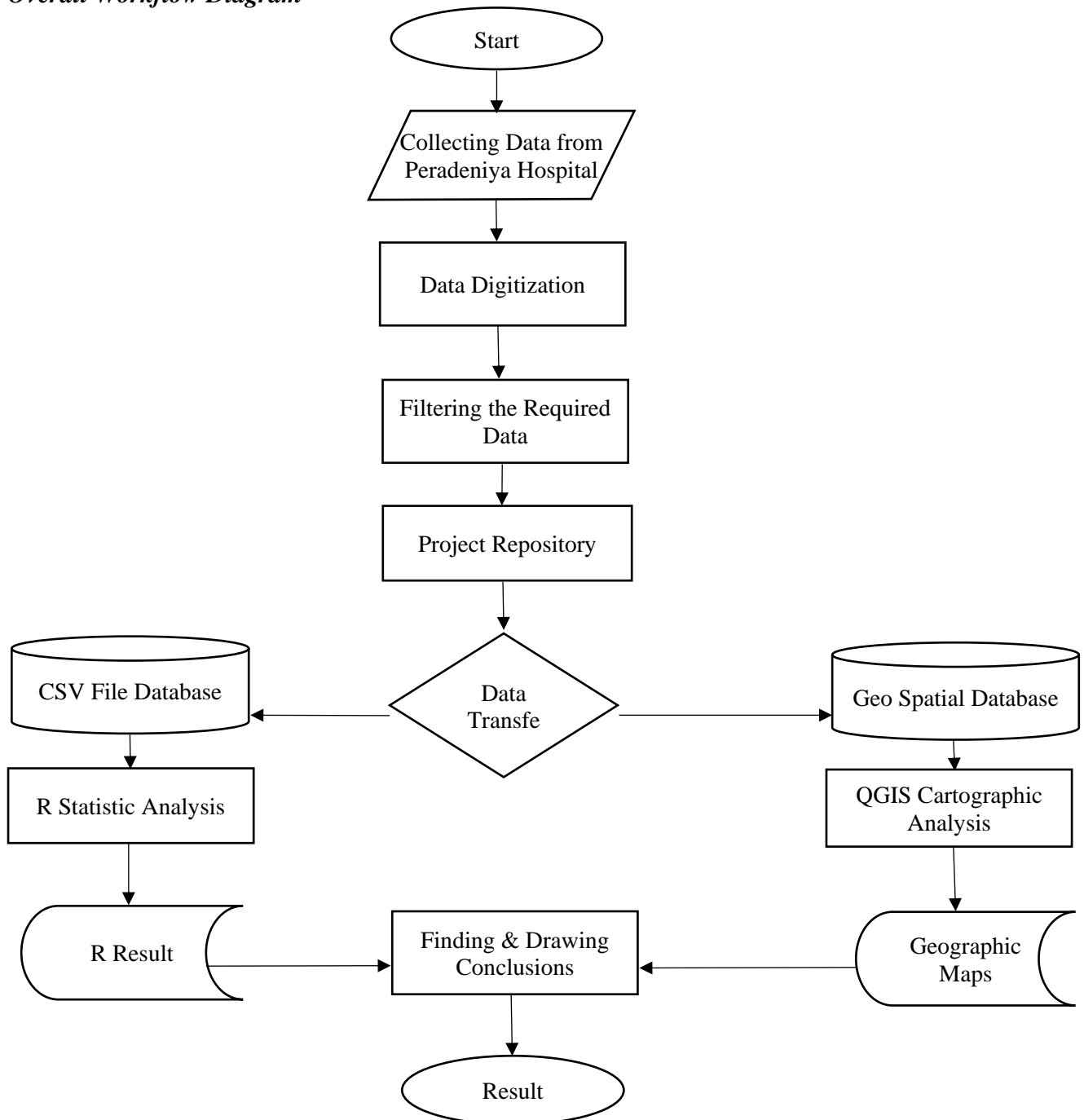


*Figure 1: work flow diagram*

*Conceptual Framework*

Independent variable                                    Dependent variable
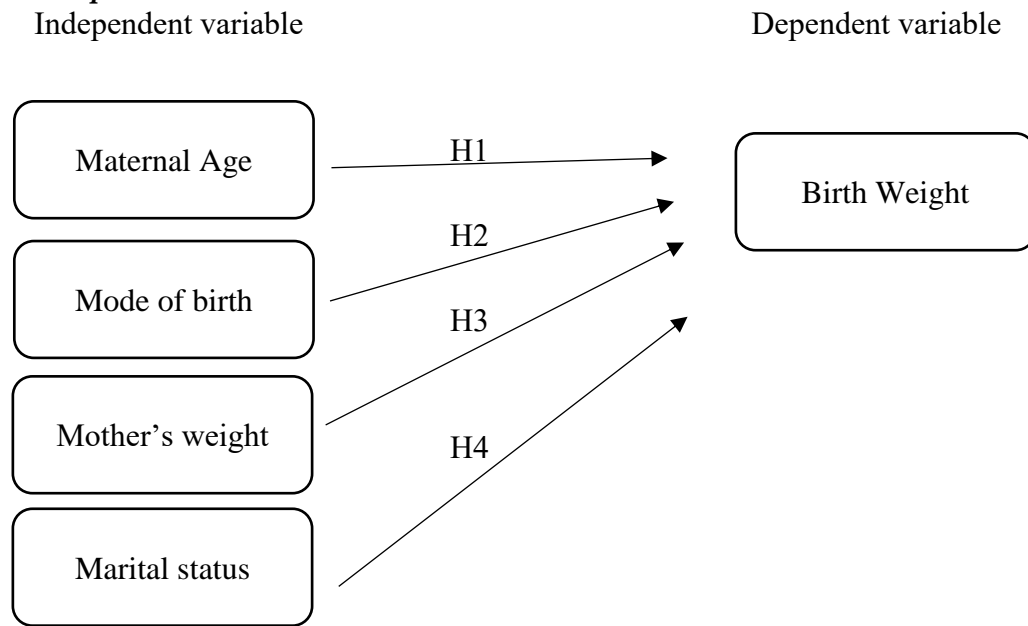


*Figure 2:Conceptual Framework*

*Hypothesis*

Hypothesis 1

H0: Maternal age has no impact on Birth weight

H1: Maternal age has impact on Birth weight

Hypothesis 2

H0: Mode of birth has no impact on Birth weight

H1: Mode of birth has impact on Birth weight

Hypothesis 3

H0: Mother's weight has no impact on Birth weight

H1: Mother's weight has impact on Birth weight

Hypothesis 4

H0: Marital status has no impact on Birth weight

H1: Marital status has impact on Birth weight

### Data Analysis

Regression analysis and ANOVA testing were done.
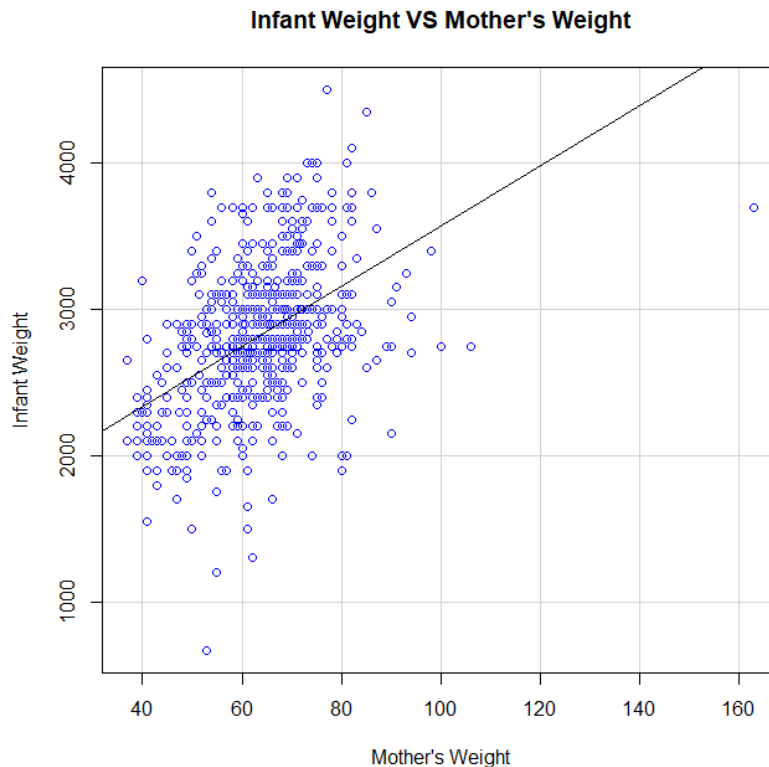


*Figure 3: Scatter Plot of Infant Weight & Mother's Weight*

Call:

lm(formula = Infant_weight ~ Mothers_weight)

Coefficients:

  (Intercept)  Mothers_weight

     1514.51          20.54

Liner general model

$$Y_{\text{Infant\_weight}} = a + bX_{\text{Mothers\_weight}}$$

Final Linear model

$$Y_{\text{Infant\_weight}} = 1514.51 + 20.54\, X_{\text{Mothers\_weight}}$$

$$Y_{\text{Infant\_weight}\,(3)} = 1514.51 + 20.54 * 2500$$

$$Y_{\text{Infant\_weight}\,(3)} = 52865.51$$

**Mother's Age Analysis**
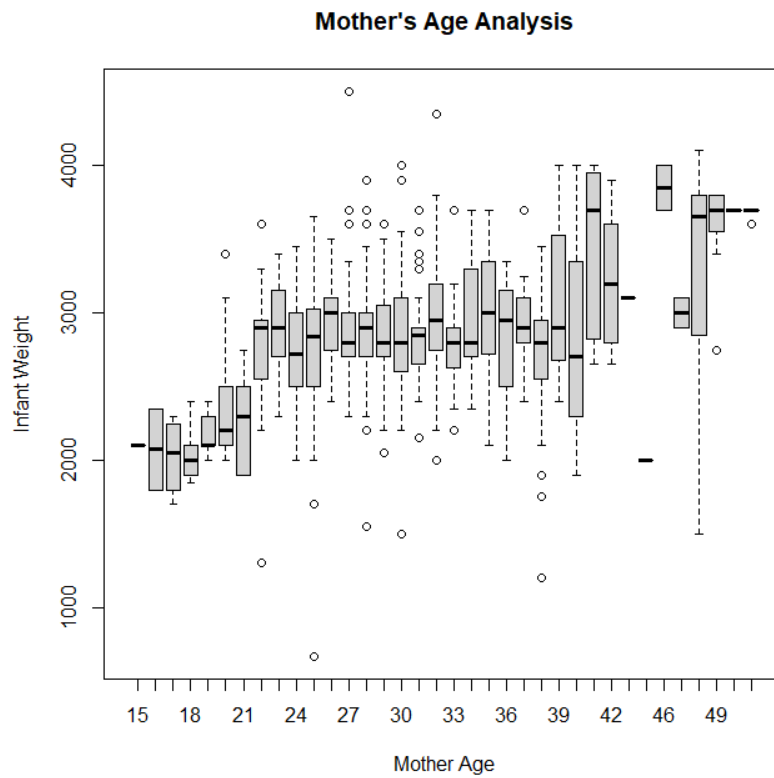


*Figure 4: Scatter Plot of Infant Weight & Mother's Age*

P-Value <2e-16

**Mode Of Birth Analysis**
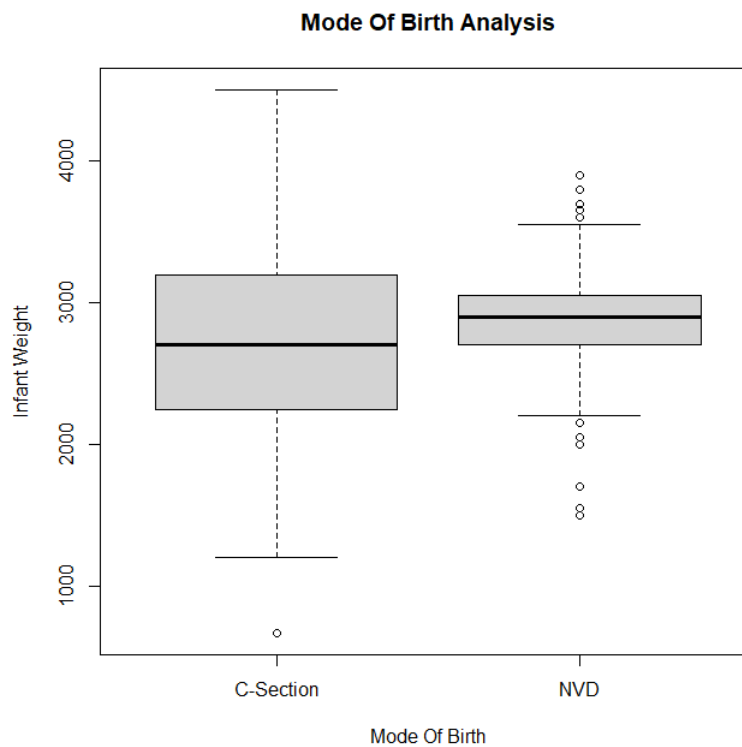


*Figure 5 : Boxplot Analysis on Mode of Birth*

P-Value 0.00819
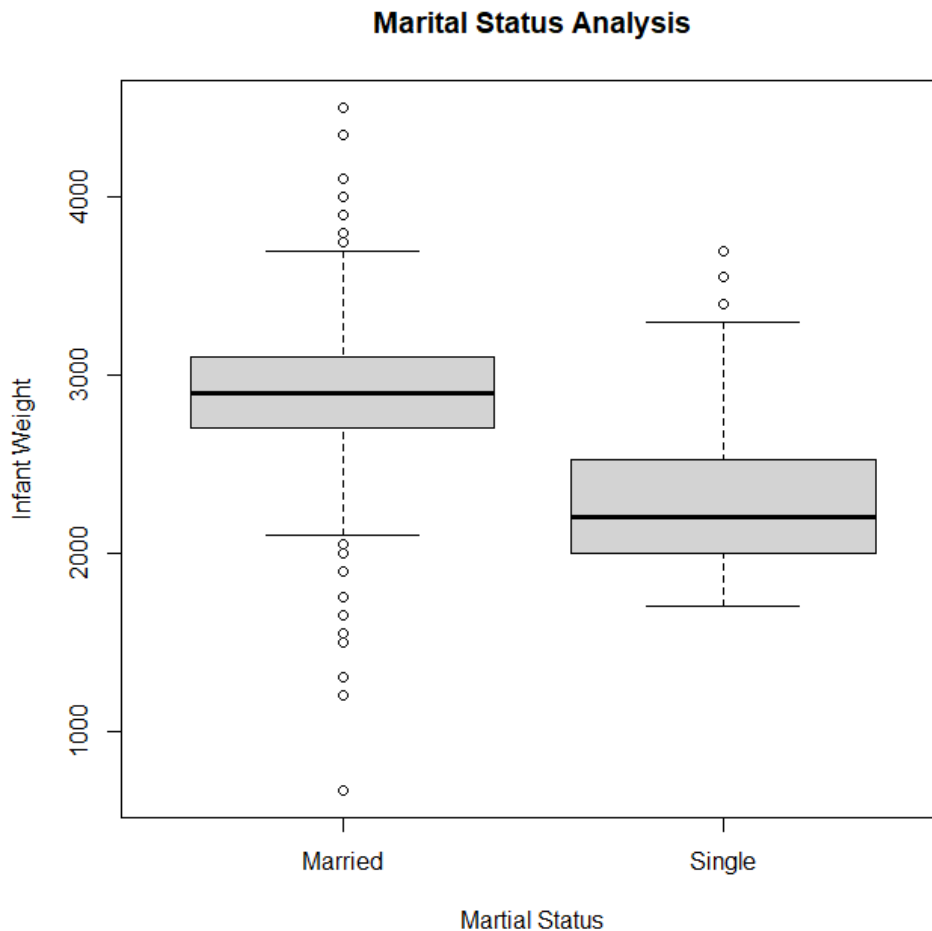
*Figure 6 : Boxplot Analysis on Marital Status*

P-Value <2e-16

**Results**

For the difference of weight ranges, for LBW is below 2500g. The normal weight birth weight is 2500g to 3500g. The High weight birth weight is 3500g. Accoring to figure 7, the least number of low-birth-weight infants are from Akurana and Deltota. The highest number of low-birth-weight infants are from Patadumbara and Kandy four Gravets. The rest are in the middle and the numbers are displayed on the map. The infant's weight at delivery is influenced by various factors including maternal lifestyle, prenatal care, genetics, and health. Healthcare providers consider these variables to determine a healthy birth weight, ensuring the baby's wellbeing.
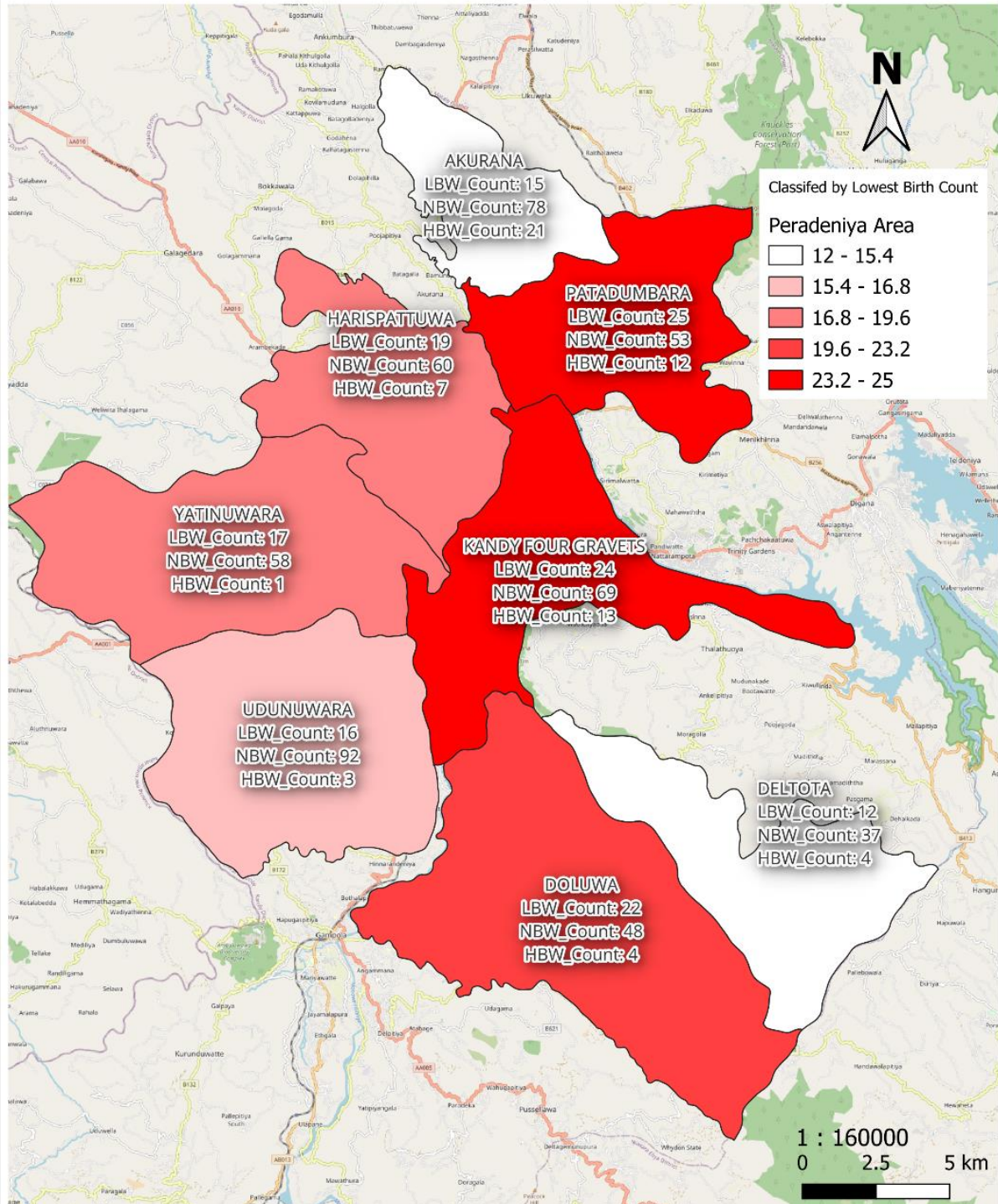
*Figure 7 :Birth Weight Count Map in Peradeniya Hospital from January to March 2023*
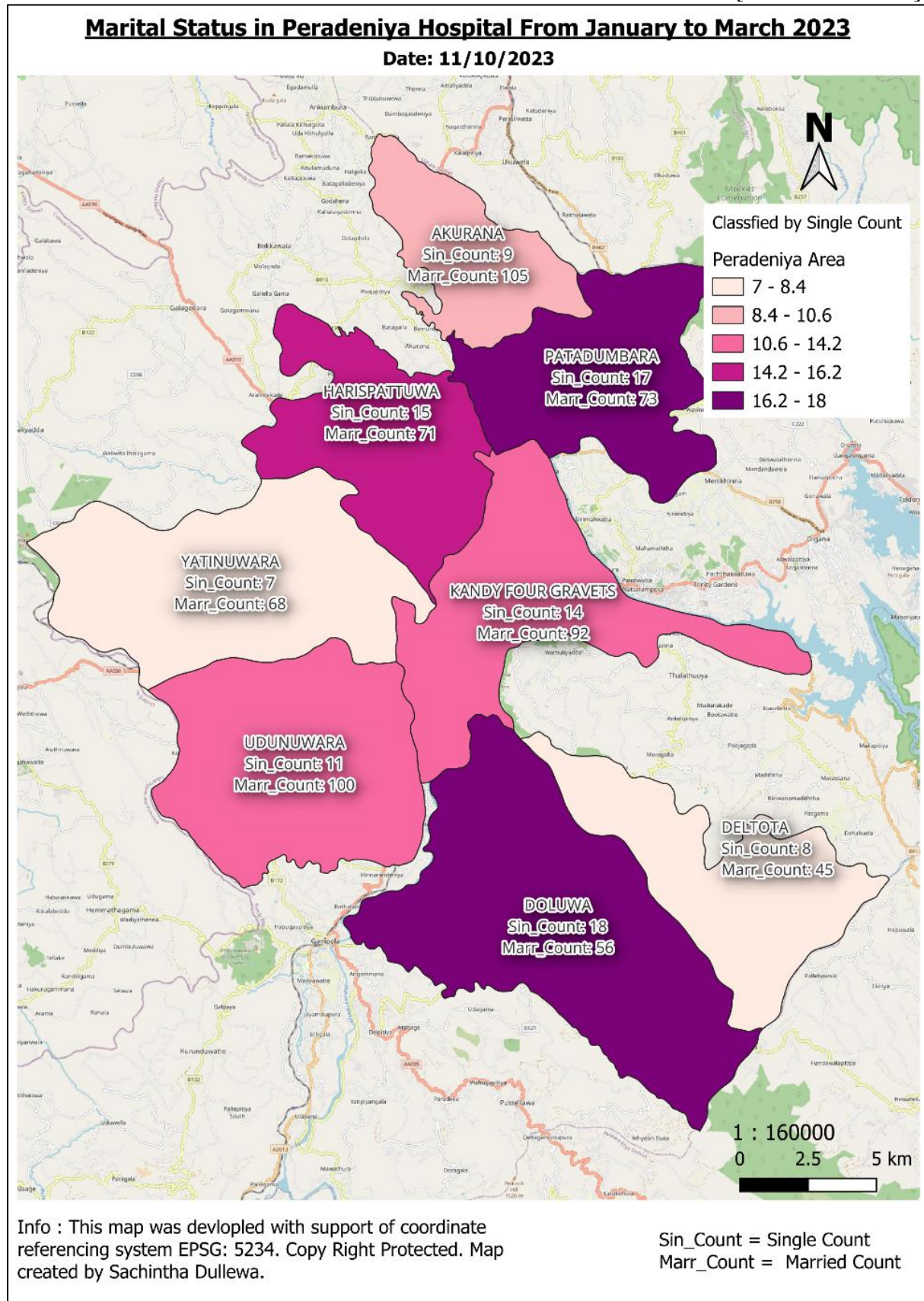
*Figure 8 : Marital Status Map in Peradeniya Hospital from January to March 2023*

The map in figure 8 is classified by single mother's count in these areas. In this map single mother's counts are lowest in Deltota and Yatinuwara and highest single counts are in Pathadumbara and Doluwa. Also, the married count is also displayed on the map. By comparing these low birth count maps and this marital status map, the low birth count was low in Akurana and Deltota. In the category of marital status with the lowest count, single status is notably observed in both Deltota and Yatinuwara. Consequently, it becomes evident that the low single status count in Deltota has a substantial impact on the remarkably low birth count in this region. In the case of Akurana, single status is not as scarce, but it is plausible that various other factors might be at play.

The low birth count is highest in Patadumbara and Kandy Four Gravets and Single count is highest in Patadumbara and Doluwa. From this observation, it becomes apparent that the single status has an impact on the low birth count. While this effect may not be universal across all locations, it is evident that in some instances, this marital status influences birth weight (Saba W. Masho, 2010).

The marriage count is highest in Akurana and Udunuwara, Akurana has the lowest birth weight count and Udunuwara also has somewhat of low-birth-weight count by this it seems higher the married count lowers the low-birth-weight infant count.

Birth weight is significantly influenced by marital status, with single moms often giving birth to children with lower weights. This is due to increased stress, lack of emotional support, limited access to financial resources, and insufficient prenatal care and nutrition. Additionally, single moms are more likely to engage in harmful behaviors like substance misuse or smoking, further affecting the unborn child's health.


The map in figure 9 is classified by the C-section count in these areas. The lowest amount of C-section counts is in Deltota and Doluwa. Compared with the birth count map, the lowest birth weight lowest count is in Deltota and Akurana. Here also there is effect in lower the C-section count lower the low birth count in Deltota. Other areas correspondingly have similar results. Akurana is a bit different, this might be due to other factors.

C-section count is highest in Akurana and Kandy four Gravets. In the birth map this highest low birth weight count was from Kandy Four Gravets and Pathadumbara. Here also there is a connection in Kandy Four Gravets. This connection is higher the C-section count, higher the low birth infant count (Hsiu-Ting Tsai, 2017).

The lowest NVD counts are in Deltota and Yatinuwara. Deltota has the lowest birth weight count. From the NVD count it's bit difficult to understand a pattern because the lower the NVD count it that place should have a higher low birth weight count.
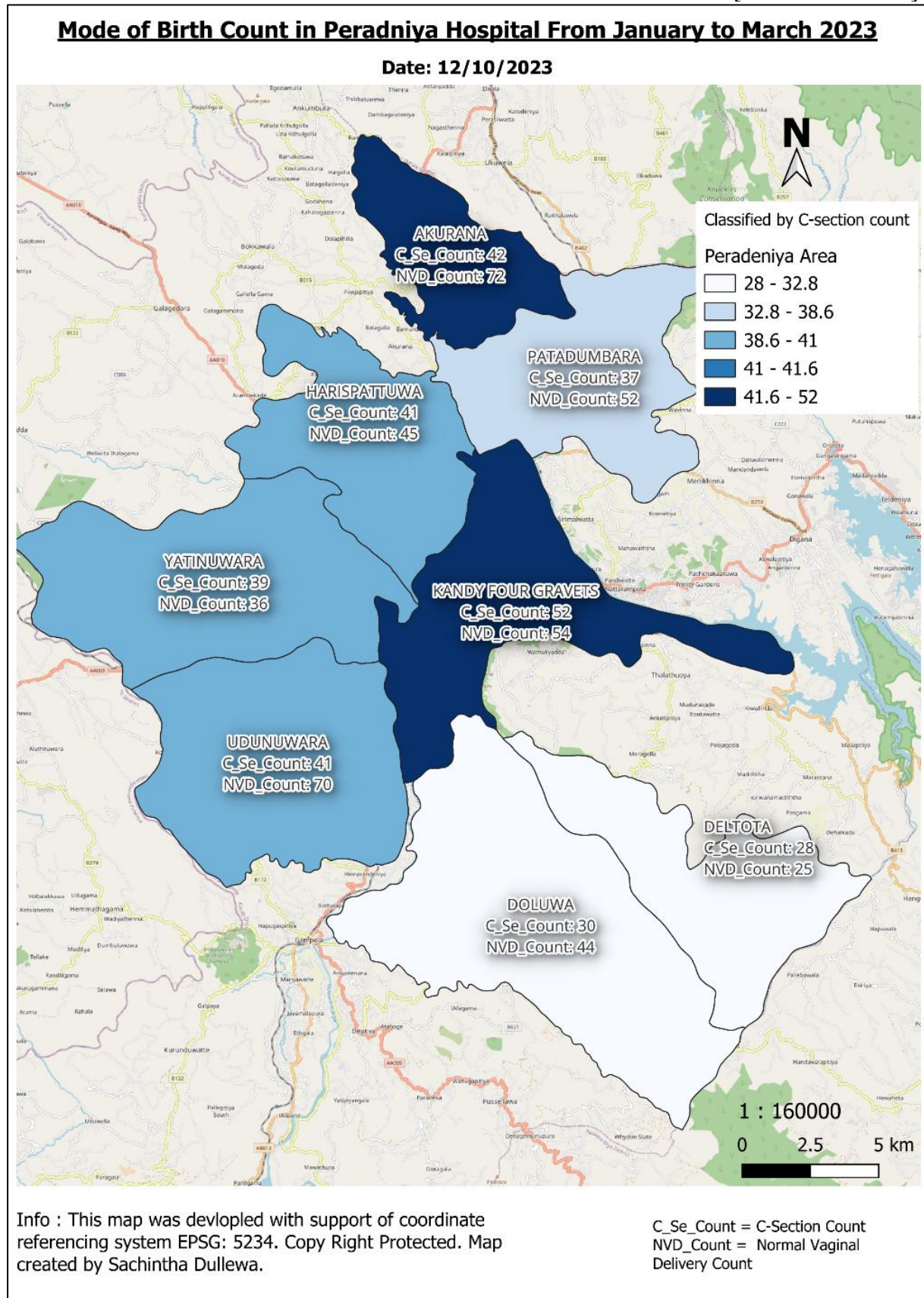
*Figure 9 : Mode of Birth Count Map in Peradeniya Hospital from January to March 2023*

*Figure 10 : Maternal Weight Count Map in Peradeniya Hospital from January to March 2023*

The map in figure 10 is classified by mother's low weight count. Assumed mother's low weight for this is less than 50kg. Normal weight and high weight mother's count is also displayed. Normal weight range is 50kg to 70kg, High mother's weight is more than 70kg. In this map Pathadumbara and Doluwa have the highest low weight mother's count. In the lowest birth weight map the highest low weight infants were reported in Pathadumbara and Kandy Four Gravets. Comparing these two maps Pathadumbara location is subjected to the highest low birth weights and highest mother's weights. Deltota and Udunuwara have the lowest mothers weight count. Maternal weight impacts infant weight through gestational gain and nutritional influence on fetal development (Viswanathan, 2008).

Kandy Four Gravets and Akurana has the highest count of mother's weight more than 70kg. In the infant weight map. Low Infant weight count is high in Kandy Four Gravets and Akurana has low infant weight count. In this situation mother's whose weight is more than 70kg has no impact if the infant weight can be low or high.

The map in figure 11 is classified by high maternal age. In this research assumed low maternal age is below 21 years old. The highest number of people below 21 years count is from Patadumbara and Doluwa. In the low birth infant map, the highest number of LBW were recorded from Pathadumbara and Kandy Four Gravets. So, the age below 21 and the lowest birth weight count is shown in Pathadumbara area. In this research assumed maternal age is high after age 35 and considered the normal maternal age range as age 21 to 35 years of old mothers. Mothers who are more than 35 are from Patadumbara and Akurana. In the low birth infant map, the highest number of LBW were recorded from Pathadumbara and Kandy Four Gravets. From this information can conclude that high maternal age mothers also are also most likely to have low birth infants due to varies medical reasons this might occur (Shanshan Wang, 2020).
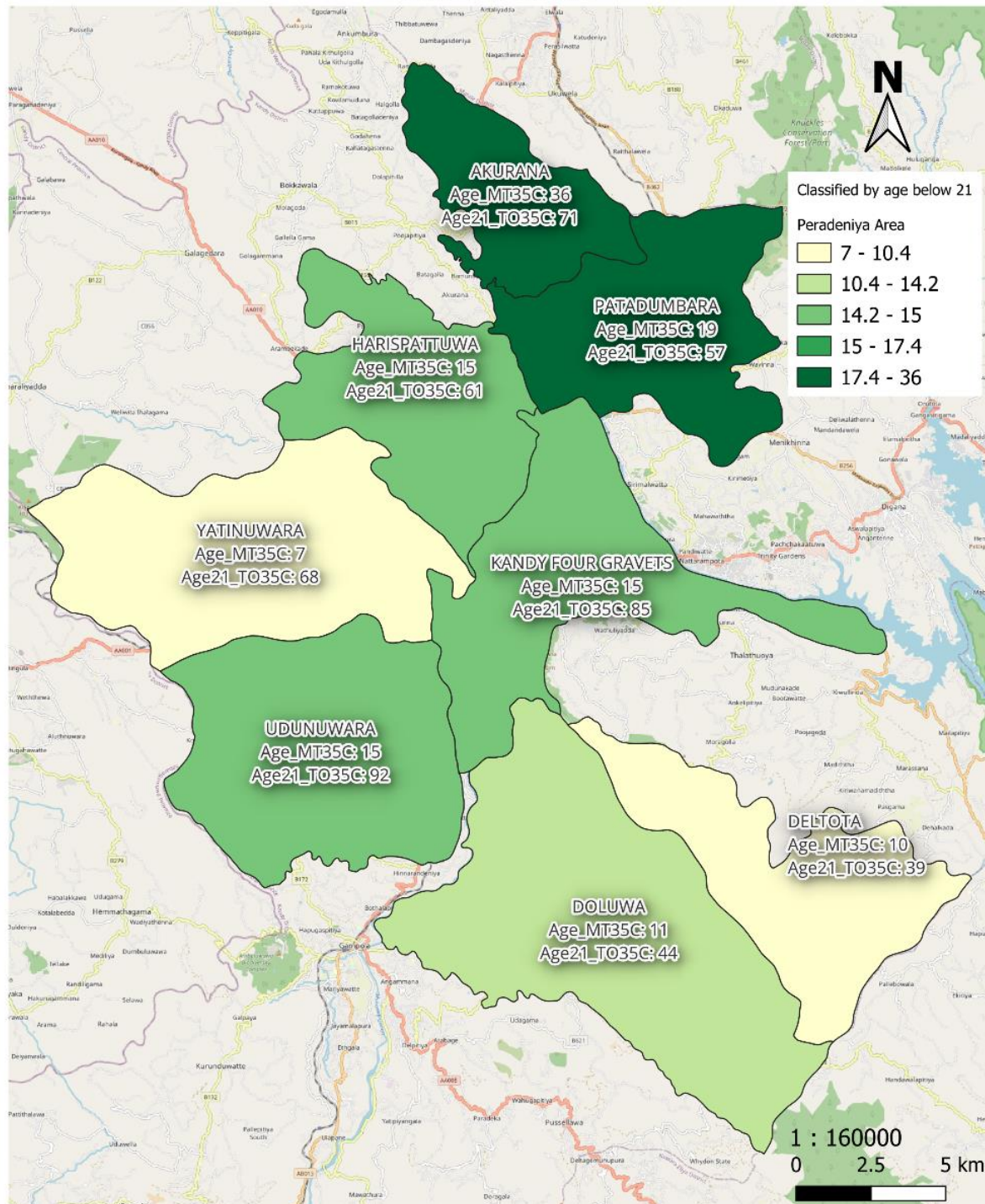
*Figure 11: Low Maternal Age Count Map in Peradeniya Hospital from January to March 2023*

High and low mother ages significantly impact infant birth weight. Young mothers, typically under 21, are at a higher risk of low-birth-weight children due to poor prenatal care, limited resources, and unsafe behaviors. Their physical development also affects their ability to provide nutritional assistance, potentially altering the baby's birth weight. Both high and low mother ages can have significant impacts on infant health.

## Discussion

Birth weight, mother's Maternal weight, marital status, maternal age, and mode of birth information was not available by the divisional sectors in Sri Lanka. This study has shown case information in maps of those divisional sectors. By comparing these maps health care professionals can easily understand what factor effect most in a certain area. In past studies researchers have found connections between these infant weight, LBW, marital Status, maternal Age, maternal weight, mode of birth. According to these past studies, some factors have affected, and some factors have not affected. In the future looking into factors smoking habits, living area, altitude, air pollution, economy, parent education and how those factors affect infant weight. By doing that will be able to narrow down and get a better understanding witch factors affect the most.

### Recommended Solution

Tiny Tracker is a mobile application that provides information for mothers and infants, promoting better health outcomes. It can be enhanced with features like data visualizations, interactive maps, and real-time updates. Ensuring the software's security, ease of use, and frequent updates is crucial for its effectiveness.

## Conclusion

The study investigates the intricate relationships between maternal traits and delivery methods, particularly in the Peradeniya area, and their impact on newborn health. It uses GIS technology, regression, and ANOVA analysis to reveal subtle insights into birth weight. Geographic differences highlight the impact of factors like marital status, birth method, maternal weight, maternal age while weaker correlations indicate potential undiscovered variables like genetic predispositions or environmental circumstances.

The paper demonstrates strengths through its comprehensive exploration of maternal variables and innovative use of GIS technology, providing a holistic understanding of factors influencing infant birth weight. Clear hypotheses and effective data visualizations enhance its structured approach. However, limitations such as data availability issues, reliance on paper records, and more variables need to research into such as elevation impact, smoking habits, economy, air pollution, living area (rural, urban), addressing these limitations would strengthen the paper's overall impact.

In the realm of infant healthcare decision-making, there has often been a reliance on intuitive estimations regarding which areas should receive medical supplies or additional attention. However, with the findings of this research, healthcare professionals can now pinpoint with precision the areas that require assistance the most. This insightful analysis, conducted through the utilization of GIS technology, enables medical professionals to have a clear understanding of the specific regions in need of support.

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# ADVANCEMENTS IN CRIMINAL SUSPECT IDENTIFICATION AND LOCATION THROUGH FACIAL RECOGNITION UTILIZING DEEP LEARNING ALGORITHM.

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**Abstract**

This research paper delves into the realm of criminal investigation, focusing on the application of cutting-edge facial recognition technology to identify and locate suspects. Employing sophisticated deep learning and machine learning algorithms, specifically TensorFlow, the study explores the efficacy of these methodologies in enhancing the precision and efficiency of suspect identification processes. Through a comprehensive examination of facial features, the proposed system harnesses the power of neural networks to discern unique patterns, enabling accurate suspect identification. The integration of TensorFlow contributes to the robustness of the model, facilitating real-time analysis and prompt suspect location. The findings showcase the potential of leveraging advanced computational techniques to revolutionize law enforcement practices, fostering a more effective and technologically-driven approach to criminal suspect identification and apprehension.

**Keywords:** Deep Learning, Machine Learning, Facial Recognition, Facial Landmarks, TensorFlow

## Introduction

### *Inspiration to the Development of the study*

This scholarly work addresses the prevailing global challenge of inadequate real-time security surveillance, emphasizing the time-consuming and error-prone nature of manual monitoring. The research explores the transformative potential of integrating facial recognition-based systems as a solution to enhance efficiency and accuracy in identifying criminals and suspects. Unlike manual methods, facial recognition operates incessantly, expeditiously analyzing extensive visual data in real-time by comparing captured faces with known databases. This approach accelerates identification processes, facilitating prompt responses to security threats and preempting potential crimes. The system's capacity to recognize individuals despite disguises or appearance changes underscores its efficacy, heralding a revolutionary paradigm in global security efforts. Furthermore, the paper delves into the exponential growth of facial recognition, face detection, and object detection technologies, attributing this surge to pivotal factors such as advancements in machine learning, deep learning, and computer vision techniques, alongside the proliferation of digital imagery and video data across diverse domains. To provide comprehensive context, the research explores the historical evolution, contemporary significance, and the driving forces propelling the rapid development of these transformative technologies.

*Objectives:*
Construct a fully functioning system which is able to utilize the deep learning and machine learning algorithms to identify and detect known criminal suspects.

*Significance of work*
Potential to enhance law enforcement efforts and improve public safety. A web-based system for identifying and recognizing criminal suspects using facial recognition can streamline the process of apprehending individuals involved in criminal activities. It could lead to quicker responses to incidents, more efficient investigations, and ultimately contribute to the overall security of communities. Of course, ethical considerations and privacy concerns should be considered, but your work could make a substantial impact on the field of law enforcement.

## Methodology

The primary research methodology employed in this study predominantly aligns with Quantitative Research Methodology, focusing on the meticulous utilization of deep learning and machine learning benchmarks. This approach necessitates a comprehensive comparison of numerical data values, including but not limited to accuracy, effectiveness, and speed. The quantitative lens allows for a nuanced evaluation of the performance metrics, forming a robust foundation for analysis.

Integral to the construction of a fully functioning system is the strategic integration of various components. In this context, Qualitative Research Methodology assumes a pivotal role, serving as the crucible for ideation and the synthesis of diverse elements. The qualitative dimension, facilitated through thoughtful brainstorming sessions, becomes instrumental in harmonizing the disparate aspects of deep learning and machine learning into a cohesive and synergistic whole.

In summation, the methodological framework employed herein bears the hallmark of a Mixed Method Research Methodology. This comprehensive approach ensures a holistic exploration of the subject matter by seamlessly blending quantitative rigor with qualitative insights. The interplay between numerical analyses and qualitative ideation cultivates a nuanced understanding of the complex facets inherent in the development of a sophisticated system.

The process of data acquisition in this research predominantly relies on open-source face databases specifically curated for the study of machine learning. Drawing from these repositories, the research harnesses a wealth of sample model face images, thereby enriching the dataset for empirical analysis. This judicious selection of data sources enhances the credibility and robustness of the study's findings.

Upon the culmination of the investigative phase, the research yields a tangible outcome in the form of a web-based system. Engineered with Node.js and TensorFlow.js, this system encapsulates cutting-edge machine and deep learning algorithms. The synthesis of these technologies' manifests in a computational paradigm that epitomizes the culmination of empirical inquiry and technological innovation.

*Hypothesis*
The project focuses specifically on using facial recognition for criminal identification and tracking, with the goal of developing a practical system to aid law enforcement. This suggests the technology has promise for this application. The research implements sophisticated deep

learning and machine learning algorithms, especially TensorFlow, for facial analysis and recognition. This implies these modern techniques can improve suspect identification. The study produces a tangible outcome - a real-time web-based system using TensorFlow.js and Node.js. Developing a working system demonstrates the feasibility of the approach.TensorFlow.js enables client-side processing, reducing latency. This hints the deep learning technology can enable real-time facial recognition systems. The methodology balances quantitative performance analysis with qualitative system design, suggesting a robust technical implementation. The results section highlights promising accuracy and confidence levels in testing. This implies the algorithms are capable of suspect identification.

### *Facial Recognition Algorithm*

Both conventional and deep learning-based methods are used for face identification. Additionally, conventional methods include neural networks, wavelets, feature descriptors, and template matches. These techniques make extensive use of a generic structure known as the pyramid in order to enable multi-scale face identification. The theory is represented in the figure below.
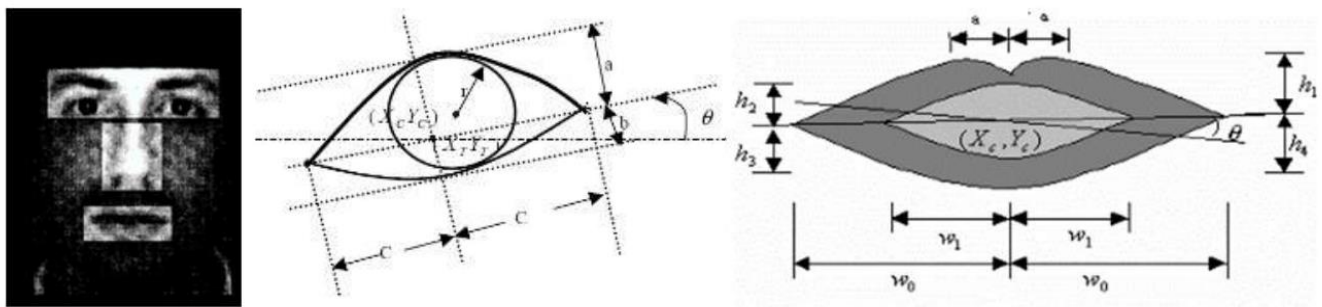


*Figure I Face Recognition Algorithm explanation*

### Results

Main outcome of the project is a Web Based System that is able to Recognize known criminal suspects and locate their last seen location.

### *Machine Learning and Deep Learning Utilization Outcomes.*

Hence the machine Learning Model used is TensorFlow JS, the outputs are as follows.
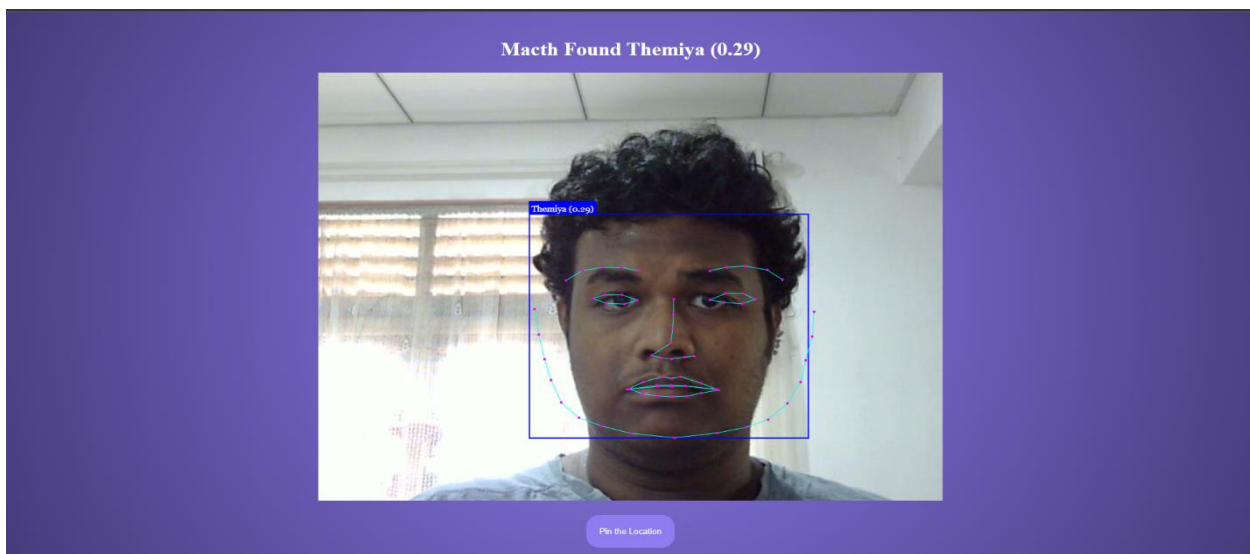
*Figure II: Real Time Facial Recognition of the author*

The above Figure II demonstrates the facial recognition that is integrated within the system. The value which is represented in the parenthesis is the facial distance which is 0.29 the e.
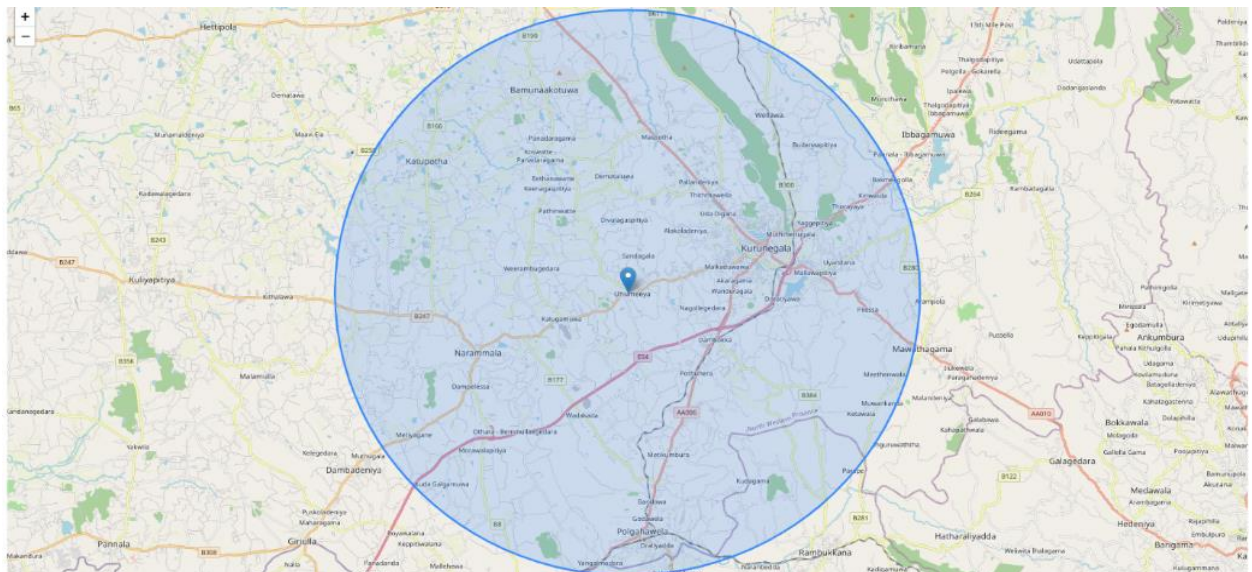


*Figure III: Real Time Geo Location of the Author*

*figure III represents how the location is pinged of the location of the criminal suspect that is last seen/captured by surveillance.*

*The Success rate of Face detection Algorithm in low light situations.*



*Figure IV Low Light Facial
Recognition of the Author*



*Figure V Low light Facial
recognition Author 2*

In the above Figure IV and Figure V the person is identified as person1 and the person1(0) stating that the face displayed in both images are the same face of the same person, however the accuracy of the accuracy and the certainty is quite low hence the lightning conditions.

Table I :Low Light Results Data

| Lighting Condition | Face Distance Accuracy | Identified (yes/no) | Face Identification Confidence Level |
|---|---|---|---|
| Image 01 | 0.88 | yes | 0.67 |
| Image 02 | 0.89 | yes | 0.74 |
| Image 03 | 0.99 | yes | 0.84 |
| Image 04 | 0.47 | yes but with lower confidence level | 0.25 |
| Image 05 | 0.20 | yes but with lower confidence level | 0.12 |
| Image 06 | 0.00 | no | 0.00 |

*Figure VI Low Light Test Subjects*

*Analyzing the Lowlight Data*
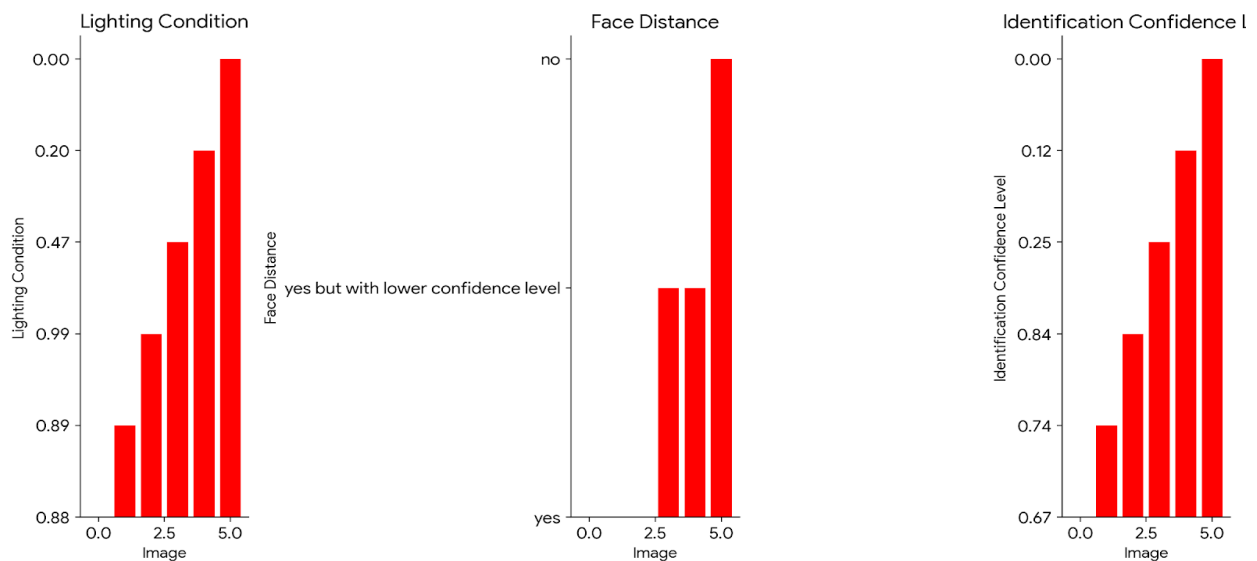


*Figure VII Analyzed Results of Low Light test*

In Conclusion the light is a crucial factor in the terms of identifying the face landmarks and as well as the detecting the face distance. There for the performance of low light conditions can be developed as below

Identified/ total tests * 100 = Performance rate of the Face detection Algorithm.

as per this project the low light performance rate is at 66.67%.

*Detecting Faces with multiple people and various Angles.*



*Figure VIII Facial Recognition test subjects*



*Figure IX Facial Recognition Test Subjects*

Table II Face recognition Data

| Person | Face Identified | Face Detected | Confidence level | Lightning Condition |
|--------|-----------------|---------------|------------------|---------------------|
| Sheldon | yes | yes | 0.47 | Well Lighted |
| Penny | yes | yes | 0.48 | Average |
| Howard | yes | yes | 0.41 | Poor |
| Leonard | yes | yes | 0.52 | Well Lighted |
| Raj | yes | yes | 0.47 | Average |
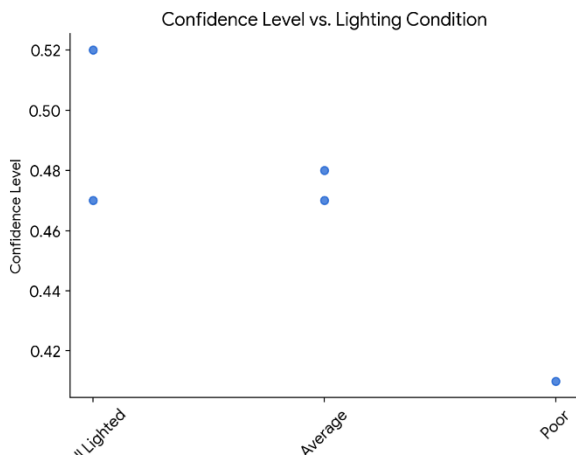
*Figure X Confidence vs Light Condition*
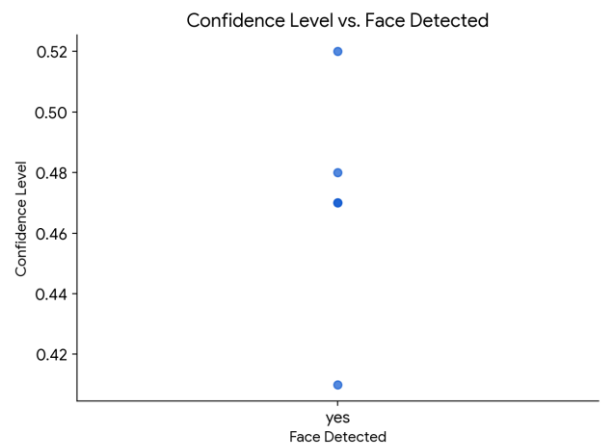


*Figure XI Confidence Vs Face Detected*
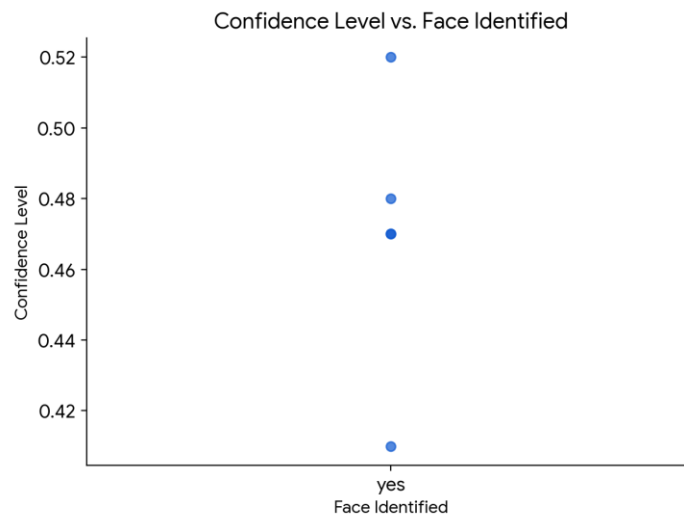


*Figure XII Confidence VS Face Identified*

The above graphs Figure X, Figure XI and Figure XII demonstrates that all the test persons have been identified by and detected by the system and as the confidence level is directly proportional to the Lighting condition.as represented in Figure X.

### Creating the Confusion Matrix
The performance of a classification model for predicting seven distinct facial recognitions is displayed in the confusion matrix.

### Comparison Between different Face recognition Frameworks
The comparison of the available Face Recognition Frameworks is represented in Table II below.

Table III: Comparing different Face recognition API

| Name | CPU Support | GPU Support | Is Continued | Usability |
|---|---|---|---|---|
| ConvNet.js | Yes (Vanilla) | | No | 3 |
| TF.js | Yes | Yes | Yes | 4 |
| OpenCV.js | Yes | Yes | Yes | 2 |
| face-api.js | Yes | Yes (TF.js) | Yes | 5 |
| Keras.js | Yes (Vanilla or Web Worker) | Yes (WebGL) | No | 3 |
| WebDNN | Yes (Web Worker or WebAssembly) | Yes (WebGL) | Yes | 4 |

**Discussion**

*Focus on Criminal Identification*
This research paper stands out for its specific focus on criminal identification and location using face recognition, emphasizing the practical application in law enforcement.

*Technologies Used*
While other Researchers explore various frameworks like TensorFlow, OpenCV, and YOLO, this research uniquely employs TensorFlow.js and Node.js for the development of a web-based application. This modern tech stack enhances accessibility and user interaction.

*Real-time Web-Based System:*
Unlike some Researches that might focus on algorithmic advancements, your research produces a tangible outcome—a real-time web-based system. This emphasizes the practical implementation of facial recognition for criminal identification and tracking.

*Integration of TensorFlow.js:*
The use of TensorFlow.js is a notable feature, as it allows for client-side processing in the web browser, potentially reducing latency and server load. This approach aligns with the latest trends in web development.

**Conclusion and Recommendations**

*Conclusion*
In conclusion, this research endeavor represents a significant stride in the domain of criminal investigation, leveraging cutting-edge facial recognition technology to address the persistent challenges faced by traditional security surveillance systems. Through the strategic application of sophisticated deep learning and machine learning algorithms, with a specific emphasis on TensorFlow, the study not only explores the efficacy of these methodologies but also pioneers the development of a fully functioning web-based system.

The research aligns with a well-balanced Mixed Method Research Methodology, seamlessly combining the precision of quantitative analyses with the ideational richness of qualitative insights. This holistic approach not only affords a nuanced evaluation of the system's performance metrics but also underscores the importance of thoughtful ideation in the construction of a sophisticated facial recognition system.

The development of the web-based system, engineered with Node.js and TensorFlow.js, represents a tangible outcome that transcends theoretical advancements. This system, capable of recognizing known criminal suspects and pinpointing their last seen locations, epitomizes the culmination of empirical inquiry and technological innovation. Additionally, integrate a weapon detecting and analyzing system.

*Screenshots of the developed system.*
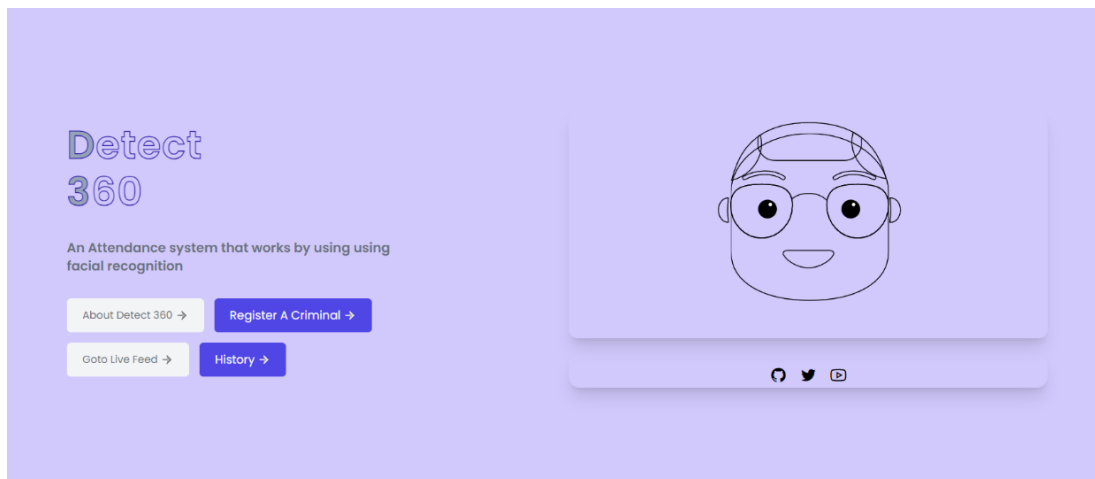


*Figure XIII Home Page*
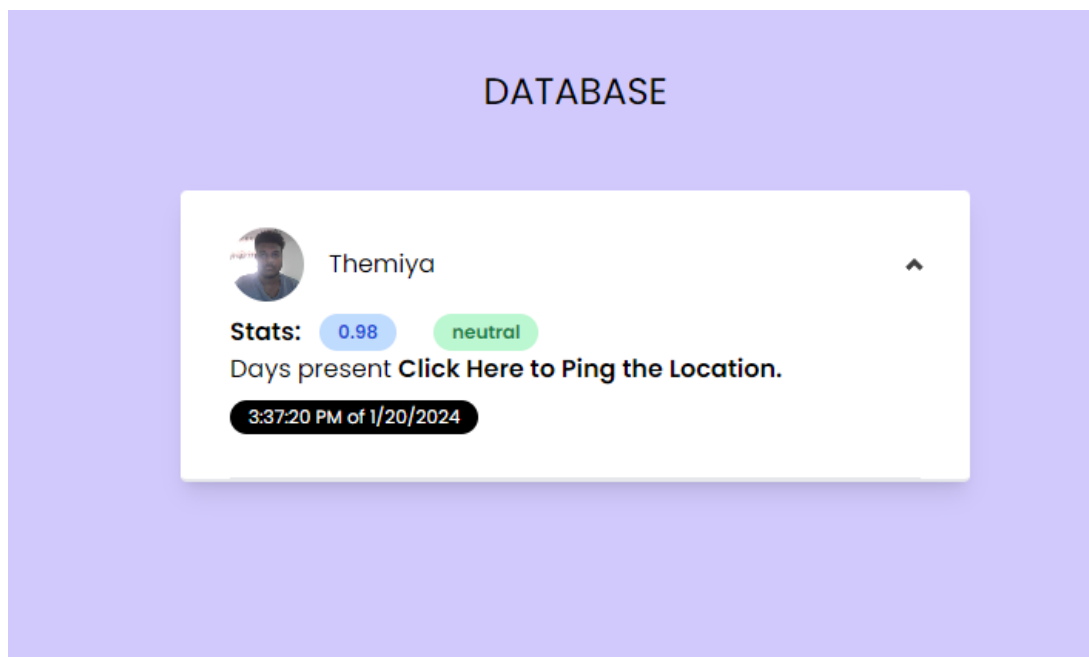


*Figure XIV History Page*
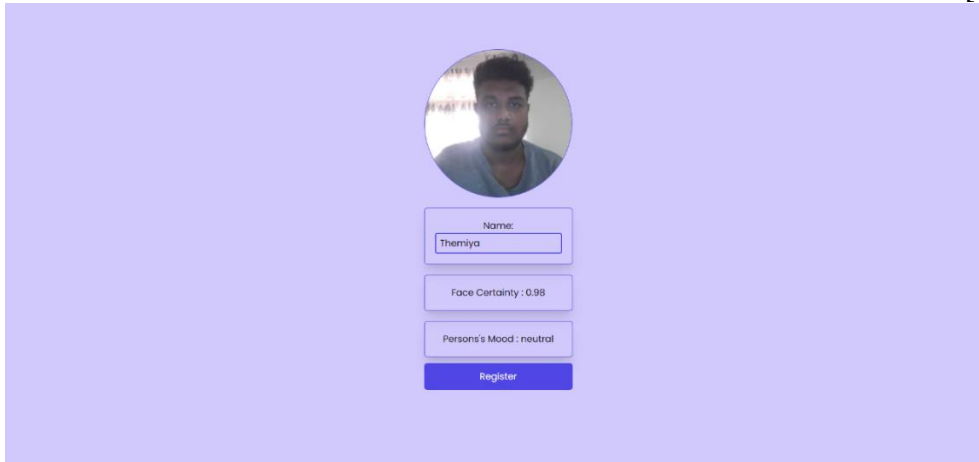
*Figure XVI Face Registration Page*
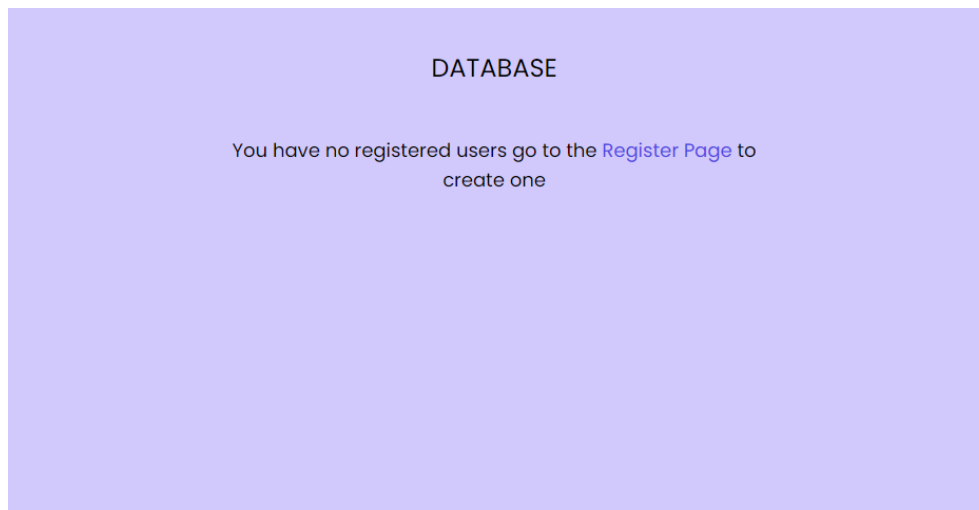


*Figure XVII Empty History Page*

***Recommendations***
***Ethical Implications and Privacy Considerations***
Future research should delve deeper into the ethical implications and privacy concerns associated with facial recognition technology in criminal investigation. Exploring frameworks for responsible deployment and addressing potential biases should be integral to the research agenda.

***Enhanced Geolocation Techniques***
Further investigation into geolocation techniques could enhance the accuracy of suspect location. Exploring advanced methods such as triangulation or integrating additional contextual data could contribute to refining the system's geolocation capabilities.

***Expansion of Datasets***
Expanding the dataset used for training the machine learning model could improve the system's adaptability to a broader range of facial features and environmental conditions. Incorporating diverse datasets can enhance the model's robustness and generalizability.

***Weapon Detection Integration***
The proposed integration of a weapon detecting and analyzing system presents an avenue for future research. Exploring the challenges and opportunities associated with incorporating

weapon detection capabilities into the web-based system would contribute to a more comprehensive approach to law enforcement.

### User Feedback and Usability Studies

Conducting user feedback and usability studies would provide valuable insights into the practicality and user-friendliness of the developed web-based system. Understanding the perspectives of law enforcement professionals and end-users can guide refinements and improvements.

### Real-world Implementation Testing

Initiating real-world implementation testing in collaboration with law enforcement agencies could validate the practical effectiveness of the developed system. This would involve field trials and assessments under diverse operational conditions to evaluate the system's real-world applicability.

### Long-Term System Sustainability

Investigating the long-term sustainability of the web-based system is crucial. Assessing factors such as system maintenance, scalability, and adaptability to evolving technologies will be pivotal in ensuring the continued effectiveness of the system over time.

### Cross-disciplinary Collaboration

Encouraging cross-disciplinary collaboration with experts in law, ethics, and human rights can provide a well-rounded perspective on the implications of deploying facial recognition technology in criminal investigation. Such collaborations could contribute to the development of guidelines and policies.

### Public Awareness and Education

Research efforts should extend to public awareness and education campaigns to inform communities about the capabilities and limitations of facial recognition technology. Engaging the public in discussions about the responsible use of such systems can foster transparency and trust.

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# SPARKSOUL - PERSONALITY-BASED USER GROUPING WEB APPLICATION USING K-MEANS CLUSTERING

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## Abstract

In the dynamic realm of social media, where personalized user experiences are paramount, Sparksoul emerges as an innovative platform integrating K-Means clustering with the Big Five Personality model. This paper presents a comprehensive methodology for personality-driven user grouping, enhancing online connections based on individual traits. The research involves a purposive sampling method, utilizing a Google Form embedded with personality assessment questions. Results from the elbow method analysis determine an optimal three-cluster solution, affirming the efficacy of the approach. The K-Means clustering algorithm successfully groups users into distinct clusters, fostering meaningful interactions. The application's design and development employ technologies such as Visual Studio Code, HTML, CSS, JavaScript, PHP, Python, and MySQL. The study not only validates the feasibility of personality-based user grouping but also provides a foundation for ongoing enhancements, emphasizing continuous refinement and cross-platform integration to meet evolving user needs.

**Keywords** : Big Five Model, K-Means Clustering, Personality, Social Media

## Introduction

In the rapidly evolving landscape of social media, where digital interactions have become integral to people's daily lives, the need for a more personalized and enriching user experience has never been more pronounced. As users navigate through the vast area of virtual connectivity, the challenge lies not only in fostering connections but also in tailoring these interactions to align with individual preferences and personalities. Sparksoul emerges as a platform where users can build connections that are more personalized according to their personality traits. With the use of technology with personality interests, the goal is to make the online world feel more personalized for each person, recognizing and celebrating their individuality. This work is not just about looking at the possibility of grouping people based on their personalities, but also about understanding how grouping might affect the connections and interactions of users.

Sparksoul manifests in creating a platform where users can build connections and interact with people having similar personality traits by integrating the K-Means clustering algorithm with the Big Five Personality model.

### *Aim*

To create and implement an innovative personality-driven web social media platform that makes use of user personality attributes to promote meaningful relationships and interactions.

*Objectives*

1. Creating an approach that is accurate and simple to use for identifying and profiling personality features of people on social media platforms.
2. Identifying the best personality evaluation tools and questionnaires for the platform integration.

*Literature Review*

In the area of personality prediction and analysis, the team's findings draw parallels with some similar previous findings. The study by Dr. S.K. Nivetha discusses personality prediction using K-Means clustering establishing a foundation for this work (Nivetha et al., 2022). In this approach, the integration of the Big Five model and K-Means clustering, extends beyond existing approaches, highlighting the significance of a comprehensive methodology.

Similarly, the research titled "Machine Learning Based Personality Classification Using Clustering Algorithm" discusses about personality classification using the Big Five Model and K-Means clustering (Vijay and Sebastian, 2022). This study not only aligns with this research on questionnaire-based analysis but also advances the field by showcasing practical applications within a social media context. The comparison highlights the broader applicability of this methodology. The research paper titled "Personality Prediction and Analysis using Clustering" discusses the importance of understanding personality traits for various applications (Goel et al., 2021). While their research focuses on academic and professional domains, this study integrates personality-based clustering into a social media platform.

Moreover, research by Gupta and his team and research by Al-Dabbas and the team also provide valuable insights into using K-Means clustering for personality based matching and customer segmentation, respectively (Gupta et al., 2022) (Al-Dabbas, Al-Tarawneh and Al-Rawashdeh, 2023).

**Methodology**

The methodology used in this design and innovative work is a carefully crafted framework designed to investigate the integration of personality-driven clustering on social media platforms. The following explains the used research strategy, the meticulous sample selection method, and the data collection methods employed in this study.

*Research Strategy*

The research strategy used here is a combination of quantitative and qualitative approaches to ensure a clear understanding of user personalities and their impact on social media interactions. This includes employing established psychological frameworks, such as the Big Five Personality Model, and advanced data analysis techniques like K-Means Clustering. This includes the integration of psychological assessments into the social media web application, utilizing a survey format for data collection. The quantitative nature of the study aimed to objectively categorize users into distinct personality-based clusters.

*Sample Selection*

The process of choosing the people who take part in the study is crucial. The target population consisted of students from diverse academic backgrounds, reflecting the potential user base of the social media application. A purposive sampling method was employed to ensure representation from various disciplines. An online Google form consisting of the same personality assessment questions embedded in the web application was used for the sample data collection. Participation in the form was voluntary, and ethical considerations, including informed consent, were strictly followed in the data collection process.

*Data Collection and Analysis Methods*

The data collection process for the study commenced with the creation and distribution of the Google form among the selected participants. The form included questions, based on the Big Five Personality model that encompasses traits such as Openness, Conscientiousness, Extraversion, Agreeableness, and Neuroticism. The participants were asked to respond to these questions, providing insights into their personality characteristics. Upon the completion of the data collection phase, the collected responses were extracted from the Google Form and organized into a structured dataset. This dataset was used for the analysis process.

The elbow method analysis was used to determine the optimal number of clusters for user categorization. This step was crucial in ensuring that the subsequent user grouping was meaningful and effective. Following the determination of the optimal number of clusters through the elbow method, the K-means clustering algorithm was applied to the dataset. The combination of psychological assessments, statistical analysis, and machine learning techniques contributed to a comprehensive and systematic methodology.

*Design and Development*

The design and development part include interface design and web application development. Diagrams such as architecture diagrams, ER diagrams, system navigation diagrams, use case diagrams, and activity diagrams were developed.
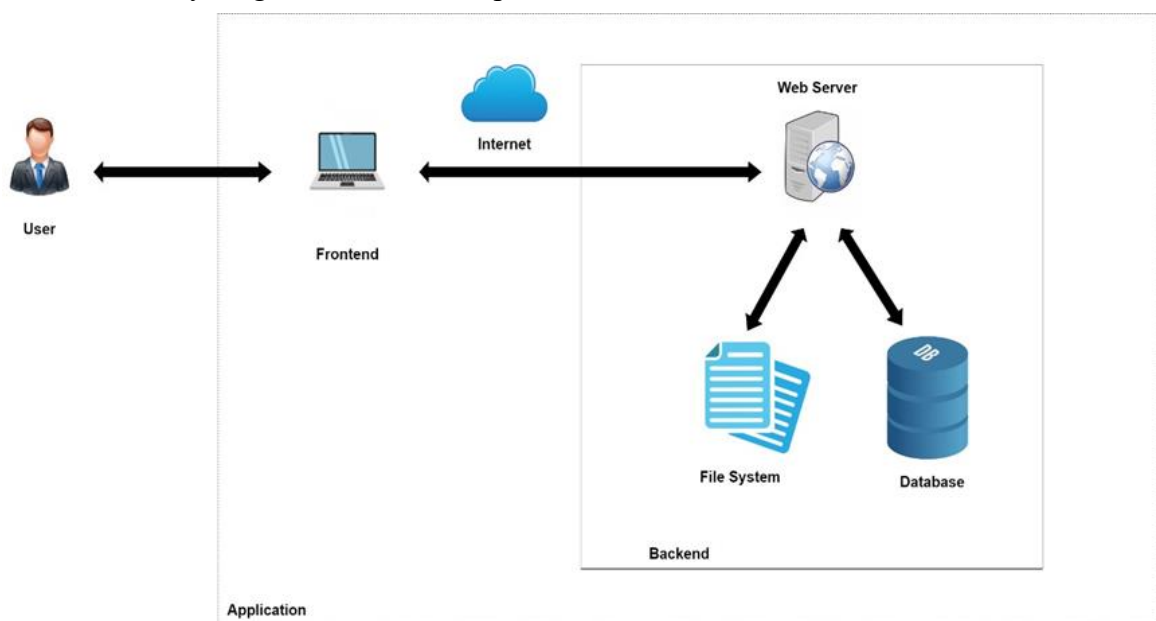


*Figure I: Architecture Diagram*

## Implementation

For the web application development, Visual Studio code was used as the IDE, and HTML, CSS, JS, and PHP languages were used for frontend and backend developments. Python was used for the clustering of users. MySQL database was chosen as the database for this application. A sample of the interfaces is shown below in Figure II, Figure III, and Figure V.

## Technologies

Table I: Technologies used for Sparksoull

| IDE | Visual Studio Code |
|-----|--------------------|
| Languages | HTML, CSS, JavaScript, PHP, Python |
| Database | MySQL |
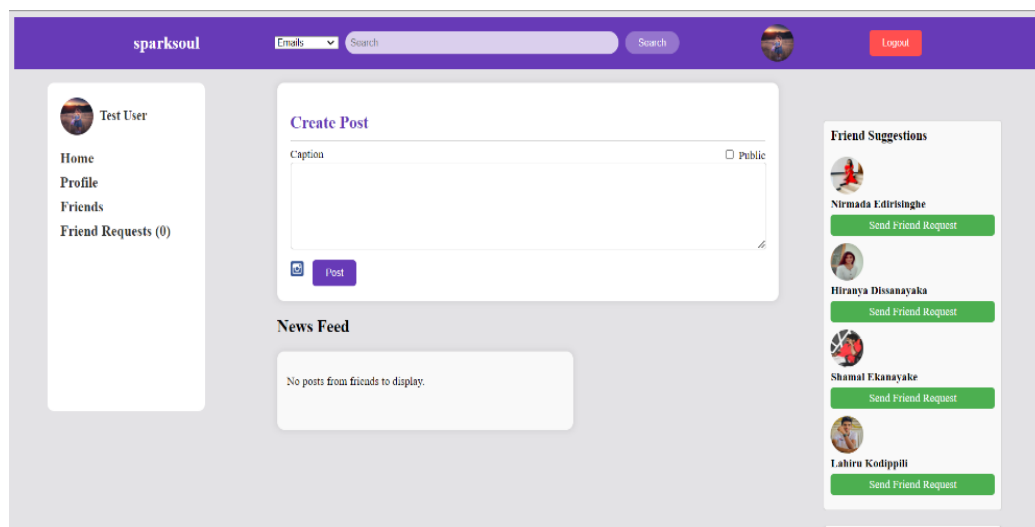


*Figure II: Home page*



*Figure III: Sample Questioners ask in the registration*
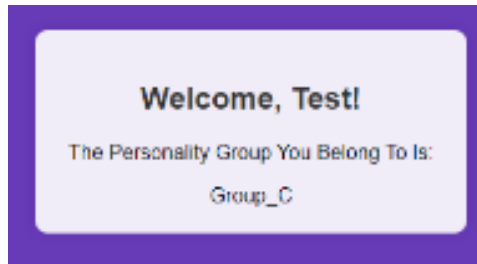
*Figure IV: Result page Indicates the Group that belongs*

**Results and Discussion**

The results obtained from the data analysis conducted for the study are as below. The application of the elbow method to the dataset provided insightful results. The analysis revealed a clear point on the graph where distortion significantly decreases until a specific cluster number, after which the reduction became more gradual. In this study, the inflection point is shown in three clusters. The graphical representation of the below method analysis, depicted in Figure V, shows the elbow point, affirming the selection of three clusters.
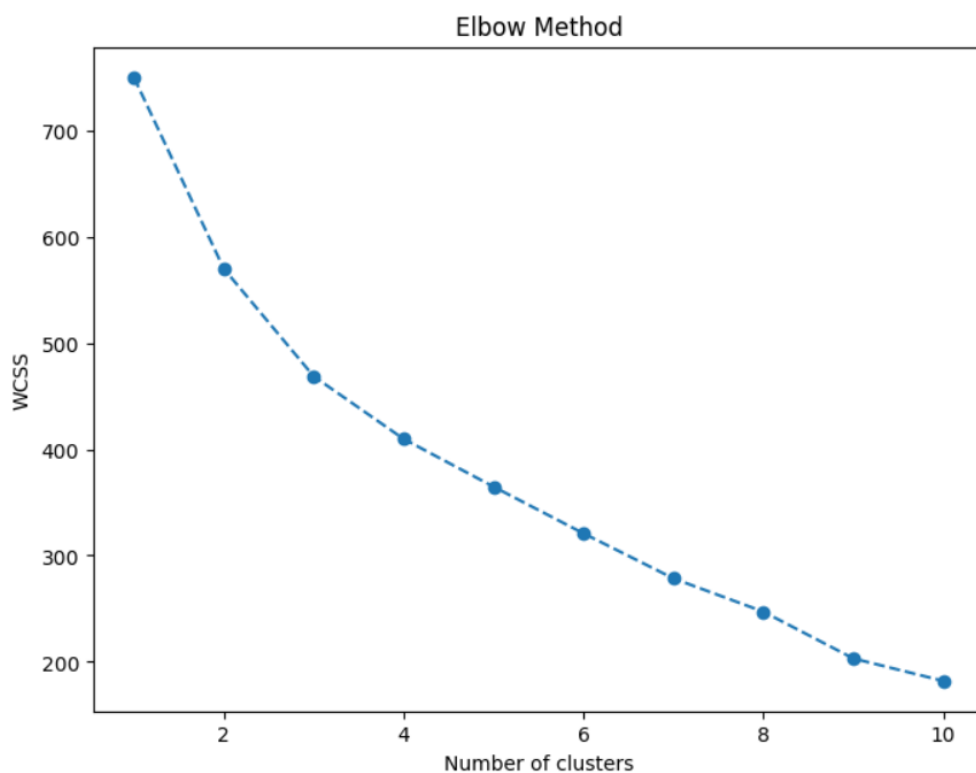


*Figure V : Elbow Method Data*

After the determination of the number of clusters, through the elbow method, the K-means clustering algorithm was applied to the dataset. Through the algorithm, the users are clustered into three distinct clusters based on their responses to the questions. The users were grouped based on the similarity of their responses. The resulting clustered data was visually represented in Figure VI, illustrating the distinct separation of users into the identified clusters.
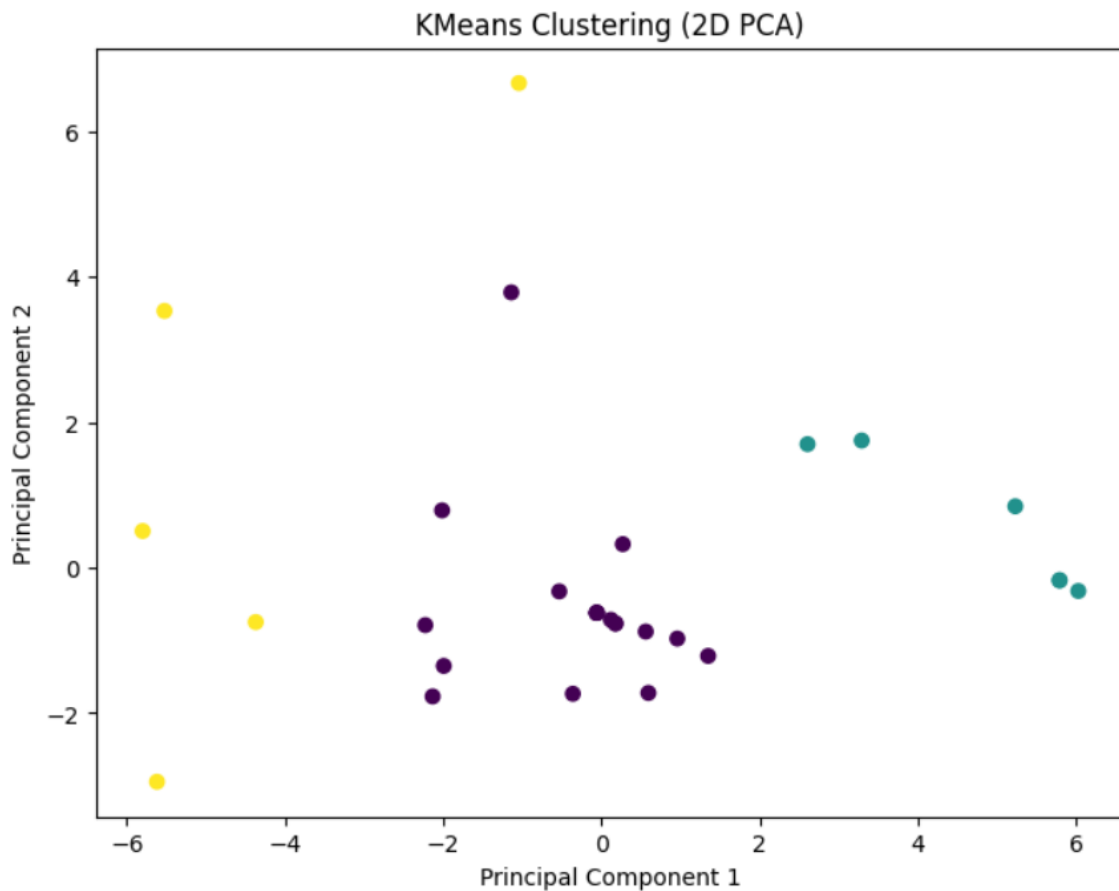
*Figure VI: Clusters obtained using K-Means Clustering*

The results obtained not only validated the effectiveness of the elbow method in determining the optimal number of clusters but also highlighted the successful application of K-Means clustering for user grouping. The visual representations in Figure V and Figure VI provide a clear illustration of the distinct sated in methodology, from the identification of clusters to the categorization of users.

To further illustrate the effectiveness of the methodology, test data were used in the analysis. Figure VII below presents a sample of the test data used for the elbow method.

| Participant | Q1 | Q2 | Q3 | Q4 | Q5 | Q6 | Q7 | Q8 | Q9 | Q10 | Q11 | Q12 | Q13 | Q14 | Q15 | Q16 | Q17 | Q18 | Q19 | Q20 | Q21 | Q22 | Q23 | Q24 | Q25 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 5 | 5 | 5 | 4 | 5 | 5 | 4 | 4 | 4 | 4 | 3 | 3 | 3 | 3 | 3 | 4 | 4 | 3 | 3 | 4 | 5 | 5 | 5 | 5 | 5 |
| 2 | 3 | 4 | 4 | 3 | 3 | 3 | 4 | 4 | 4 | 3 | 3 | 2 | 2 | 2 | 1 | 4 | 4 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 3 |
| 3 | 5 | 4 | 1 | 1 | 4 | 4 | 2 | 5 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 1 | 5 | 5 | 4 | 2 | 5 | |
| 4 | 5 | 5 | 5 | 5 | 5 | 5 | 4 | 5 | 5 | 5 | 4 | 4 | 4 | 4 | 5 | 4 | 1 | 3 | 4 | 3 | 4 | 4 | 1 | 2 | |
| 5 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 5 | 5 | 4 | 4 | 4 | 4 | 5 | 4 | 4 | 5 | 3 | 4 | 4 | 3 | 4 | 3 | 4 |
| 6 | 4 | 4 | 4 | 4 | 4 | 3 | 3 | 4 | 4 | 3 | 4 | 4 | 4 | 4 | 4 | 5 | 5 | 5 | 5 | 4 | 5 | 4 | 3 | 5 | |
| 7 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | |
| 8 | 4 | 4 | 4 | 4 | 4 | 4 | 2 | 2 | 4 | 4 | 4 | 4 | 4 | 1 | 1 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 5 | |
| 9 | 5 | 4 | 4 | 5 | 5 | 5 | 4 | 5 | 5 | 4 | 5 | 5 | 5 | 4 | 4 | 5 | 4 | 3 | 4 | 5 | 3 | 3 | 4 | 2 | 3 |
| 10 | 4 | 4 | 4 | 4 | 4 | 2 | 3 | 3 | 4 | 4 | 3 | 2 | 4 | 3 | 2 | 3 | 4 | 2 | 4 | 5 | 5 | 5 | 5 | 4 | 5 |
| 11 | 5 | 4 | 5 | 4 | 4 | 2 | 1 | 4 | 5 | 3 | 2 | 2 | 2 | 2 | 2 | 4 | 4 | 3 | 4 | 1 | 3 | 4 | 2 | 2 | |
| 12 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 3 | 3 | 3 | 3 | 3 | |
| 13 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| 14 | 4 | 5 | 4 | 4 | 4 | 4 | 5 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 2 | 5 | 5 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | |
| 15 | 4 | 4 | 5 | 5 | 4 | 4 | 4 | 4 | 4 | 4 | 1 | 4 | 4 | 5 | 4 | 4 | 2 | 4 | 5 | 4 | 4 | 4 | 2 | 5 | |

*Figure VII: Sample Dataset*

The obtained results after performing K-Means clustering for the sample dataset are presented below. Figure VIII below shows a sample of the data after performing K-Means and identifying the personality group.

| | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R | S | T | U | V | W | X | Y | Z | AA | AB |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Q1 | Q2 | Q3 | Q4 | Q5 | Q6 | Q7 | Q8 | Q9 | Q10 | Q11 | Q12 | Q13 | Q14 | Q15 | Q16 | Q17 | Q18 | Q19 | Q20 | Q21 | Q22 | Q23 | Q24 | Q25 | Participant | Cluster_Label | Personality_Group |
| 2 | 3 | 4 | 4 | 3 | 3 | 3 | 4 | 4 | 4 | 3 | 3 | 2 | 2 | 2 | 1 | 4 | 4 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 1 | 0 | Group A |
| 3 | 5 | 4 | 1 | 1 | 4 | 4 | 2 | 5 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 1 | 5 | 5 | 4 | 2 | 5 | 2 | 1 | Group B |
| 4 | 5 | 5 | 5 | 5 | 5 | 5 | 4 | 5 | 5 | 5 | 4 | 4 | 4 | 4 | 5 | 4 | 1 | 3 | 4 | 3 | 4 | 4 | 1 | 2 | 3 | 0 | Group A |
| 5 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 4 | 5 | 5 | 4 | 4 | 4 | 5 | 4 | 4 | 4 | 5 | 3 | 4 | 4 | 3 | 4 | 4 | 0 | Group A |
| 6 | 4 | 4 | 4 | 4 | 4 | 3 | 3 | 4 | 4 | 3 | 4 | 4 | 4 | 4 | 4 | 5 | 5 | 5 | 5 | 4 | 5 | 4 | 3 | 5 | 5 | 0 | Group A |
| 7 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 6 | 0 | Group A |
| 8 | 4 | 4 | 4 | 4 | 4 | 4 | 2 | 2 | 4 | 4 | 4 | 4 | 4 | 4 | 1 | 1 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 5 | 7 | 0 | Group A |
| 9 | 5 | 4 | 4 | 5 | 5 | 5 | 4 | 5 | 5 | 4 | 5 | 5 | 5 | 4 | 4 | 5 | 4 | 3 | 4 | 5 | 3 | 3 | 4 | 2 | 3 | 8 | 0 | Group A |
| 10 | 4 | 4 | 4 | 4 | 4 | 2 | 3 | 3 | 3 | 4 | 3 | 2 | 4 | 3 | 2 | 3 | 4 | 2 | 4 | 5 | 5 | 5 | 5 | 4 | 5 | 9 | 0 | Group A |
| 11 | 5 | 4 | 5 | 4 | 4 | 2 | 1 | 4 | 5 | 3 | 2 | 2 | 2 | 2 | 4 | 4 | 4 | 3 | 4 | 1 | 3 | 4 | 2 | 2 | 10 | 0 | Group A |
| 12 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 3 | 3 | 3 | 3 | 3 | 11 | 1 | Group B |
| 13 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 12 | 0 | Group A |
| 14 | 4 | 5 | 4 | 4 | 4 | 5 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 2 | 5 | 5 | 4 | 4 | 4 | 4 | 4 | 4 | 13 | 2 | Group C |
| 15 | 4 | 4 | 5 | 5 | 4 | 4 | 4 | 4 | 4 | 4 | 1 | 4 | 4 | 5 | 4 | 4 | 4 | 2 | 4 | 5 | 4 | 4 | 2 | 5 | 14 | 0 | Group A |
| 16 | 5 | 5 | 5 | 3 | 5 | 4 | 5 | 5 | 4 | 3 | 5 | 4 | 5 | 5 | 3 | 5 | 4 | 5 | 5 | 3 | 5 | 5 | 4 | 5 | 15 | 0 | Group A |

*Figure VIII: Sample dataset after grouping*

The results obtained not only validate the effectiveness of the elbow method in determining the number of clusters but also highlight the successful application of K-Means clustering for user grouping.

The personality traits in each group are shown in Figure IX, Figure X, and Figure XI below.
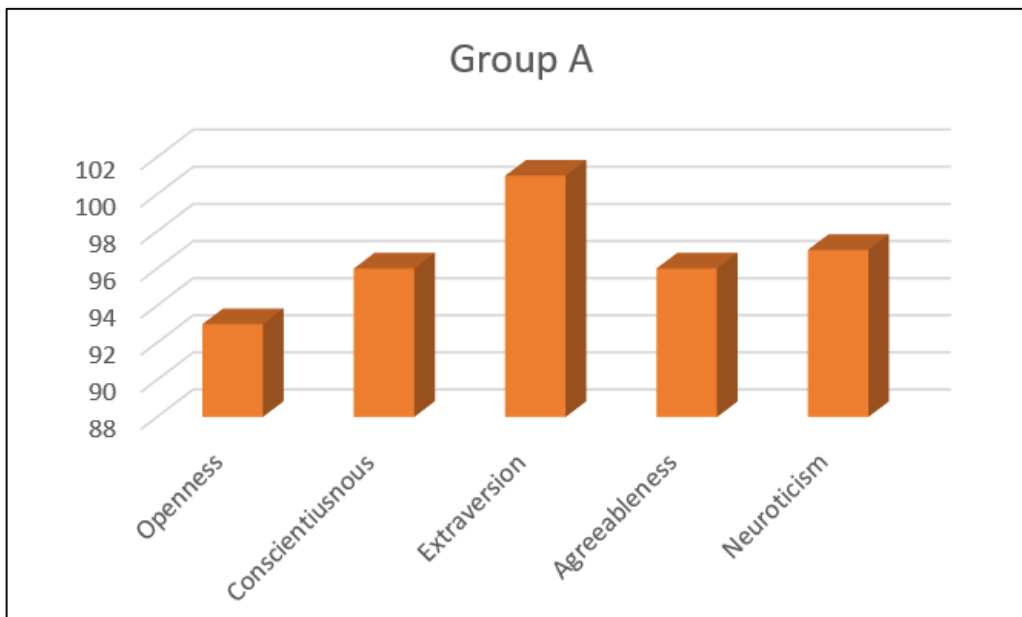


*Figure IX: Group A Results*
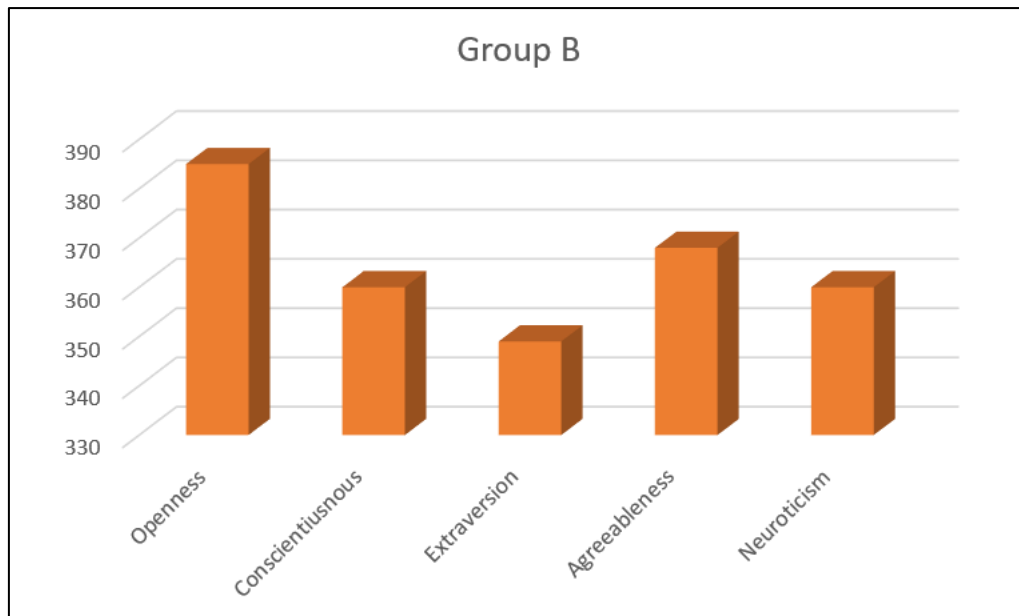
*Figure X: Group B Results*
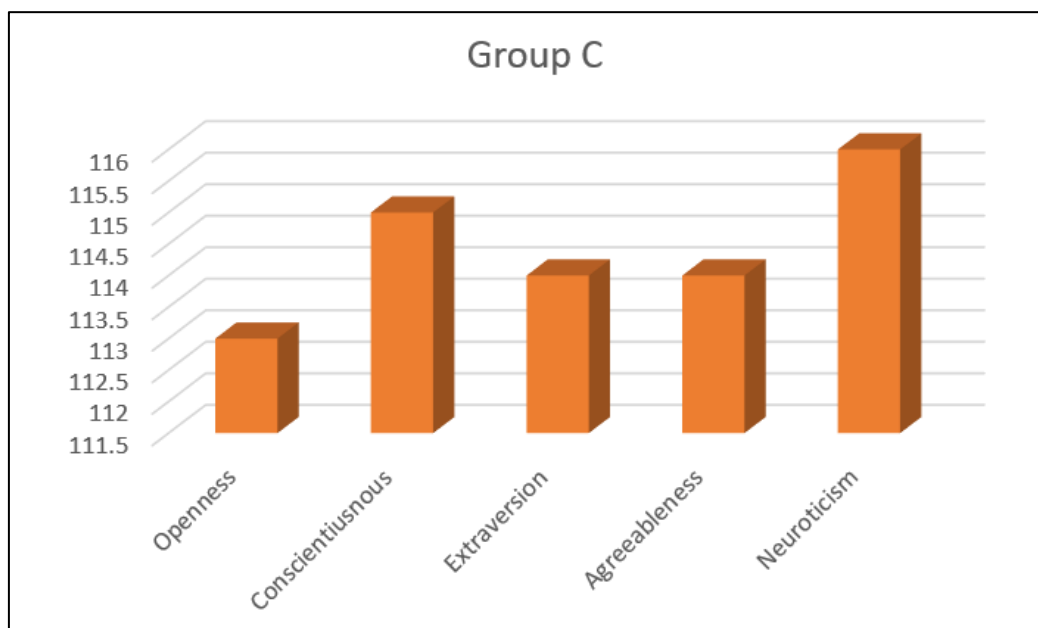


*Figure XI: Group C Results*

This research builds by introducing a methodology designed for social media user grouping. The results achieved through the combination of the Big Five Personality model and K-Means clustering not only enhance the accuracy but also offer a model that is useable to various platforms.

**Conclusion and Recommendations**

In conclusion, the research validates the feasibility of personality-based user grouping in social media, archived by combining the K-Means clustering algorithm and the Big Five Personality model. This approach efficiently categorizes users into distinct clusters, reflecting their diverse personalities. The clusters not only serve as a foundation for personalized user experience but also create an opportunity for users to connect with like-minded individuals, enhancing more meaningful interactions.

This research suggests future recommendations, emphasizing the need for continuous refinement and expansion. In the future, more advanced clustering algorithms can be used to enhance user grouping. Implementing methods for continuous user feedback, to improve accuracy and relevance. Cross-platform integrations can also be done.

In summary, this research not only establishes a robust foundation for personality-based user grouping in social media but also provides a roadmap for ongoing enhancements and adaptations to meet evolving user needs.

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# RIDE SHARERS - ENHANCING COST-EFFECTIVE DAILY TRAVEL FOR SRI LANKAN COMMUTERS THROUGH AN ANDROID BASED MOBILE APPLICATION

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**Abstract**

Ridesharing emerges as a tailored solution for Sri Lankan citizens grappling with transportation challenges like depleting oil supplies, rising gas prices, traffic congestion, and environmental concerns. The Ride Sharers application, developed using the Agile model, uniquely caters to this issue. Utilizing Android Studio, Java, and Firebase ensures a seamless experience, enabling users to effortlessly switch between roles as riders or sharers, promoting efficient vehicle sharing. Rigorous testing, spanning multiple Android brands, affirms the application's effectiveness. Extensive evaluation of ridesharing and booking functionalities ensures robust performance across various devices. The Agile methodology facilitates adaptability and responsiveness to user feedback, with ongoing research and development promising continuous improvement. A chat feature enhances user interaction, addressing communication needs. This comprehensive approach underscores the commitment to refining the application, making it a reliable and user-friendly solution for the complex transportation landscape in Sri Lanka.

**Keywords:** Ridesharing, Transportation Challenges, Agile Development, User Chats, Mobile Application

## Introduction

Traffic congestion, vehicle emissions, and the rising cost of fuel present substantial challenges in the transportation sector of developing nations, notably Sri Lanka. The prevalence of vehicles in urban areas exacerbates these issues, prompting the need for a strategic approach to optimize vehicle usage, like maximizing car occupancy (Chorfi et al., 2015).

In situations where individuals lack personal vehicles, people of various age groups often rely on taxis (tuk-tuks) and cabs. This can involve traditional methods like visiting tuk-tuk parks or using modern solutions like ride-hailing apps. Despite these options, persistent challenges such as traffic congestion and environmental impact persist.

This research aims to address transportation challenges in Sri Lanka through the development of "Ride Sharers," a mobile application tailored for carpooling and ridesharing. The application, following the System Development Life Cycle (SDLC) and Agile methodology, incorporates ride booking and sharing features. The foundation of

the research is a thorough survey on transportation costs during the requirement-gathering phase, guiding subsequent system planning with budget and time estimations. The design phase involves creating a detailed framework, including use case diagrams, activity diagrams, class diagrams, flowcharts, ER diagrams, database models, and architecture diagrams. Developed using Java in Android Studio, the application undergoes comprehensive testing, supported by a detailed test plan.

The significance of this research lies in its potential to transform daily commuting. By enabling vehicle sharing among individuals from the same location, the "Ride Sharers" application provides a practical solution to reduce travel costs and contribute to environmental conservation. This research addresses a crucial gap in Sri Lanka's transportation sector, emphasizing the transformative impact of innovative ridesharing solutions tailored to the unique needs of the local community.

### *Objectives*

Objective 1: Enhance Cost Efficiency - Facilitate a substantial reduction in individual transportation expenses by encouraging users to share rides.

Objective 2: Optimize Vehicle Capacity - Strategically maximize the utilization of empty seats within vehicles, ensuring a more efficient and eco-friendly transportation system.

### *Aim*

The primary aim is to revolutionize daily commuting for Sri Lankan citizens through the Ride Sharers Android application, promoting collaboration to seamlessly share rides, reduce transport costs, and enhance sustainability.

### Methodology

The research strategy employed in this study centers on the Agile Methodology within the System Development Life Cycle (SDLC). Agile was chosen for its adaptability to evolving requirements, enabling prompt adjustments without project delays. This approach ensures high-quality outcomes while maintaining control over the development process. The Agile model facilitates ongoing updates, allowing the incorporation of the latest features post-application build.

### *Requirement Definition*

In this comprehensive phase, the team executed brainstorming, literature review, and discussions. This involved scrutinizing approximately thirty relevant research papers to extract essential insights, with the overarching goal of identifying both functional and non-functional requirements crucial for the successful realization of the project objectives. After dedicating days to scouring through the internet and examining previous works in foreign countries, I gained valuable insights into a few key requirements essential for the project's success.

Functional Requirements:

1. Efficient ride-sharing functionality.
2. Seamless user interface for booking and sharing rides.
3. Effective chats between driver and passenger (sharer and joiner).

Non-Functional Requirements:
1. Real-time data integration for dynamic user experience.
2. Scalability to accommodate future updates.
3. Faster performances for hassle free usage.

### *Planning*

This stage involved meticulous planning of budget, time estimation, and mobile application diagrams. Factors like network, hardware, and associated costs were considered in budget planning. Time estimation was facilitated through Gantt charts in Microsoft Project, outlining tasks and timelines for efficient project management.

### *Design and Development*

The design phase incorporated Adobe XD for interface design and Android Studio for application development. Pre-development diagrams, including architecture diagrams, system navigation diagrams, use case diagrams, ER diagrams, flowcharts, and activity diagrams, were crafted to streamline the development process.
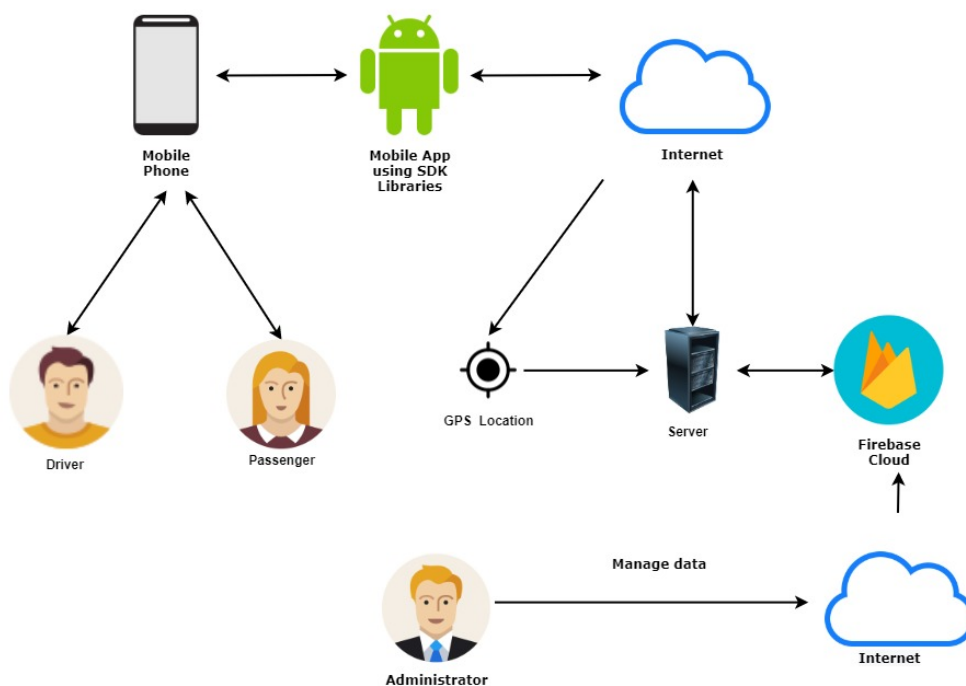


*Figure 1: Architecture Diagram of Ride Share*
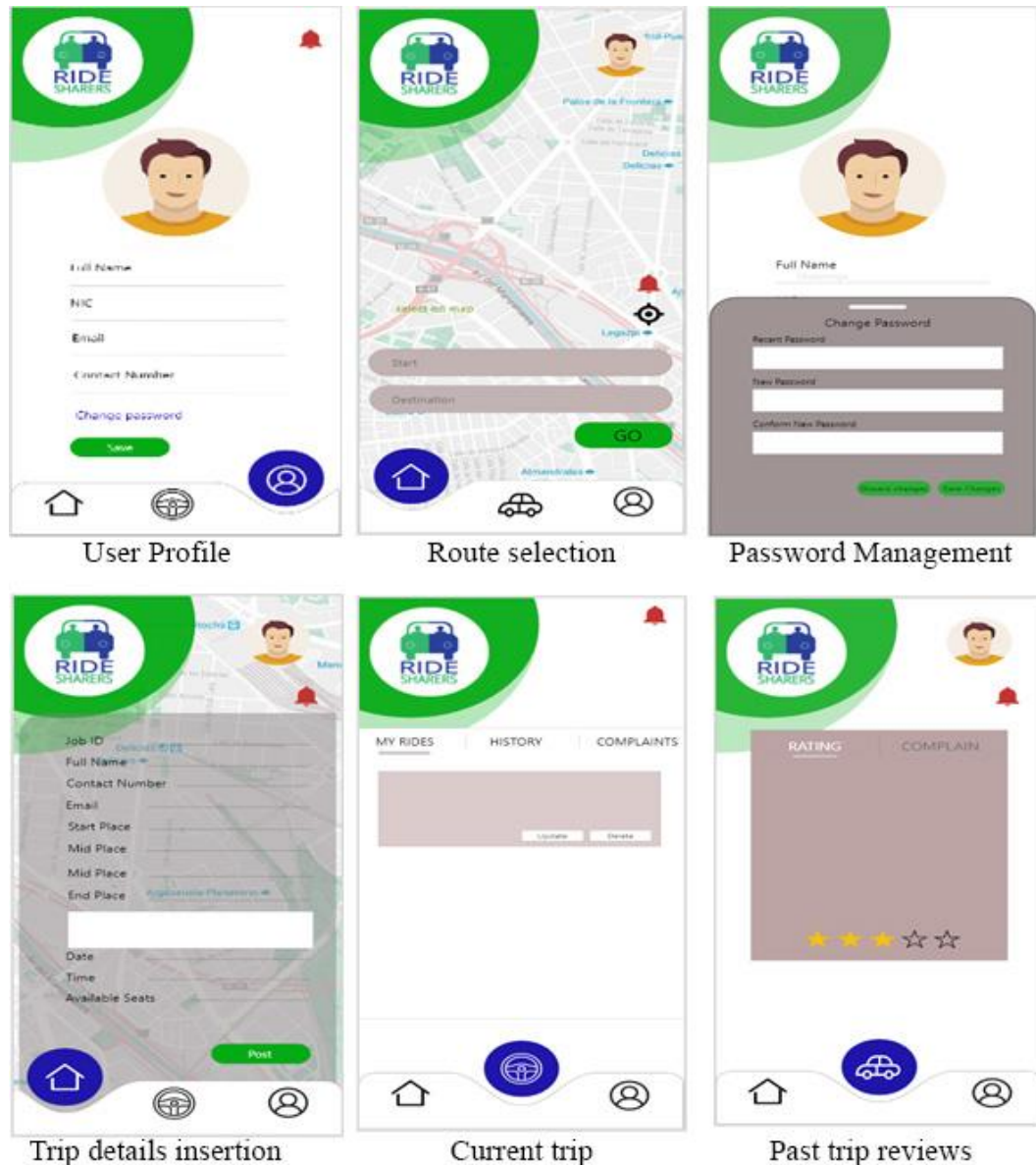
*Figure 2: User Interfaces of Ride share – Prototypes*

***Implementation***

Application development occurred using Android Studio and Java programming language. XML was utilized for interface design, enhancing the overall user experience. Firebase served as the chosen database for real-time data integration, while Google Maps API facilitated precise location extraction and search functionalities.

In the implementation phase, the driver's side of the app smoothly handles the sharing trip function. This involves sharing the driver's current location, trip route, and time, along with vehicle details. Team use Google APIs, like geolocation, directions, and places, along with a few other minor ones, to get accurate location and trip details. Riders can check shared rides in the app, and they can instantly message or call the driver, thanks to the quick updates provided by the Firebase Real-time Database.

### Review and Monitoring

Post-application development and testing, the focus shifts to continuous improvement. Future updates will introduce the latest features and address any identified bugs, ensuring the application remains up-to-date and user-friendly.
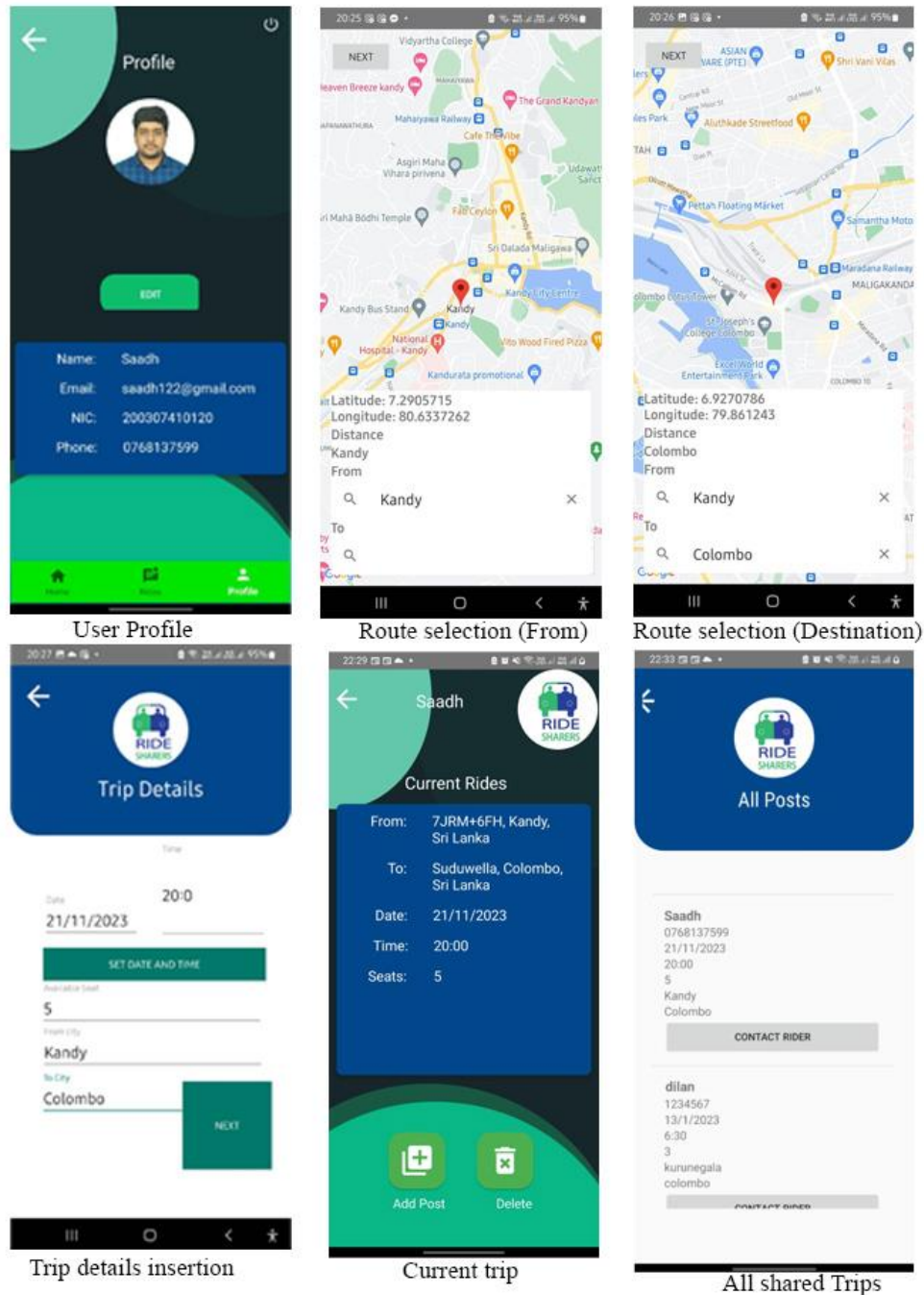


*Figure 3: User Interfaces of the Application*

### Technologies Used

Table 1: The Technologies Used in The Development

| IDE | Android Studio |
|---|---|
| Programming Language | JAVA |
| Database | Firebase |
| API | Google Maps API |

### Research Strategy

The research employed a combination of literature review, discussions, and technological analysis to inform the application development process. A broad spectrum of research papers was scrutinized to ensure the alignment of the developed application with contemporary industry standards and user expectations.

### Sample Selection and Data Collection

The study did not involve a specific sample selection, as the focus was on the development of a mobile application rather than empirical data collection. Instead, the research drew insights from existing literature and technological analysis to inform the application's design, development, and subsequent refinement.

### Results

The Ride Sharers application successfully enables ridesharing among Sri Lankan users, meeting predefined criteria during rigorous testing. However, a notable operational aspect requires potential sharers to directly contact riders for booking rides. The absence of prior research on regular ridesharing among daily commuters in Sri Lanka highlights the significance of team's contribution in addressing this specific gap in the transportation landscape.

### Test Cases

Ensuring seamless functionality, operational performance under various conditions, user-friendly interfaces, and effective communication features, the tests validate the application's suitability for the unique needs of Sri Lankan commuters. The most important test cases are provided below.

### Ride Sharing Test

Here the driver will log into the application and share a ride.
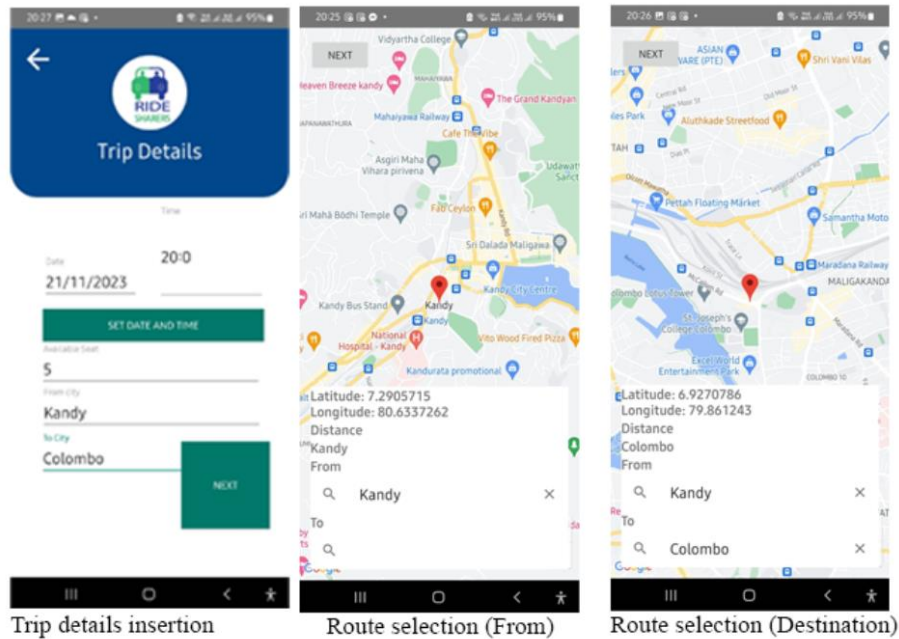
Figure 4: Adding trip details.

*Ride Joining Request Test*
The passenger will check whether the shared ride is available and can join it.
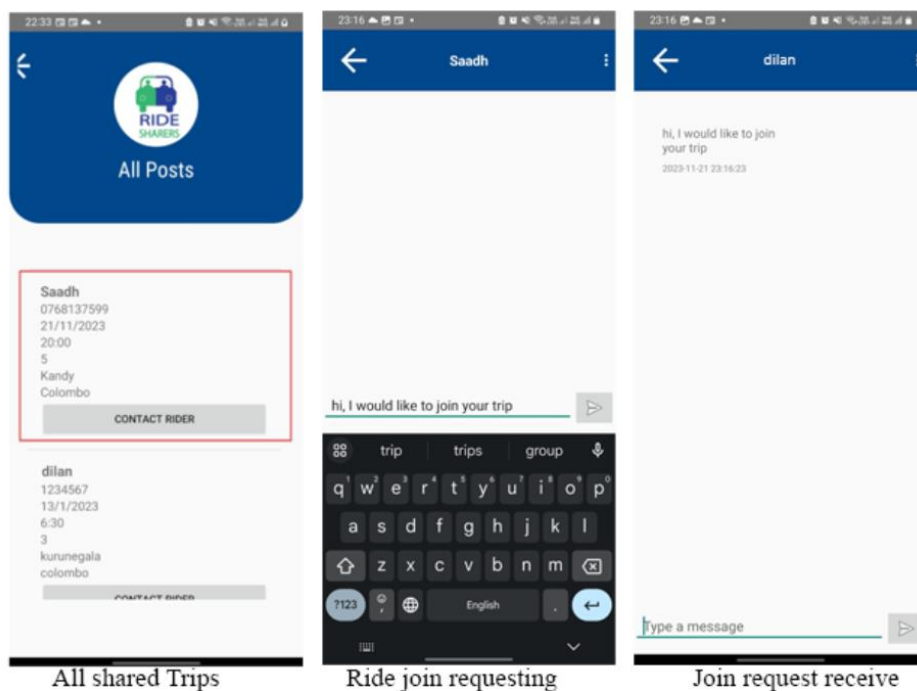


Figure 5: Ride join request.

Validation of the test cases affirms the successful functionality of the ride-sharing feature within the application. While its effectiveness is demonstrated, opportunities for improvement lie in enhancing UI consistency. Additionally, future developments could

include the expansion of the application to cater to iOS users, broadening its accessibility and usability across different platforms. These considerations mark potential avenues for refining and extending the application's capabilities.

**Discussion**

The absence of prior research on daily ridesharing in Sri Lanka underscores the novelty and importance of the study. The Ride Sharers application addresses a unique aspect of commuting within the country, presenting an innovative solution to the transportation challenges faced by daily commuters and workers.

While the application serves as a pioneering effort to promote ridesharing, limitations exist. The user's requirement for a smartphone, stable internet connection, and GPS functionality could exclude certain demographics. Additionally, users need basic application knowledge, potentially limiting the accessibility of the platform.

The direct calling approach for booking rides, while functional, may pose scalability challenges as user numbers increase. Future research and development efforts could explore integrating more user-friendly booking methods, enhancing the overall user experience.

In summary, the Ride Sharers application not only addresses a specific research gap in Sri Lanka but also opens avenues for further enhancements and exploration. The limitations identified pave the way for future refinements and improvements, ensuring the continuous evolution of ridesharing solutions tailored to the unique needs of Sri Lankan users.

**Conclusion and Recommendations**

In conclusion, the successful development of the Ride Sharers application marks a significant milestone in providing ride-sharing capabilities to daily commuters in Sri Lanka. The project, conducted in multiple stages, commenced with an extensive requirement gathering process through surveys, shaping the aims and objectives of the research.

Despite facing challenges such as economic and fuel crises, the planning process proceeded, culminating in the decision to develop a mobile application. The agile model facilitated adaptability, allowing for adjustments as needed. The design and development phase witnessed iterative changes reflecting the agile approach, challenging the team to overcome obstacles and notably enhancing their Java knowledge.

Testing, a crucial aspect of the project, incurred expenses due to the nature of a ride-sharing application, requiring extensive fuel usage. However, the team's gathered knowledge enabled successful design and testing, resulting in an operational application used for daily commuter ridesharing.

The current application incorporates fundamental features like Firebase data imports, map pointers, and ride booking. Looking forward, future development aims to enrich the user experience for both riders and drivers. Planned enhancements include live path viewing, tracking sharers' locations, introducing a chat function with ride partners, and implementing a payment system for sharers. This envisioned evolution positions the

application not only as a practical transportation solution but also as a socially engaging travel platform, aligning with user needs and desires.

### *Recommendations for Future Research*

The success of this project opens avenues for further research and development. Future studies could delve into refining the user interface and experience, ensuring a seamless and user-friendly platform. Additionally, exploring sustainable practices within the ridesharing framework could contribute to environmental conservation. Research on the societal impact and behavioral aspects of adopting ridesharing as a daily commute strategy would further enrich the understanding of its implications.

The Ride Sharers application, with its current and potential features, stands as a testament to the adaptability and innovation achievable through collaborative research and development efforts. The ongoing commitment to enhancing user satisfaction and addressing evolving transportation needs positions the application as a promising solution in the dynamic landscape of Sri Lanka's daily commuting challenges.

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# TRASH TO TREASURE: EFFECTIVE WEB-BASED WASTE MANAGEMENT SYSTEM FOR MAKING LINKAGE BETWEEN WASTE SOURCES JUNK-BUYERS

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**Abstract**

"Trash to Treasure" proposes a groundbreaking online waste management system for Sri Lanka, addressing the inefficiencies in waste collection and disposal. Serving as both a marketplace and a solution, the platform connects responsible garbage buyers with producers, focusing on plastics, polythene, and e-waste. Real-time location tracking ensures accurate waste disposal. This initiative aims to transform waste into a valuable resource, fostering a circular economy, reducing environmental impact, and creating economic opportunities. The existing challenges, such as low-value waste transactions and lack of a centralized market, are addressed through an online platform, promoting ethical waste exchange. The Agile Methodology is adopted for system development, allowing flexibility to adapt to evolving requirements, ensuring the timely delivery of a high-quality product. "Trash to Treasure" envisions a cleaner, greener, and more prosperous future for Sri Lanka through sustainable waste management and environmental responsibility.

**Keywords :** Agile methodology, Circular Economy, Real-time Location Tracking, Sustainability, Waste Management,

**Introduction**

Waste management in Sri Lanka poses a persistent challenge. Addressing this issue proactively, "Trash to Treasure" emerges as an innovative online waste management system transforming waste collection into a profitable venture. Functioning not merely as a waste management system but as a marketplace, Trash to Treasure connects responsible garbage buyers with producers. This platform facilitates the buying and selling of various waste products, with a focus on plastics, polythene, and e-waste, aiming to both diminish environmental impact and generate economic returns.

A key feature of Trash to Treasure is the utilization of real-time location tracking, ensuring the efficient and precise disposal of waste. All stakeholders in the waste management ecosystem can establish accounts, including both consumers and purchasers. The overarching objective of Trash to Treasure is to propel sustainability, mitigate pollution, and nurture a circular economy by offering a practical and environmentally responsible waste management solution. This initiative invites collaborative engagement towards a cleaner, greener, and more prosperous Sri Lanka, envisioning a sustainable future achieved through the transformation of waste into valuable resources.

*Objectives*

Objective 1: Develop a web application for managing waste

Objective 2: Make relationship between customer and sellers

*Aim*

Manage and dispose waste collections properly and give value to waste.

**Methodology**

The System Development Life Cycle process that was selected for the study is represented by the Agile Methodology. This model was chosen because it can quickly adapt to new requirements without delaying the project. Agile gives greater control over work and facilitates the delivery of high-quality products when compared to other SDLC process models.

*Requirement Definition*

In this phase of the research, requirements have been systematically compiled through diverse methodologies, including idea generation, literature searches, and extensive discussions. The software development life cycle has been enriched by the assimilation of information obtained through these processes. Approximately five research papers pertinent to the project were critically examined during the literature review, and comprehensive discussions were conducted with both team members and the instructor to discern essential requirements. The collaborative analysis and synthesis of ideas derived from various sources contribute to the foundational understanding of the project's prerequisites within the academic framework.

*Design and Development*

The user interfaces for Trash to Treasure have been developed using Figma, while the website itself has been constructed utilizing Visual Studio. The website's implementation involves the utilization of HTML, C#, and JavaScript programming languages. Preceding the application development phase, comprehensive diagrams have been employed to expedite the website design process. Architectural representations and system navigation diagrams have been articulated, and additional diagrams encompassing use case diagrams, entity-relationship diagrams (ER), flowcharts, and activity diagrams will be furnished in advance of the program development stage. These schematic representations serve as integral tools in the conceptualization and structuring of the software, adhering to best practices in academic software engineering methodologies.
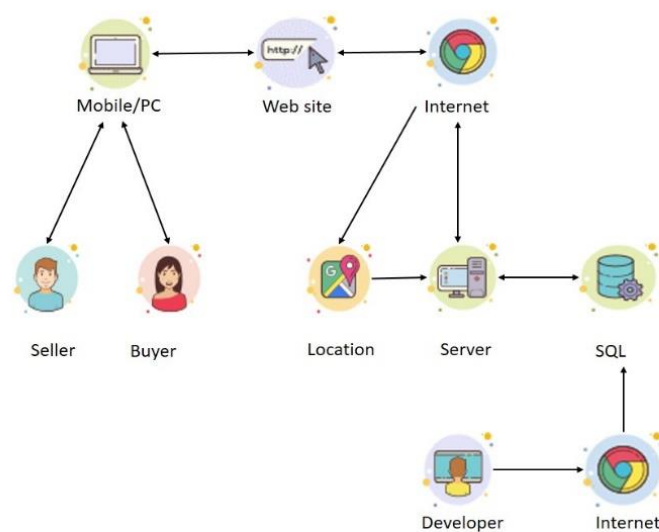


*Figure 1 : System Architecture Design*

***Technologies***

| IDE | Visual Studio |
|---|---|
| Programming Languages | HTML, C#, Java Script |
| Database | SQL Database |
| API | Google Maps API |
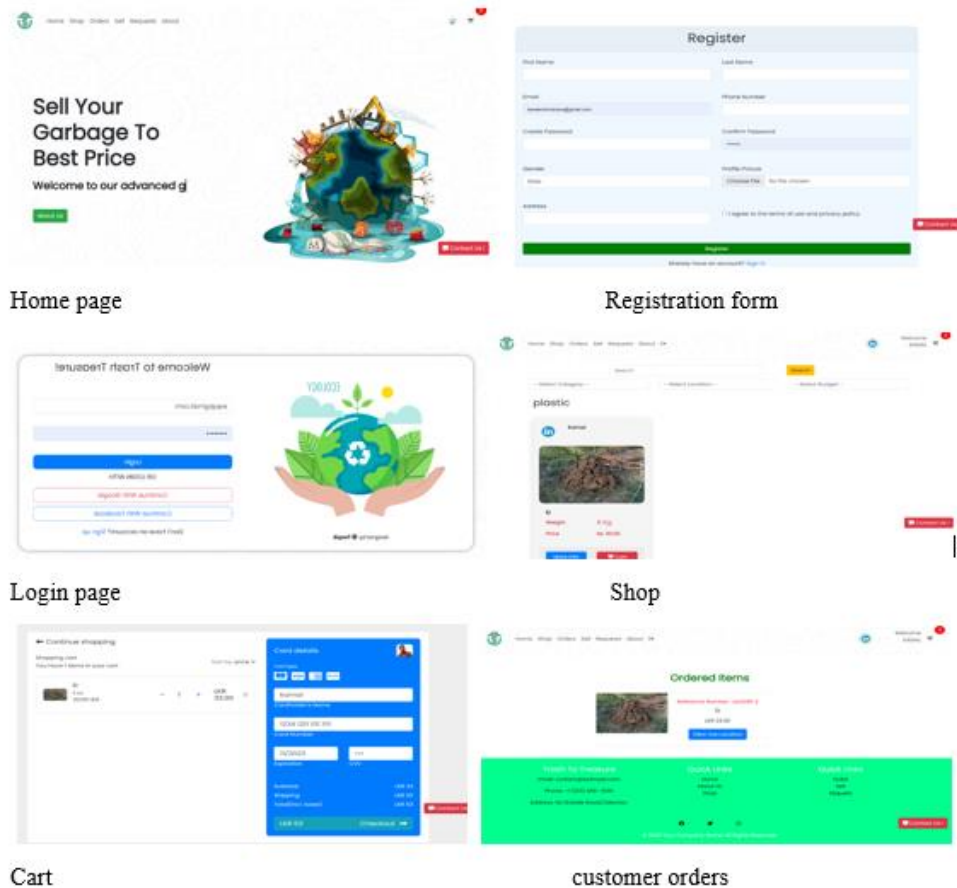


*Figure 2 : Website Interfaces*

***Test Cases***

Testing is a cornerstone of software development, ensuring that the "Trash to Treasure" Waste Management Website meets its objectives by providing reliability, functionality, and user-friendliness. The project employed a variety of testing methodologies, including manual and automated testing, unit testing, integration testing, and regression testing, to comprehensively assess different aspects of the platform.

The testing process covered critical phases, including navigation, selling, login, registration, and request functionalities. The "Trash to Treasure" website was rigorously tested, addressing issues promptly and remaining flexible to accommodate updates.

Login          Register



Item list
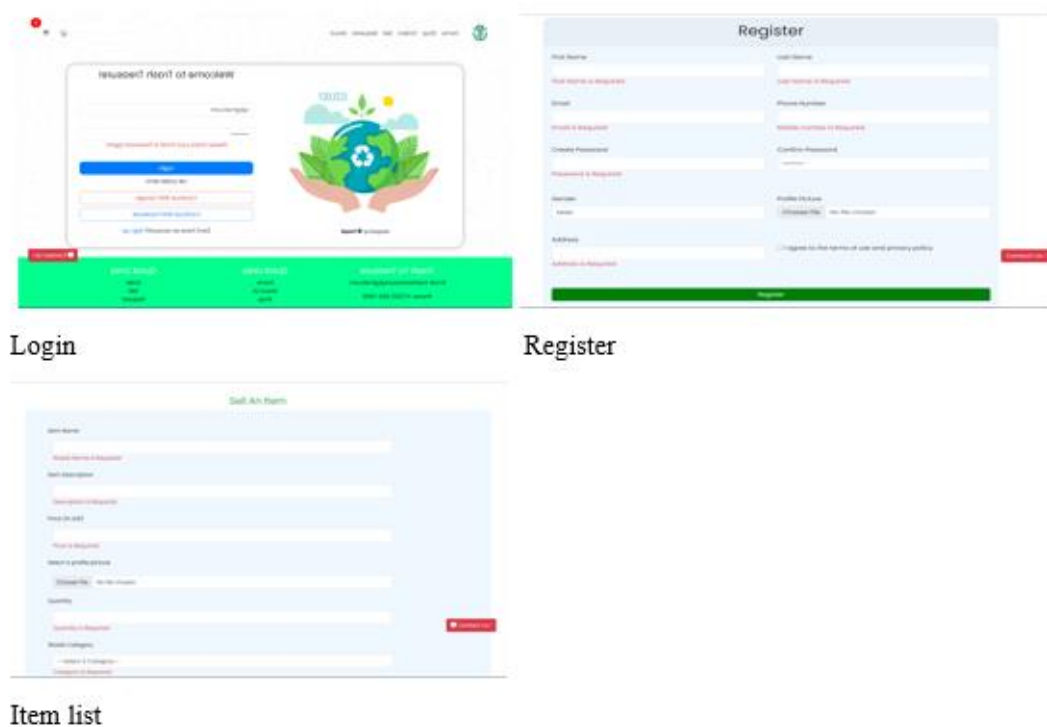
*Figure 3 : Test cases*

**Results**

Resulting from the research, the successful development of the Trash to Treasure website has transpired. Through this platform, users engage in buying and selling their waste collections, ensuring efficient management. Users can establish and manage their accounts seamlessly. The incorporation of Google Maps enables users to pinpoint collection locations for efficient retrieval. Online payment methods streamline transactions, enhancing user convenience.

**Discussion**

We looked for other works that are similar to our suggested research before we started this project. We have reached a decision about them after reading and comprehending them. The most crucial elements necessary for the success of our report will be included in these summaries.

Hassan Jabar and team have introduced an online trash management system aimed at efficient waste distribution and collection in smart cities. The solution, developed using Java, XML, C++ net, Framework 2.0, and 4G technology, integrates web-based and mobile application interfaces, achieving an impressive 80% faster convergence than conventional methods. Real-time data visualization using the Google Maps API enhances route optimization, contributing to economical and eco-friendly garbage management.

Zainal Hisham Che Soh and team have devised an Internet of Things (IoT)-based smart waste collection monitoring and alert system. This solution, utilizing an Arduino Uno board with an Ethernet Shield and an ultrasonic sensor, effectively monitors garbage bin levels. The system sends alerts to cleaners via Ubidots IoT Cloud, offering a promising approach to improving

garbage collection efficiency, mitigating environmental impact, and reducing health risks associated with ineffective waste management.

Abdul Mannan Zafar and team propose a GIS-based waste-to-energy and improved solid waste management practice for urbanizing and industrializing regions, focusing on Lahore, Pakistan. The solution involves digitizing municipal solid waste disposal using GIS, optimizing waste-to-energy plant sites, and employing cutting-edge sensors for online monitoring. The study evaluates waste composition, quantity, and the cost-effectiveness of incineration as a waste-to-energy option. The outcomes are crucial for waste-to-energy deployment in Lahore and similar urban areas.

**Conclusion and Recommendation**

The "Trash to Treasure" Waste Management Website project signifies a comprehensive effort to tackle waste management challenges while promoting environmental sustainability. This initiative not only provides a user-friendly platform but also incorporates advanced technologies for efficient waste exchange. The project's success is attributed to a robust foundation, inclusive user integration, and a systematic testing and improvement approach. Valuable insights have been gained, particularly in waste categorization, order fulfillment, and user experience enhancement. Looking forward, recommended enhancements include incorporating user reviews and ratings, implementing a user verification system for increased trust, collaborating with local recycling centers, and introducing a waste storage center with an online delivery service. These recommendations position the project to further its positive impact on waste management practices, emphasizing transparency, security, and a holistic approach to environmental responsibility.

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# A MACHINE LEARNING APPROACH FOR SNAKE IDENTIFICATION AND GEOGRAPHIC MAPPING OF SNAKE PREVALANCE IN SRI LANKA

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**Abstract**

This system is a comprehensive solution that combines a snake identification mobile application and a web platform to provide valuable information about snake prevalence in Sri Lanka. The mobile application utilizes Machine Learning technology to identify different species of snakes in real-time. Users can take a photo of a snake they encounter, and the application will analyze the image to identify the species, providing the snake name. The web platform displays the data collected from the mobile application, illustrating the prevalence of different snake species in different regions of Sri Lanka. The platform also offers a wealth of educational resources about snakes. Mobile Application will get the location details of the user after the identification and save it in a database to generate Maps utilizing the data. This system aims to raise awareness about snakes, promote safety and conservation, and aid people make informed decisions when encountering these fascinating and often misunderstood creatures.

**Keywords**: Machine Learning, Image Identification, Snake Identification, Snake Prevalence

**Introduction**

Sri Lanka boasts one of the world's highest rates of ecological endemism, housing an extraordinary diversity of animal and plant species, particularly in the realm of snakes. Despite this rich biodiversity, the country also holds the unfortunate distinction of having the highest rate of snake bites globally. This discrepancy is exacerbated by a lack of public awareness regarding endemic snakes, leading to harmful encounters and fatalities. In response to this issue, recent advancements in artificial intelligence and computer vision have paved the way for a potential solution—a mobile application utilizing image recognition technology to identify endemic snake species. This application not only aids in snake identification but also compiles location data, creating a comprehensive database. By employing clustering techniques, the app generates heat maps, offering valuable insights into snake species prevalence in Sri Lanka. Such an innovative tool addresses the pressing need for public education and facilitates a more informed and proactive approach to snake encounters in the region. The aim of this research is to generate heat maps for the visual representation of snake prevalence in Sri Lanka. This endeavor employs a snake identification mobile application with the intention of assisting the general public in acquiring knowledge regarding the prevalence of various snake species in the region. The research objectives are to employ clustering techniques and data derived from snake identifications to generate heat maps, offering a visual depiction of snake prevalence in Sri Lanka. Additionally, the project seeks to develop a comprehensive database on endemic snakes through the utilization of crowd-sourcing methods.

**Methodology**

For this research Agile methodology was selected. Agile methodology is widely used in both mobile and web application development, since there are various snake species in Sri Lanka, highly venomous and common snakes were selected for the research. King Cobra, Sri Lankan Krait, Sri Lankan Green Viper and Russell's viper were selected as highly venomous snakes. Those snakes were the most common and highly venomous snake that can be found in Sri Lanka according to the data that gathered from the questionnaire. Images were collected from websites and Google image. 100 different images were collected for each snake; total 400 images were collected for the research. Since android users are common in Sri Lanka, Android Mobile Application were decided to implement.
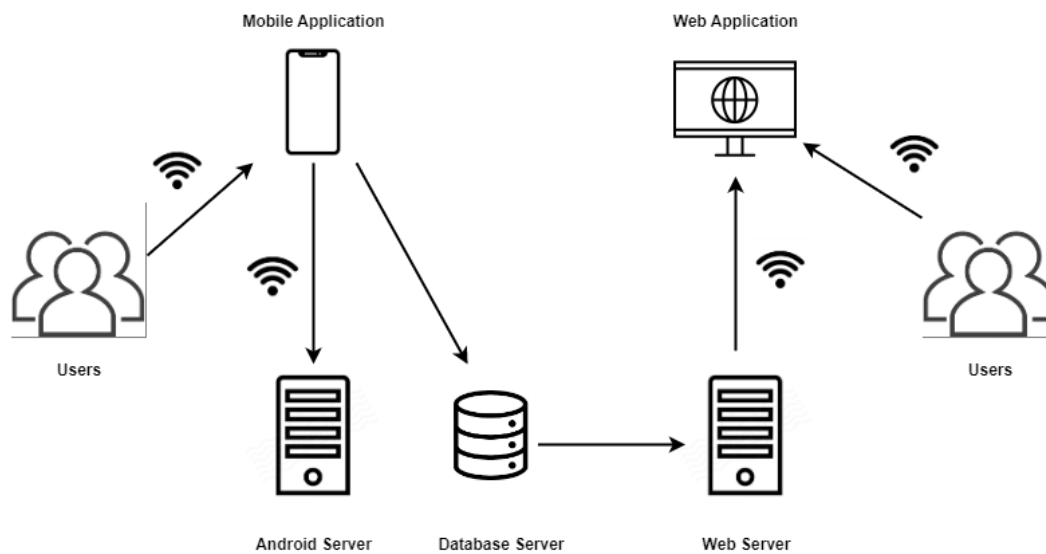


*Figure I: System Architecture Diagram*

*Real Time Snake Identification Process*
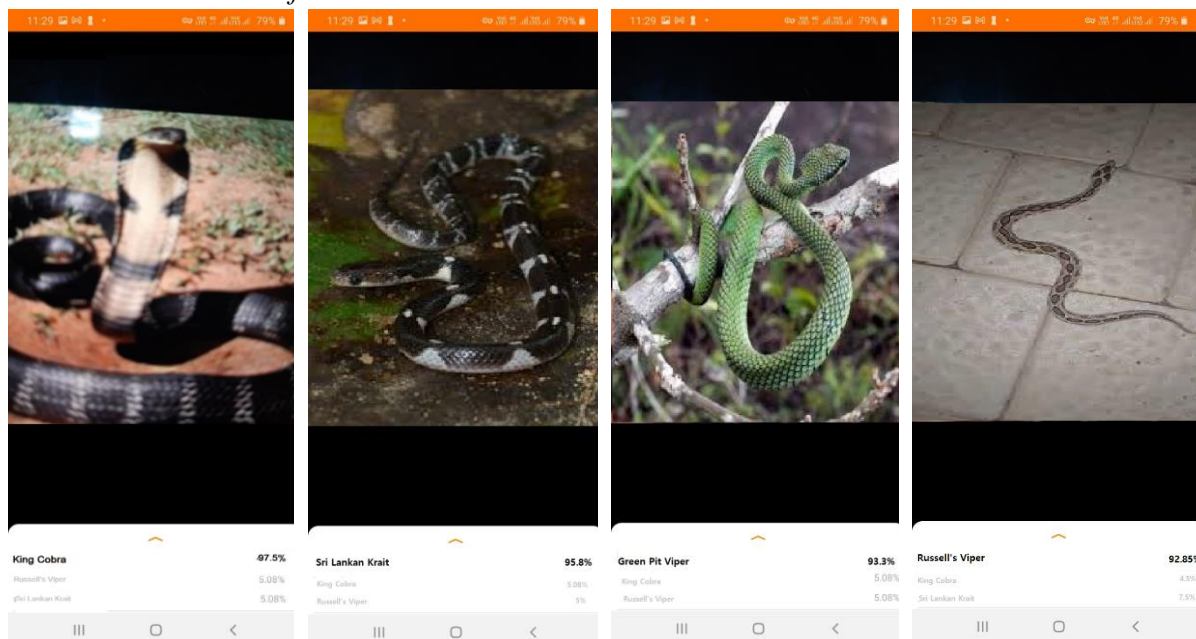


*Figure II: Identifying Snakes from App*

After collecting all the images for the research, training the machine learning model was started. Yolo framework was used to train the model for this research. 100 images were trained for each snake. 100 images were divided to two parts. Training images and testing images were divided before starting to train the model. Model was trained few times to get a good accuracy for each snake. 90%- 100% were the targeted accuracies for each snake in this research.

Mobile application was implemented using Android Studio. Mobile application was creating as a simple mobile app for the users. Users can login, sign up to the app and after successfully login, users can use the mobile application to identify snakes in real time from their Android Mobile Phone.

When users identify a snake in real time, mobile app will show the name of the snake and the accuracy of the identification. After that identification process, the snake's name and the location details (latitude and longitude) will be stored in the database with a primary key. From that database heat map will be generated in the web application. Mobile application is connected to the MySQL database and web application also connects to it. While the mobile application is storing the data, the web application will generate the heat map. Users can see the snake prevalence heat map from the web application. Heat Map will be a simple map to understand for common people about the snake prevalence in Sri Lanka. R-Script will generate a heat map using the data of the database in the web application.

**Result and Discussion**

Total 400 images were trained with 70 epochs and 15 samples. 85% of the samples were used to train the model. 85 images per each class were used to train the model in this project. Totally 340 images were used to train the model with 70 epochs in this scenario.

Table I Data-Set

| Train Images | 340 | 85% |
|---|---|---|
| Test Images | 60 | 15% |
| Total Images | 400 | |

Table II: Accuracy per Class

| **Class** | **Accuracy** |
|---|---|
| King Cobra | 0.93 |
| Sri Lankan Krait | 0.93 |
| Green Pit Viper | 1.00 |
| Russell's Viper | 0.93 |

Table III: Report of Accuracies

| Accuracy for a snake | Times we got the accuracy | Percentage |
|---|---|---|
| 75%-77% | 0.2 | 20% |
| 78%-80% | 0.25 | 25% |
| 81%-83% | 0.555 | 55.5% |
| 84%-87% | 0.6 | 60% |
| 88%-90% | 0.75 | 75% |
| 91% | 0.8 | 80% |
| 92% | 0.8 | 80% |
| 93% | 0.88 | 88% |
| 94% | 0.9 | 90% |
| 95% | 0.9 | 90% |
| 96% | 0.99 | 99% |
| 97% | 0.98 | 98% |
| 98% | 0.98 | 98% |
| 99% | 0.95 | 95% |
| 100% | 0.25 | 25% |

Accuracy per class is calculated using test samples. 15% were used to test the model. That 15% were never used to train the model. After the model has been trained on the training samples, test samples were used to check how well the model is performing on new, never before seen data. Since 70 epochs has been used to train the model in here.
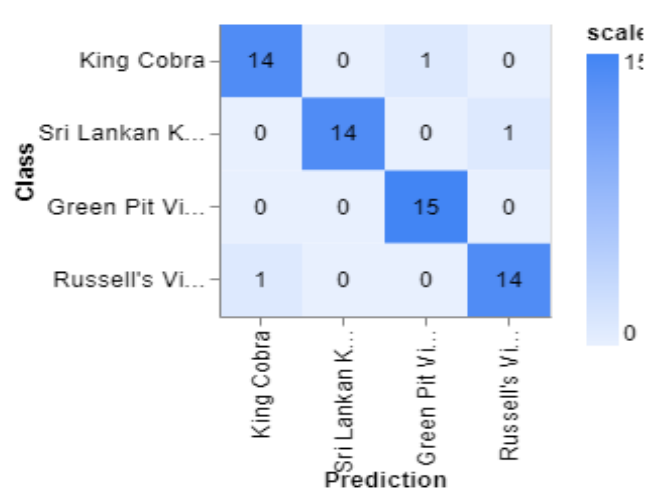


*Figure III: Confusion Matrix*

Figure III is illustrating the confusion matrix of the trained model. This summarizes how accurate the model's predictions are. The Y axis (class) represents the class of the samples. The X axis (predictions) represents the class that the model after learning. Evaluation can be done using confusion matrix for the classification model. It compares the actual labels of a data set with the predicted labels generated by the model. The matrix consists of four metrics, namely True Positive (TP), False Positive (FP), True Negative (TN), and False Negative (FN). As

mentioned earlier one snake (class) had 15 samples. A total of 57 samples were correctly predicted out of total 60 samples. Therefore, final accuracy is 95% of the model. There are 0s in the confusion matrix. In that kind of cases, model doesn't confuse in there.
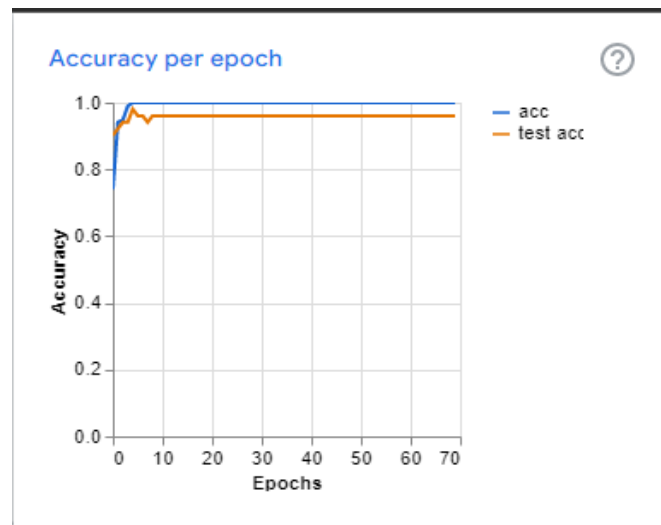


*Figure IV: Accuracy per Epoch*

Figure IV represents the accuracy for epoch in this trained model. Accuracy is the percentage of classifications that the model gets while training. The model gets 0.93 accuracy and 1.00 accuracy. That defines model classified 93 samples right out of 100, the accuracy is 93/100 = 0.93. If the model's prediction is perfect, the accuracy is 1.00.



*Figure V: Loss per Epoch*

Figure V illustrates the loss per epoch on this model. Loss is a measure for evaluating how well the model has learned to predict the right classifications for a given set of samples. If the model's predictions are perfect, the loss is 0. Otherwise the loss is greater than 0.

After the training of the model, the model was connected to the mobile application. Mobile application is storing the data in a database after the identification process.
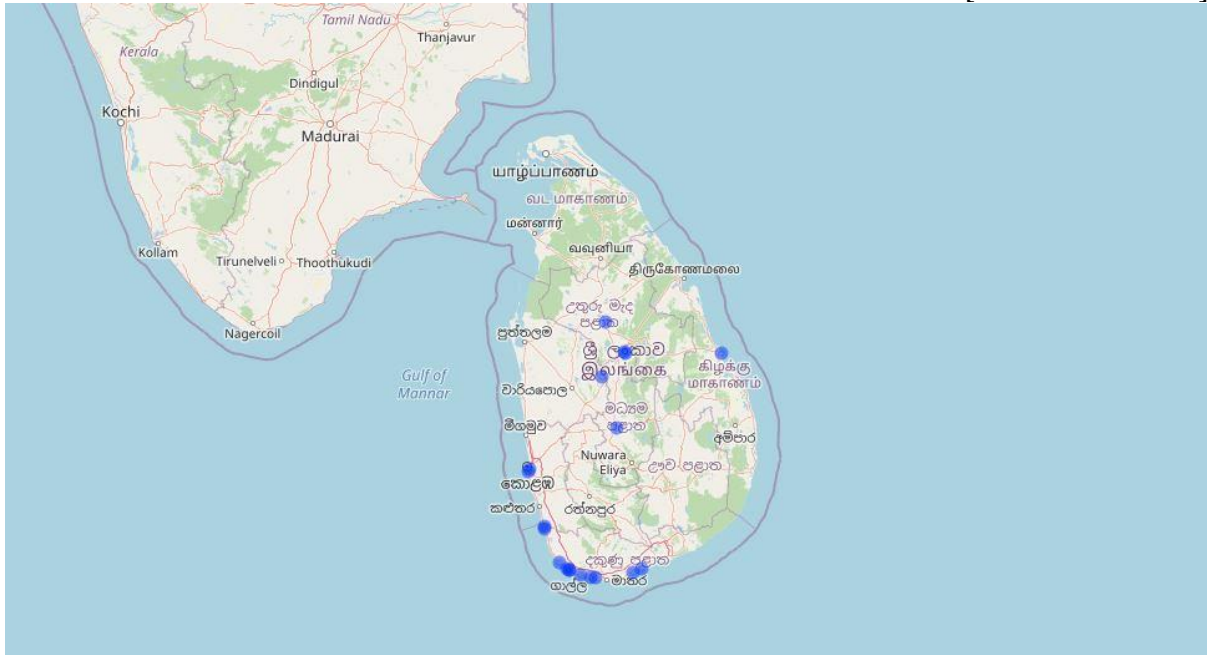
*Figure VI: Heat Map 1*

After saving a good amount of data in the database, R-script can generate a real time map to illustrate the snake prevalence. Since heat maps are easy to understand common people can get an idea about snake prevalence in their area for the safety.

*User Interfaces for the mobile application*



*Figure VII: Interfaces of Mobile Application*

Figure vii shows that there are two clusters have been identified based on the geo locations of the snake's data in the database. This map generates real-time. Anyone who is interested in a particular snake type can do some study based on the areas identified based on clustering.
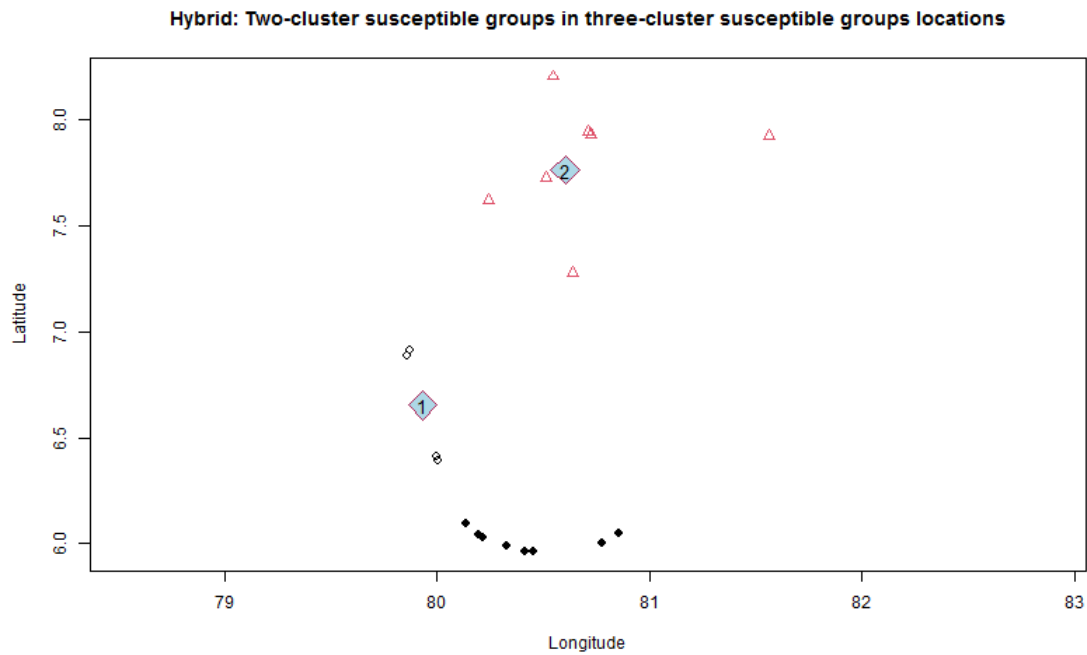
*Figure VIII: Snakes Geo Locations as clusters*
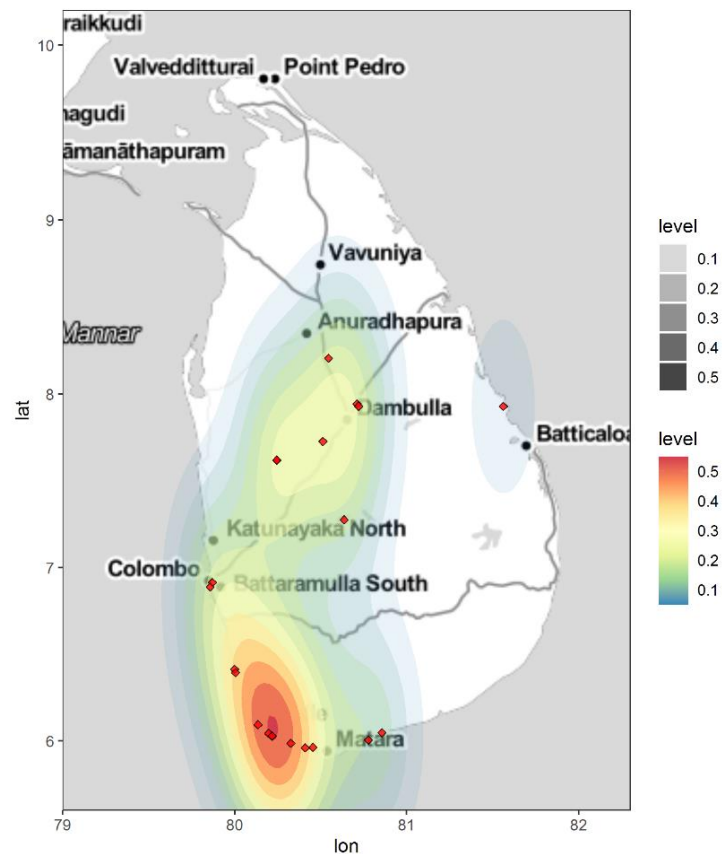


*Figure IX: Snakes Geo Locations as a Heat Map*

From above heat maps users can get a clear understanding about the snake prevalence in Sri Lanka. In these graphs, the X-axis typically represents the frequencies of latitude and longitude.
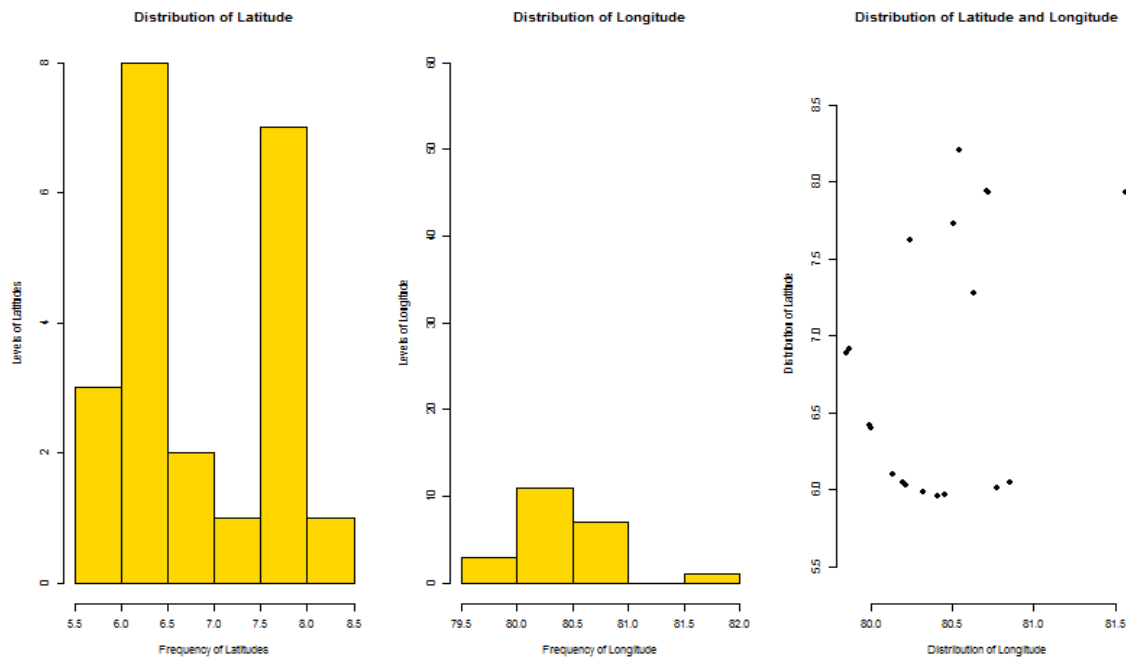
*Figure X: Snakes Geo Locations as a Histogram*

These data were collected during the testing phase and illustrated by graphs to get a good understanding. As the heat map illustrates, southern province has a high prevalence of snakes in Sri Lanka in this time period.

In this research Null Hypothesis (H0) is there is no significant difference in snake prevalence in Sri Lanka as detected by the mobile app compared to traditional methods. And alternative Hypothesis (H1) the mobile app's snake identification and location data collection result in a significantly different distribution of snake prevalence in Sri Lanka compared to traditional methods.

In other words, the null hypothesis assumes that the mobile app's data collection does not provide any new or different information compared to traditional methods, while the alternative hypothesis suggests that the mobile app does reveal a distinct pattern or distribution of snake prevalence in Sri Lanka. The significance of any differences would need to be determined through statistical analysis of the collected data.

**Conclusion and Future Work**

This study can be carried out to gain more accuracy in snake identification by using a large image size for training and can be trained on a Deep Learning algorithm such as NasNetMobile. Furthermore, more images can be collected for each snake specie and try out the accuracy of above Convolutional Neural Networks. This study is focusing on snake species in Sri Lanka. Sri Lanka is a country which has a great snake fauna. However, this study can be carried out in other countries context. This application can be modified to identify snakes in other countries and that would help many people around the world. This mobile application has limited features. Therefore, changing language settings, displaying brief information about identified snake can be added to the future versions. In future versions Mobile App can have Notification System. The application can have a notification system that alerts users to nearby areas where

specific species of snakes have been identified. This will help users take necessary precautions when visiting these areas. In next version of this mobile application can have Social Sharing feature that allow users to share their snake sightings and identification results with other users through social media platforms. In future versions Mobile Application should store more data in database such as snake's venomousness, head shape, symptoms etc. Future versions should generate more than heat maps using the upgraded database. And also can be do predictions. Web Application's upgraded versions can have more detailed maps and details about snakes.

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# THE IMPACT OF TECHNOLOGICAL ASPECTS TO WORK FROM HOME MODEL OF SCRUM TEAM

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**Abstract**

Over the past two years, Sri Lanka confronted a global pandemic issue of COVID-19 along with a rigorous crisis in the country's economic landscape. Business organizations, including individuals, had been encountering numerous challenges in procuring their day-to-day requisites in this turbulent environment. As a provisional remedy and short-term mitigation plan to address these issues the concept of Work from Home (WFH) model was introduced, and especially more precise advantage vested on Information Technology (IT) individuals due to their job preservation. As a country in the low-income category, various technological barriers were encountered as a consequential outcome. Hence, the main objective of this study is to investigate the potential technological factors affecting the selected set of software development teams who practice agile methodologies in fintech domains. The overall study was launched by identifying four variable factors affecting the technological impact in IT teams by targeting selected members of SCRUM teams of ISO:27001 certified software development companies. The study emphasizes the need for strong communication via teammates, new innovations of the technological stack to enhance the knowledge and strong awareness of latest security technologies and trends to develop minimum vulnerable products in secure environment.

**Keywords:** Innovation, Scrum, Security, Sprint, Agile

**Introduction**

The Sri Lanka is a low middle income nation with overall population density of around 22 million and annual personal income is calculated to be around 3852 USD as per World Bank report 2021 **(Group, 2021)**. The principal factor influencing the ranking of Sri Lanka from upper middle-income category to low middle-income category nation is the financial unviability due to unsustainable debt and crisis on balance of payments. The import-export level trade restrictions were the ultimate result of the crisis and therefore they affected human lives in a disastrous way. Here most of the small and medium industries collapsed due to running out of money and some companies were saved due to strong policies imposed on employees and material usage. The research is basically conducted in a temporal epoch where employees experience excessive strain in work life balance. This basically focuses on the Information Technology industry. Agile based software development is a trend in the emerging companies and the impact of work from home model on that aspect in financial solution providers in a target distribution is to be analyzed here. To reduce the expenses in a turbulent environment the government and private sector authorities suggest work from home model and

some rules and regulations are imposed on employees to focus employee to work and obtain maximum output. **(Dahanayake, 2021)**

The overall research commitment is to study the factors affecting the technological enhancement of individuals in the sector of software development in the IT industry. Here to observe the nature in statistics a small, clearly visible, and closed sample was selected with the feasibility of data collection in limited period. When we identify the basic factors which are involved in identifying technical standards will be closely monitored and to what extent the individual has achieved those factors is followed here. Then a management can understand who future and processes be continued to increase individual technical performance which is very important in 2023. With technically skilled staff the company can find new business opportunities and goals, which is the final goal in the research.

### *Objectives*
- To study current technological enhancement practices and their relationships on developing the team's technical capabilities.
- To study best practices influencing technological enhancement in a team.
- To suggest a framework that could be used for better technological enhancement practices leading to an increase in revenue.

## Methodology
### *Conceptual Framework*
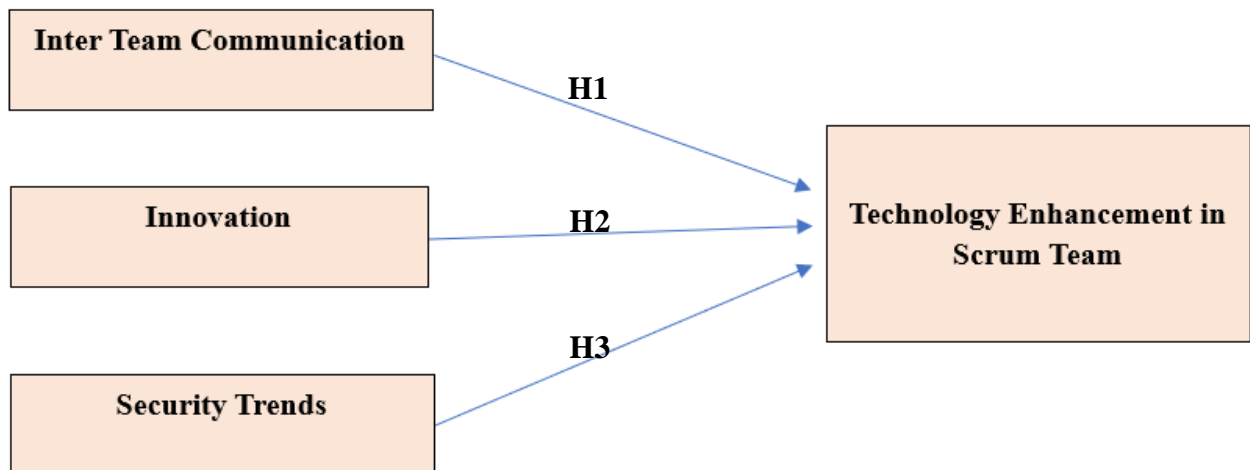


### *Hypothesis*
**H1:** Inter communication in team has a significant impact on technological enhancement of scrum team under work from home model.

**H2:** Innovations in team has a significant impact on technological enhancement of scrum team under work from home model.

**H3:** Security trends identification in team has a significant impact on technological enhancement of scrum team under work from home model.

The study proceeded with the independent and dependent variables mentioned in the conceptual map.

*Design Methodology*

*Sample Selection*

Here as per the department of census and statistics in Sri Lanka, the overall IT related population is 72000 in numbers **(DCS, 2021)**. This entire population is distributed in various fields in information technology related fields such as academic, industrial, data processing etc. From the overall population the condition of working in financial technology related scrum team only considered. Accordingly, well known scrum teams in financial solutions providing teams were considered. The used sample size was a hundred (100 individuals). The process of data collection form was selected as google form because the data collection domain is technically matured. Here a pre-defined set of questions were included so that they can pick for their choices in a short period of time by applying quantitative approach of data collection.

**Results**

*Data Analysis and Hypothetical Testing*
*STATISTICAL ANALYSIS*

*Analysis of the distribution of levels of experience in sample population*
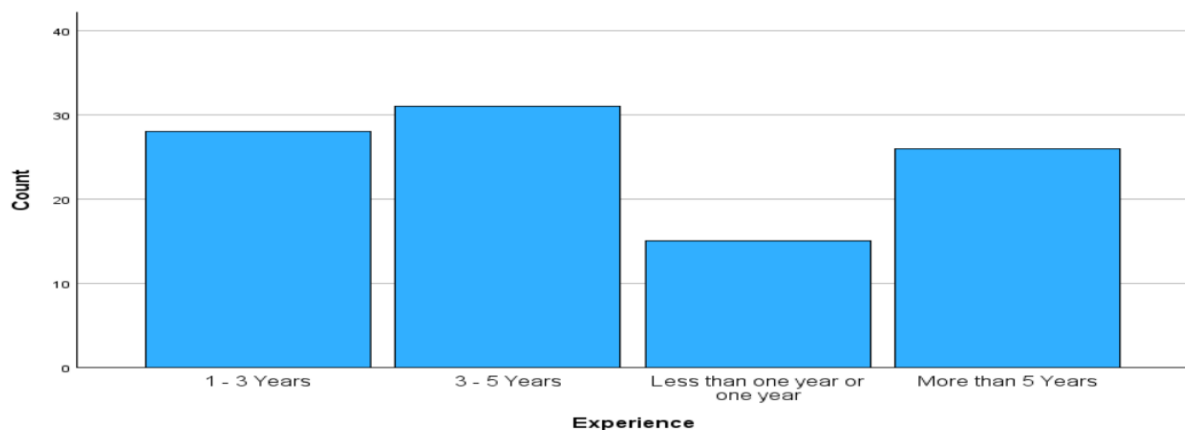


*Figure 1 : Experience Level Analysis*

According to the experience level analysis of the respondents, the maximum experience in years is 3-5 years and most respondents have experience of more than three years. The entire domain can be considered as a high skill domain which may increase the accuracy and credibility of the result.

*Analysis of the distribution of academic excellence of sample population*
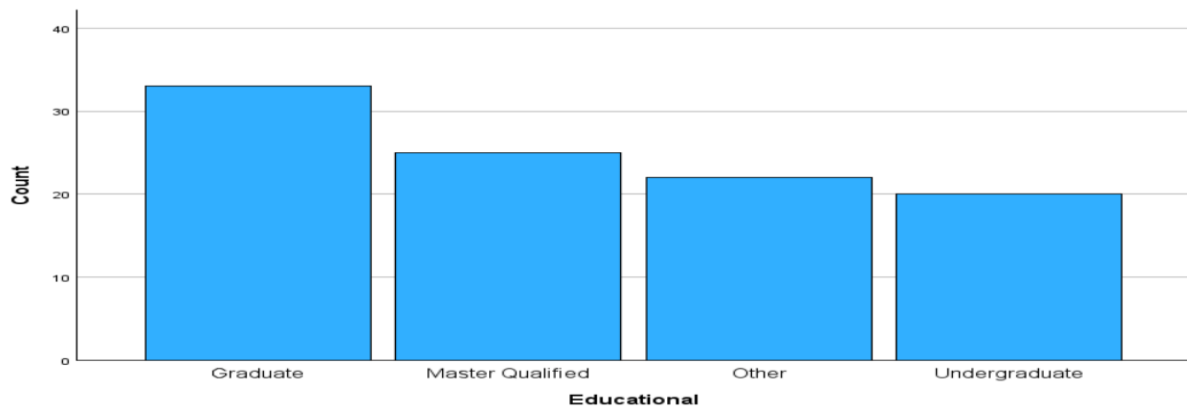


*Figure 2 : Educational Level Analysis*

As per the analysis, more than 50% of the population is pertaining to an acceptable educational background and the responses of the population may lead to more precise analysis and ending with a proper discussion to the problem domain.

### Reliability Testing

Cronbach's method of measuring reliability was used to check the reliability of the data collected. (Cronbach's alpha >= 0.7)

Table 1 - Cronbach's Alpha value table

|   | Section | Cronbach's Alpha Beginning | Cronbach's Alpha Final |
|---|---------|----------------------------|------------------------|
| 1. | Inter Team Communication (Independent) | 0.646 | 0.646 |
| 2. | Technology Enhancement in Team (Dependent) | 0.602 | 0.602 |
| 3. | Innovation (Independent) | 0.5 | 0.612 |
| 4 | Security Trends | 0.589 ~= 0.6 | 0.6 |

As per the study of Cronbach's alpha of the questionnaire innovation related question set is less reliable due to its low alpha value. Here the question set is further modified and rearranged to get the Cronbach's alpha value to 0.6 then it is an acceptable reliability value.

### *Regression Testing*

**Model Summary**

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate |
|---|---|---|---|---|
| 1 | .676ᵃ | .458 | .441 | .68264 |

a. Predictors: (Constant), Mean_Inter_Team_Communication, Mean_Security_trends, Mean_Innovations

**ANOVAᵃ**

| Model | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| 1 | Regression | 37.736 | 3 | 12.579 | 26.993 | <.001ᵇ |
| | Residual | 44.735 | 96 | .466 | | |
| | Total | 82.471 | 99 | | | |

a. Dependent Variable: Mean_Tech_Enhancement_in_team
b. Predictors: (Constant), Mean_Inter_Team_Communication, Mean_Security_trends, Mean_Innovations

**Coefficientsᵃ**

| Model | | Unstandardized Coefficients B | Std. Error | Standardized Coefficients Beta | t | Sig. |
|---|---|---|---|---|---|---|
| 1 | (Constant) | .575 | .318 | | 1.810 | .073 |
| | Mean_Innovations | .603 | .116 | .532 | 5.218 | <.001 |
| | Mean_Security_trends | .216 | .099 | .196 | 2.194 | .031 |
| | Mean_Inter_Team_Communication | .029 | .083 | .032 | .351 | .726 |

a. Dependent Variable: Mean_Tech_Enhancement_in_team

*Figure 3 Regression Analysis*

The accuracy of the independent variables as per the data set is 0.458 which is overall 45.8% and this implies that in a percentage of 52% other factors may affect the technological enhancement of team. Further the ANOVA test predicts the sig value to be less than 0.05 where we can use this model as an acceptable model. Further the correlation factors show significance in innovation (p = <0.001) and security trends (p =0.0321) only. The inter team communication (p =0.726) is not significant at 0.05 levels. Therefore, it predicts that only innovation and security trends have an impact on technological enhancement of team and inter team communication have no impact on technological enhancement. Therefore, as per multi regression analysis only **H2** and **H3** hypothesis are accepted.

**Discussion**

The present study was conducted to investigate the impact of technological aspects on work from home model of in the scrum teams of financial solutions providing information technology companies. The linier regression analysis and multi linear regression analysis were done with the data set and the summary of results from both analyses represented in Table-2 below. Accordingly, the research findings well represent those new innovations in technology, latest security trends significantly impacted positively on technological enhancement in the scrum team. When employees experience a sufficient level of innovation and good background knowledge on latest security trends technological skills are getting positively impacted and technological fluency increases. In contrast, inter-team communication may not significantly affect the team level technological enhancement. As per linier regression analysis all the three independent variables related hypothesis are acceptable due to their individual significance at their threshold levels. In multi regression analysis done for the data set only H2, H3 are acceptable due to their significance in the identifiable threshold levels. Therefore, based on the well-known accuracy and acceptability of multi regression analysis H2, H3 can be highly accepted as the closest factor for the problem domain. Furthermore, considerable research testing can be done with H1 to ensure the accuracy of the problem domain in future research.

Table 2 - Final Summary

| Description | Linear Reg: sig: | Accept / Reject | Multi Linear Reg: Sig: | Accept / Reject |
|---|---|---|---|---|
| **H1** = The inter team communication feasibility positively impacts the technological enhancement of Scrum team. | <0.001 | Accepted | 0.726 | Rejected |
| **H2** = The innovations/ innovative ideas of the team members positively impact the technological enhancement of Scrum team. | <0.001 | Accepted | <0.001 | Accepted |
| **H3** = The awareness of security trends of team members positively impacts the technological enhancement of Scrum team. | <0.001 | Accepted | 0.031 | Accepted |

**Recommendations**

As per the study done on the factors affecting the technological advancement of the scrum team, more focus must be given to innovations and security trends. Here the lower and middle management must direct employees on fulfilling the necessary requirements in technological aspects of employee which increase the company's qualifications of the technical staff and other hand adopting to latest technologies make business opportunities. In this aspect continuous training sessions, internationally accepted certifications and webinar programs need to be suggested on the employee based on the technological stack they follow. On the other hand, awareness of the latest security trends is a must for technology staff because every day the world is getting new with the latest innovations and vulnerabilities of the existing programs must be handled with proper awareness. The time must be allocated to discussing the latest security trends in sprints and making the team aware of these trends. Continuous discussions of trends and issues in security make the individuals more aware and knowledgeable and minimize future failures. Even though the inter team communication was less significant it is also a must factor for overall project success and delays in sprits may lead to various problems. Here much more focus is to be given on this aspect to continuously maintain proper communication channels among employees and to verify that the individuals are giving proper responses each time. So, if the low level, middle level management gives much priority to discussed aspects of technology the inconveniences can be eliminated and rather controlled so that it affects the overall project success in a turbulent environment of the scrum team.

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# REVIEW: A THEORETICAL FRAMEWORK FOR SERIOUS GAME BASED INFORMATION SYSTEM FOR THE SRI LANKAN SOFTWARE DEVELOPMENT INDUSTRY

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## Abstract

Organizations have increasingly sought to develop and use game-based information systems to increase engagement among employees and customers. Other than that, serious games have emerged as a powerful tool for learning and skill development in various domains. However, many game-based information systems have failed due to poor design. Game-based information systems' design must align with an organization's need or problem and users' motives. To help designers create game-based information systems that align with an organization's needs, this research proposes a comprehensive Game-Based Information System Design Framework (GSDF) for the integration of serious game-based information systems within the context of the Sri Lankan software development industry. This Serious Game-Based Information System (SGIS) framework aims to leverage the potential of serious games to address challenges in knowledge transfer, skills acquisition, and professional development in the Sri Lankan software development industry by merging the principles of information systems and serious game design, this research offers a structured approach to create effective and engaging learning experiences for software development industry professionals. The proposed framework covers the design considerations, development methodologies, and evaluation strategies tailored to the unique needs of the Sri Lankan software development landscape.

**Keywords :** Serious Game-based Information Systems (SGIS), Game-based Information System Design, Information System Gamification, Information System (IS)

## Introduction

Serious games have the potential to offer an engaging and interactive learning experience for professionals in the Sri Lankan software industry. The integration of pedagogy within the software part of serious games can play a crucial role in enhancing learning experiences and addressing industry-specific challenges. Furthermore, the framework's applicability extends beyond traditional learning contexts, offering the potential to foster engagement and creativity in learning, as well as in cultural heritage systems.

The Sri Lankan Software Development Industry is a rapidly evolving landscape driven by technological advancements and global demands. However, the industry faces challenges such as skill gaps, knowledge transfer, project management, and effectively transferring knowledge and developing practical skills among its professionals.

This research presents a Game-Based System Design Framework (GSDF) that engages attributes of serious games with the integration capabilities of IS. The framework is designed to revolutionize learning experiences, enhancing knowledge transfer, skill acquisition, and

engagement for software practitioners within Sri Lanka's dynamic software ecosystem. This framework utilizes the unique context of Sri Lanka's software industry to provide an interactive and engaging learning experience for professionals in the field. The serious game based IS framework will incorporate various parameters, such as user profile, serious game modalities, user interface design, game attributes, and cognitive activities, to cater to the specific needs of the Sri Lankan software development industry. By leveraging these parameters, the framework aims to enhance learning experiences, address industry-specific challenges, and contribute to the overall growth and competitiveness of the software sector. As the demands on software professionals continually evolve in the Sri Lankan context, this framework emerges as a strategic response to address skill gaps, enhance knowledge retention, and provide a platform for continuous professional development. This research proceeds as; background information related to the existing literature on game-based IS in organizations, designing game-based IS, and user motivation in the game-based IS context. Then move on to the game-based development framework (GSDF).

### Serious Games

A serious game is a type of video game designed and developed for a purpose, beyond entertainment. These games are created to deliver specific educational, informational, or training-related content while the interactive nature of gaming. Serious games are designed to address real-world problems or deliver a particular message engagingly and interactively.
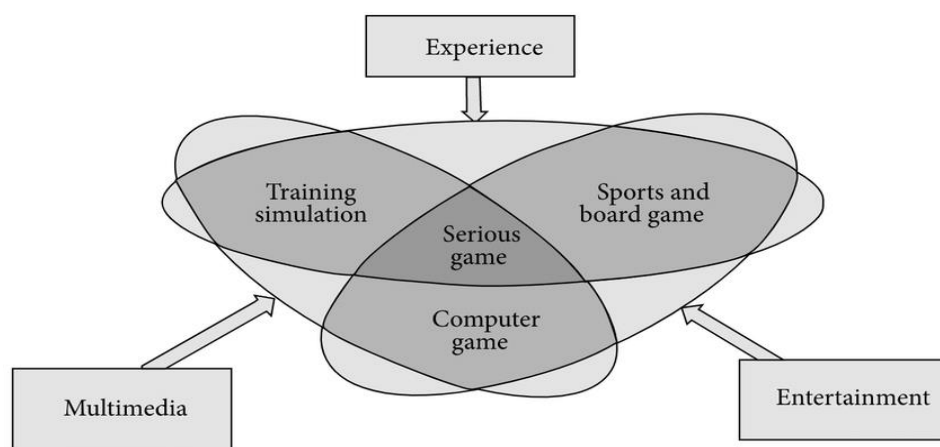


*Figure 1: Serious Game Definition*
Source:
https://www.researchgate.net/publication/355486594_Serious_Game_Classifications_and_Models_in_Higher_Education_and_Serious_Training/figures?lo=1

### Background

Organizations have increasingly incorporated game-based elements into non-gaming contexts (Deterding, Khalid, Nacke, Dixon, 2011; Landers, 2014; Silic & Lowry, 2020) to introduce play elements in the workplace. Organizations must design game based IS to enable users to achieve the goals while simultaneously allowing the latter to indulge in hedonistic digital elements that support their personal needs, motives, and goals (Suh & Wagner, 2017). Research

related to game based IS has also encouraged designers to consider the context of these systems. Integrating game-based thinking into IS design requires designers to move beyond creating a game to develop for a meaningful strategy that has real-world effects and impacts on users' motivation and behavior. For example, game-based IS for training employees must incorporate game-based elements differently from enterprise systems that introduce game-based elements to achieve higher levels of organizational efficiency. Recent papers offer examples of designing rich and useful game based IS to meet specific organizational needs, such as training employees on IS security practices and policies (ex: Silic & Lowry, 2020) or predicting sales performance.

### *Designing Game-based Information Systems*
### *Mechanics, Dynamics, Aesthetics (MDA)*

The widely known framework in the video gaming research community is the mechanics, dynamics, and aesthetics (MDA) framework. This game design element is popular among stakeholders, such as designers, programmers, and researchers (Hunicke et al., 2004). MDA explains video games by separating; 1) a system's design or control mechanisms (mechanics), 2) the interactions between users and the system (dynamics), and 3) users' emotional response to the game (aesthetics) (Hunicke et al., 2004). The aesthetics component focuses on the desired feelings or emotions that users should sense through the gameplay, such as enjoyment and curiosity. A game's dynamics, which include the actual conditions in the game (ex: defining how players cooperate with others, creating means to incite tension or release while playing, or receiving feedback within the game), evoke aesthetics. The mechanics create these dynamic elements; that is, "the various actions, behaviors and control mechanisms afforded to the player within a game context" (Hunicke et al., 2004, p. 3), such as rules or game content that provide structure for the game.

MDA explains how video game's function "as dynamic systems which helps to develop techniques for iterative design and improvement and allows to control for undesired outcomes, and tune for designed behavior" (Hunicke et al., 2004, p. 5). Researchers have applied MDA as a framework in other contexts beyond video games to describe the design of virtual worlds (Cowley, Charles, Black, & Hickey, 2008)

Therefore, researchers integrate concepts from MDA with the knowledge about game-based IS to guide how to combine game-based elements to create an interactive and engaging user experience that accomplishes an organization's goals. For Sri Lankan software development companies should implement game-based elements such as emotional gameplay and interaction dynamics to players' knowledge and skill development.

### *Game-based Elements*

Game-based elements constitute the building blocks that introduce the game-like aspects in an IS to evoke emotion, specify how users interact with the game or other players, and engage the user in a meaningful way. The gamification literature includes many studies that list game-based elements. Common game-based elements include levels, leader boards, badges, and timers, and some research seeks to classify game-based elements into categories. The game-based design framework incorporates multiple taxonomies of game-based elements to

demonstrate how game designers can select game-based elements to address an organization's needs.

| | Games for Health | Advergames | Games for Training | Games for Education | Games for Science and Research | Production | Games as Work |
|---|---|---|---|---|---|---|---|
| Government & NGO | Public Health Education & Mass Casualty Response | Political Games | Employee Training | Inform Public | Data Collection / Planning | Strategic & Policy Planning | Public Diplomacy, Opinion Research |
| Defense | Rehabilitation & Wellness | Recruitment & Propaganda | Soldier/Support Training | School House Education | Wargames / planning | War planning & weapons research | Command & Control |
| Healthcare | Cybertherapy / Exergaming | Public Health Policy & Social Awareness Campaigns | Training Games for Health Professionals | Games for Patient Education and Disease Management | Visualization & Epidemiology | Biotech manufacturing & design | Public Health Response Planning & Logistics |
| Marketing & Communications | Advertising Treatment | Advertising, marketing with games, product placement | Product Use | Product Information | Opinion Research | Machinima | Opinion Research |
| Education | Inform about diseases/risks | Social Issue Games | Train teachers / Train workforce skills | Learning | Computer Science & Recruitment | P2P Learning Constructivism Documentary? | Teaching Distance Learning |
| Corporate | Employee Health Information & Wellness | Customer Education & Awareness | Employee Training | Continuing Education & Certification | Advertising / visualization | Strategic Planning | Command & Control |
| Industry | Occupational Safety | Sales & Recruitment | Employee Training | Workforce Education | Process Optimization Simulation | Nano/Bio-tech Design | Command & Control |

*Figure 2: Preliminary Serious Games taxonomy (Sawyer and Smith 2008)*

*User Motivation*

In the game-based IS context, researchers have focused on finding ways to use game-based elements to increase individuals' intrinsic motivation (Engage in a behavioral activity to get personal rewarding rather than for external reward). Prior research has demonstrated that rewards offered to simulate extrinsic motivation among game-based IS users tend to decrease in effect over time and simultaneously negatively impact users' intrinsic motivation (Perryer, Celestine, Scott-Ladd, & Leighton, 2016; Xi & Hamari, 2019). Therefore, the game-based elements that designers select when designing a game-based IS can influence users' motivations toward the system.

Scholars have identified some game-based elements such as competition, engagement and immediate rewards are identified that are more likely to support intrinsic motivation. Which evoke users; 1) sense of meaningfulness, 2) sense of choice, 3) sense of competence and 4) sense of progress.

The organization needs to consider which game-based elements it selects and implements in a game-based IS to ensure that they promote intrinsic motivation and, thus, motivate users to use the system and achieve the organization goals. Many game-based elements may intrinsically motivate users depending on how one operates the elements in a game-based IS and the needs or nature of the users who interact with the elements. The game based IS designers should carefully consider how these systems "feel" as they seek to engage and motivate users.

### Game-based System Design Framework

When it comes to the creation of a game-based system design framework (GSDF), classified game-based elements as mechanics, dynamics, or aesthetics based on the definitions that the MDA framework provides. The GSDF requires that designers first identify the appropriate aesthetics for a game-based IS. By selecting aesthetics as opposed to mechanics first in the game element-selection process, designers can ensure that the chosen dynamics and mechanics complement the "feel" they intend the game-based IS to evoke. The chosen aesthetic game-based elements can promote users' intrinsic or extrinsic motivations to use these systems. Understanding an organization's problem and users' motives for their behaviors can help designers identify which aesthetics they should include in a game-based IS.



*Figure 3: Serious game design methodology*
Source: Digital Education Strategies, Ryerson University (2018)
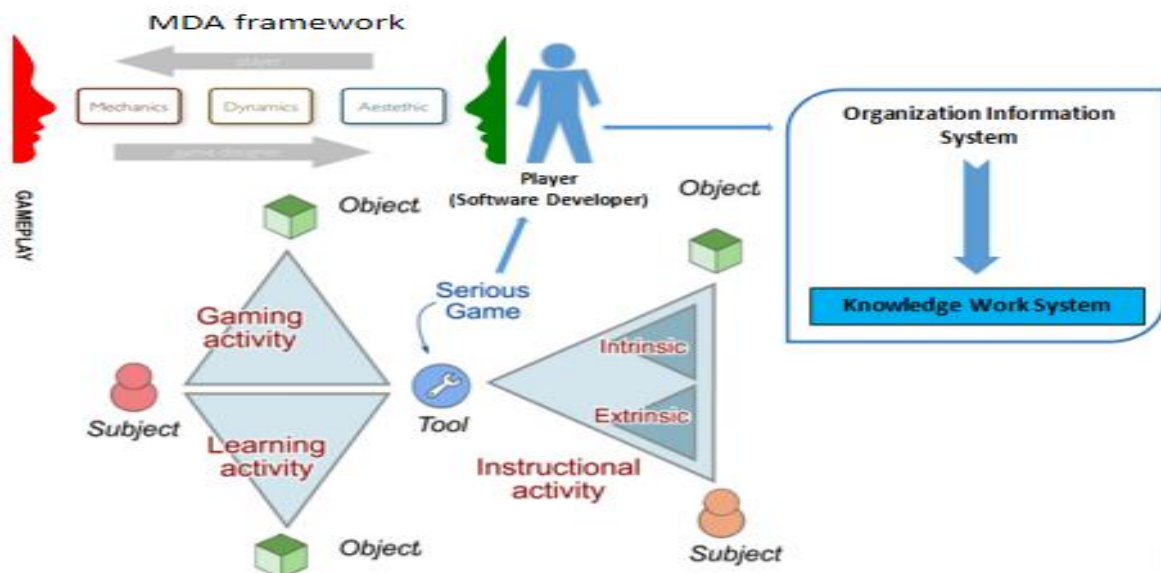


*Figure 4: Conceptual Design of Game-Based System Design Framework (GSDF) for Serious Game-Based Information Systems (SGIS)*

**Discussion**

This research reviews how a GSDF interconnects serious games with the IS. By enhancing learning experiences, and skill development and addressing knowledge transfer challenges, the GSDF holds the potential to reshape professional education within the Sri Lankan Software Development Industry. As the industry continues to evolve, the GSDF can be adapted for various skill levels, integrated into corporate training, and extended to embrace emerging technologies and continue cycle of innovation and growth.

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# VIRTUAL AYURVEDA: A MIXED REALITY SIMULATION GAME CONCEPT FOR KNOWLEDGE ENHANCEMENT AND SKILL DEVELOPMENT IN SRI LANKAN TRADITIONAL MEDICINE

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**Abstract**

Ayurveda, an age-old holistic healing system, and the right knowledge is fading away. In Sri Lanka have plenty expertise and decentralized knowledge about ayurveda. Because of modernization and decentralization, the exact medical knowledge in danger. As a solution to safeguard the knowledge and train interested party this paper introduces "Virtual Ayurveda," concept of Mixed Reality (MR) simulation game design to enhance knowledge and cultivate skills in the realm of Sri Lankan traditional medicine. With authentic Ayurvedic principles, the game offers a unique blend of technology and tradition, creating an immersive digital environment aimed at revitalizing and modernizing ancient healing practices. This simulation game, rooted in authentic Ayurvedic principles, serves as a bridge between ancient healing practices and modern learning methodologies. Through interactive engagement, Virtual Ayurveda seeks to preserve, revitalize, and transmit the profound knowledge of traditional medicine to the learners, specially ayurvedic medical students. The study encompasses the design elements, educational implications, and potential impact of Virtual Ayurveda on the future of Ayurvedic education.

**Keywords:** Simulation Game, Ayurveda, Traditional Medicine, Mix Reality (MR), Virtual Learning

## Introduction

Sri Lankan Traditional Medicine, deeply rooted in centuries-old Ayurvedic knowledge, now faces challenges in knowledge transfer, skill development and adapting to educational methodologies. This paper introduces Virtual Ayurveda as a solution, which bridge the gap between ancient practices and modern learning.

This simulation game stands as a technological tribute to the heritage of Ayurveda, presenting an innovative approach to knowledge enhancement and skill development within the context of traditional healing practices. Rooted in centuries-old knowledge, Virtual Ayurveda give solutions for limitations of conventional educational.

The Virtual Ayurveda begins with an exploration of the historical and cultural context of Sri Lankan Ayurvedic medicine. It unfolds the challenges faced by these age-old practices in the modern educational landscape.

This simulation game is offering a digital workplace for learners to delve into the ayurvedic principles, get theoretical, practical knowledge and develop medicine identification, practice identification for each medical issue and develop existing skills through the hands-on applications in game.

### Background

Sri Lankan traditional medicine, a repository of ancient knowledge which deep rooted in the profound cultural and historical context of Ayurveda, this simulation game seeks to address the evolving challenges faced by traditional healing practices in the theoretical and practical educational landscape. However, the transmission of this existing knowledge encounters various challenges because of the complexities such as the ancient, half destroyed / misplaced books named puskola poth (the palm leaf manuscripts), the different ayurvedic families who specialized in different but vast medical areas such as snake bites. The matching modern education with such practical knowledge which has loopholes is complex task. So that Virtual Ayurveda platform should work as knowledge repository and with help of MR powered simulation provide learner the practical skill and improve medicine identification. This simulation game platform does not seek to replace traditional methods but rather enhance them. The simulation game becomes a bridge between the ancient and the modern, offering a dynamic platform where learners can immerse themselves in the essence of Ayurveda through a medium that speaks to the language of the digital age. The main objective is to develop and implement Virtual Ayurveda, MR powered simulation game designed to serve as an innovative educational tool for the knowledge enhancement and skill development of target group (ayuvedic doctors, ayurvedic medical students, ayurvedic teaching institutes, hospitals, and interested learners across the Sri Lanka) who interested in Sri Lankan Traditional Medicine.

### The Utilization of MR Technology for Virtual Ayurveda

Virtual Ayurveda concept marks a pivotal shift in how the intricate knowledge and practices of Sri Lankan traditional medicine are preserved, taught, and experienced. MR, which encompasses both Augmented Reality (AR) and Virtual Reality (VR), which offers an immersive and interactive medium that revolutionizes the learning process. When considering it AR overlays digital content onto the real world, making it an ideal tool for showcasing practical applications of Ayurvedic principles. Users can, scan, identify real plants or medicinal herbs, and AR can provide detailed information about their medicinal properties, uses, and preparation methods according to the identified medical emergency. This provides hands-on experience and enhances the understanding and retention about ayurveda. The VR part transports users into a completely virtual environment, allowing them to engage in simulated scenarios that replicate incidents, different poisons, different snake bites, symptoms, then diagnostic processes, patient consultations, herbal preparations, and treatment implementations. This immersive simulation enables users to practice and refine their skills in a safe, controlled environment. The incorporation of MR facilitates dynamic learning modules that adapt to learners' proficiency levels. Beginners can start with fundamental concepts and progress to advanced levels where complex diagnostic challenges and treatment protocols are presented, ensuring a personalized learning experience. For the personalized experience use Bayesian approach.

Also, MR technology creates culturally authentic environments. Users can virtually visit Sri Lankan historical Ayurvedic centers, interact with virtual mentors called wedamahaththaya, and explore traditional healing spaces, thus fostering a deeper connection with the cultural heritage of Sri Lankan Ayurveda and give new experience of exploring the medical culture

roots. The gamification of Ayurvedic learning through MR enhances learner engagement. Learners automatically motivated to progress through levels, earn rewards, and participate in challenges, find new medicines, making ayurvedic concoctions, critical thinking, and skill development in a fun and captivating manner. Through VR simulations, the learners can improve their diagnostic skills, learn about personalized treatment plans, and practice therapeutic interventions, this practice bridging the gap between theoretical knowledge and practical application.

### *Design Elements of Virtual Ayurveda*

The simulation environment and interactive scenarios are described to enable experiential learning of ayurvedic concepts, herbal remedies, diagnostic techniques, and therapeutic modalities. Simulated scenarios represent real-life diagnostic challenges, various patient interactions, herbal/ayurvedic concoction preparation processes, and treatment implementations. Interactive modules allowing learners to engage in hands-on activities like identifying herbs, preparing concoctions, and conducting consultations. Adaptive learning with Bayesian modeling catering to learner's proficiency levels, allowing beginners to start with fundamental concepts and progress to advanced diagnostic and treatment scenarios. When considering AR features, AR provides information about medicinal plants, their properties, uses, and preparation methods according to different case scenarios and learners can interact with real-world herbs or necessary tools and techniques. When it comes to VR simulations, that enabling learners to step into the shoes of an ayurvedic practitioner, conducting consultations, diagnosing, and recommending personalized treatment plans. Considering progression system with gamification, a structured level such as beginner to master level, challenges, achievements, and rewards to motivate learner and can track their learning curve.

### *Proposed Practical Implementation*

When considering practical implementation of Virtual Ayurveda MR Simulation, can consider a breakdown of the practical steps which can be involved in implementing the game concept. When considering the Development and Technology, should choose a game development engine like Unity or Unreal Engine that supports MR features. Meanwhile should consider factors like team expertise, budget, and desired functionalities. Then the 3D Modeling and Design, when it comes to 3D modeling capable of Ayurvedic elements creation like herbs, plants, body parts, and treatment tools. This process includes the accuracy of visual appeal. Next step is MR Integration.Integrating MR functionalities such as object recognition, spatial mapping, and hand tracking can be use to create an immersive experience. Meanwhile these processes should develop educational content such as engaging storyline and quests that incorporate accurate Ayurvedic knowledge and practices. In this case should aquire knowledge of Ayurvedic experts to ensure authenticity. When considering game mechanics should plan to design engaging gameplay mechanics like resource management, patient diagnosis, and treatment simulations. These should balance with learning objectives. When considering hardware and user interface (UI), first should choose an MR headset which compatible with the development platform (Unity or Unreal engine) and target audience. Consider factors like cost, comfort, and field of view. The UI design should be user-friendly interface for interacting

with the MR environment and game mechanics. Considering voice commands and gesture controls for natural and accurate interactions.

### *Educational Implications*

Mainly, the potential learning outcomes such as practical application of ayurvedic concepts, and the diagnostic and therapeutic skills will be achieved. Furthermore, the scalability of the Virtual Ayurveda simulation game across diverse platforms, helps to improve accessibility to various learners. The simulation allows learners to experience ayurvedic practices, and helps beyond theoretical knowledge. Learners can engage in simulated diagnostic scenarios, treatment implementations, and herbal, ayurvedic concoction preparations, enhancing learners practical understanding of ayurvedic principles. Virtual Ayurveda provides a safe, controlled environment for learners to practice diagnostic skills, therapeutic interventions, and health recommendations. As learners progress through the game, they can improve their abilities in patient assessment, herbal remedies, and personalized treatment planning. The game design accommodates different learning styles and proficiency levels from beginner to master level. Beginners can start with fundamental concepts and gradually progress to advanced levels, ensuring achievement of learning outcomes on various expertise. Gamification elements such as levels, challenges, rewards, and interactive tasks keep users engaged and motivated to explore deeper into ayurvedic practices. The interactive nature of the game improve interest and encourages continuous learning.

### *Potential Impact and Challenges*

The main potential impact of Virtual Ayurveda is the platform can serve as a bridge between ancient healing knowledge and healthcare practices, fostering a deeper understanding of diagnostic approaches among ayurvedic healthcare professionals. Also, this platform offers learners and ayurvedic medical practitioners to enhance their diagnostic skills, treatment approaches, new ayurvedic concoction preparation for new diseases and improve healthcare outcomes.

Considering development there are some challenges such as creating authentic environment and technology integration. when it comes to authentic environment development should ensure accurate and culturally sensitive depictions of ayurvedic practices and traditions within a digital medium. Then technology integration such as AR and VR while maintaining accessibility across different devices and platforms requires significant technical expertise and resources. The complexity of ayurvedic concepts is challenging for learners and requires thoughtful design to make it accessible and engaging for diverse audiences. The other challenge is device accessibility. Access to VR headsets or AR-enabled devices are limited and with current country situation device purchase cause some financial issues.

### Conclusion

The proposed Virtual Ayurveda platform has potential of revolutionizing Sri Lankan ayurvedic education and skill development. Furthermore, this platform can act as a knowledge hub and serve for local learners and open a doorway to every learner regardless of the geographical

boundaries. The implementation of MR and simulations achieves learner engagement which is challenging task when it comes to traditional education system.

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# AIRS' 23

## *Chapter 06:*
## SOCIAL SCIENCE

# THE MENTAL WELL-BEING AND SOCIAL ISOLATION OF FINAL-YEAR UNDERGRADUATES DURING THE COVID-19 PANDEMIC

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**Abstract**

This study investigates the mental well-being and social isolation of final-year undergraduates in Sri Lanka during the COVID-19 pandemic. Utilising a cross-sectional survey with 120 participants, the research reveals a negative correlation ($r = -.430$, $p < 0.01$) between mental well-being ($M = 44.03$) and social isolation ($M = 5.83$). The results revealed that 59.2% reported average mental well-being, challenging assumptions about the severity of pandemic-induced distress. Gender-specific analyses underscore females experiencing lower mental well-being ($M = 42.28$) than males ($M = 48.67$). This highlights the need for targeted interventions and contributes valuable knowledge to the global discourse on student well-being during crises.

**Keywords:** Mental Well-being, Social Isolation, Undergraduates, COVID-19, Sri Lanka.

## Introduction

The COVID-19 pandemic has introduced unprecedented challenges to various facets of society, including the well-being of university students (Perera, 2014). In Sri Lanka, the pandemic unfolded in late January 2020, prompting governmental responses such as social distancing measures, school closures, and island-wide curfews (Wickramaarachchi et al., 2020). This study delves into the mental well-being and social isolation experienced by final-year undergraduates in Sri Lanka during this global crisis (Clair et al., 2021; O'Connor et al., 2020). The rationale for this exploration is grounded in the need to comprehend the unique socio-cultural factors influencing students in a Sri Lankan context. The study, guided by the significance of mental health in academic settings, focuses on final-year undergraduates due to the potential compounding stressors associated with their academic culmination amidst a pandemic (Hamza et al., 2021).

Research addressing the mental health of university students during the COVID-19 pandemic is notably scarce in the Sri Lankan context. Mental well-being encompasses an individual's potential to realize abilities, cope with life stresses, and contribute to the community (Trousselard et al., 2016). It plays a crucial role in educational success, affecting motivation, focus, and overall academic achievement (Capone et al., 2020). The pandemic intensified challenges, impacting the mental well-being of final-year undergraduates who faced academic stressors heightened by social isolation (Spasovski & Kenig, 2020). Social isolation, a multi-dimensional phenomenon, involves insufficient quality and quantity of contact with others (Smith & Lim, 2020). The COVID-19 pandemic amplified social isolation, affecting university students globally (Clair et al., 2021). The study aimed to contribute empirical evidence that can inform targeted interventions and support mechanisms, thereby enhancing the well-being of students.

As exemplified by Capone et al. (2020), prior studies have not extensively explored the Sri Lankan population's mental health status. The limited empirical research conducted has primarily concentrated on stress, depression, anxiety, and self-esteem among undergraduate students in Sri Lanka (e.g., Perera, 2014). Notably, the specific context of the mental well-being of final-year undergraduates and its association with social isolation has not been adequately investigated. The current research addresses existing gaps in the literature, offering a nuanced understanding of the intricate interplay between mental well-being and social isolation (Al Issa & Jaleel, 2021).

This research provides a novel perspective on final-year undergraduates' mental well-being and the effects of social isolation during the ongoing pandemic. It aids academic institutions and governing bodies in understanding and addressing the challenges students face. The study's findings can inform strategies to enhance social support, mental health services, and overall well-being, contributing to students' resilience during the pandemic.

*Objectives:*

I. To assess the level of mental well-being in final-year undergraduates during the COVID-19 pandemic.

II. To assess the level of social isolation in final-year undergraduates during the COVID-19 pandemic.

III. To investigate the statistically significant relationship between mental well-being and social isolation in final-year undergraduates during the COVID-19 pandemic.

*Hypothesis:*

I. Null Hypothesis (Ho): There is no statistically significant relationship between mental well-being and social isolation in final-year undergraduates during the COVID-19 pandemic.

II. Alternative Hypothesis (Ha): There is a statistically significant relationship between mental well-being and social isolation in final-year undergraduates during the COVID-19 pandemic.

**Methodology**

*Study Design*

The study followed a quantitative research approach utilizing a cross-sectional survey design.

*Sampling Technique*

The convenience sampling technique was employed to select 120 participants aged 20-28 from state universities and private degree-awarding institutions. The utilization of convenience sampling was necessitated by the logistical challenges imposed by these restrictions, thereby presenting impediments to a more systematic or random sampling approach for data collection.

*Study Setting and Materials*

Data collection occurred online through self-administered questionnaires, the Warwick-Edinburgh Mental Wellbeing Scale (WEMWBS) and the De Jong Gierveld Loneliness Scale provided quantitative tools for assessing mental well-being and social isolation, respectively (Tennant et al., 2007; Gierveld et al., 2021). Statistical analyses, including descriptive statistics and Pearson's correlation coefficient, facilitated the exploration of the collected data.

**Results**

Demographic scrutiny unveiled a predominantly female sample, constituting 72.5% of the participants(Figure 1), with an average age of 23.18. The majority completed their undergraduate programs within three years (55.83%). None of the participants reported a history of COVID-19 infection. The mean mental well-being score, as per the WEMWBS, was 44.03, indicating an overall average mental well-being status. Furthermore, females showed lower levels of well-being ($M = 42.28$) than males ($M = 48.67$) (Figure 2 & 3).

**Figure 1**

*Demographic Characteristics of Sample - Gender*
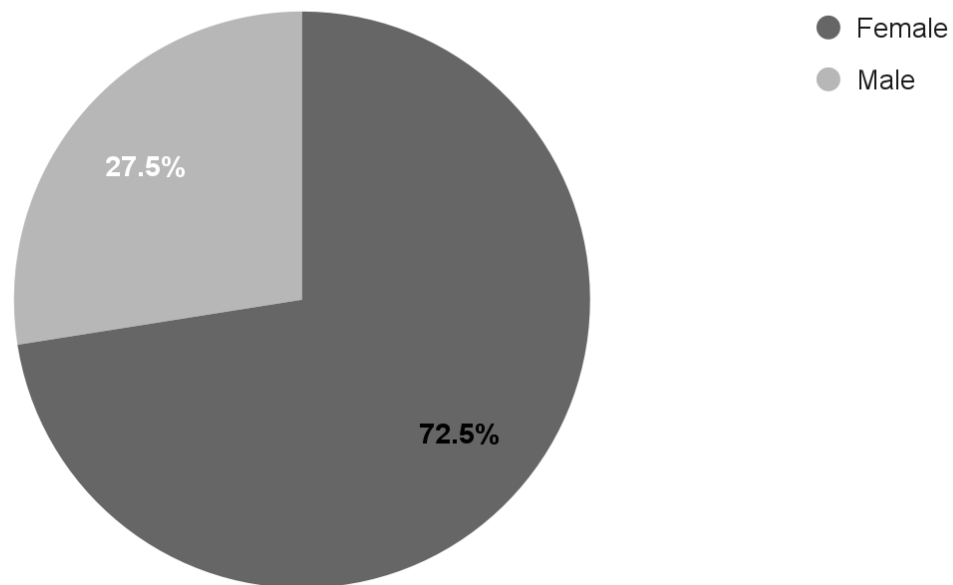


**Figure 2**

*Mental Well-Being Levels Obtained Using WEMWBS*
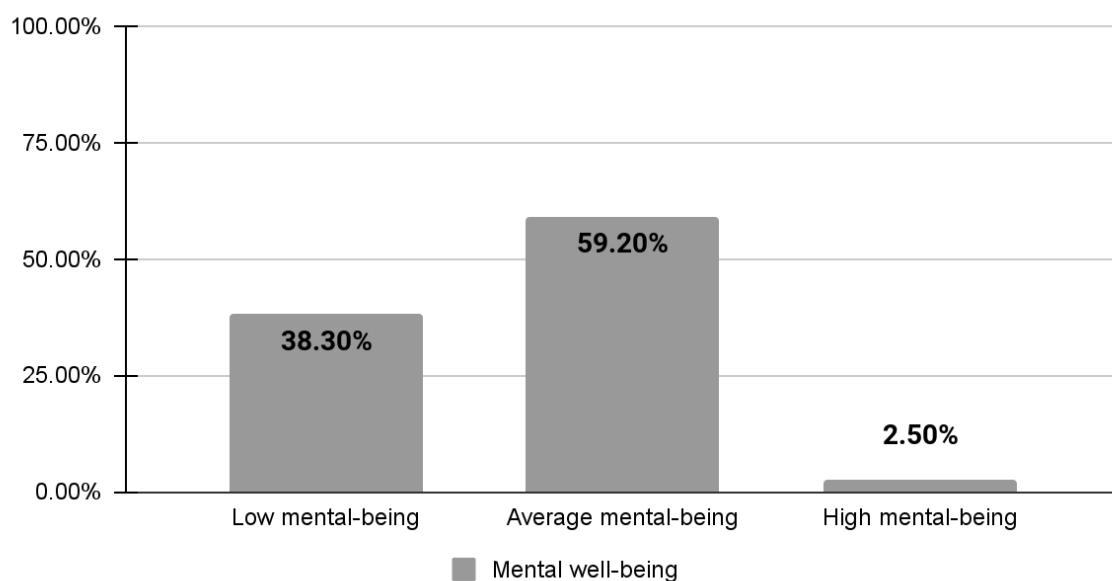
The De Jong Gierveld Loneliness Scale revealed a mean social isolation score of 5.83, signifying a state of moderate loneliness among both males and females. Of notable significance was the moderately statistically significant negative correlation ($r = -.430$, $p < 0.01$) between mental well-being and social isolation (Table 01). Thus, the alternative hypothesis stating that "There is a statistically significant relationship between mental well-being and social isolation among final-year undergraduates during the COVID-19 pandemic", is accepted while the null hypothesis was rejected.

**Table 01**

*Pearson Correlation Coefficient Between Mental Well-Being and Social-Isolation*

| Measure | Mental well-being |
| --- | --- |
| Social isolation | -.430** |

*Note.* **$p < 0.01$; $n = 120$

Comparative analysis indicated a moderate, negative correlation for females ($r = -.446$, $p < 0.01$) and males ($r = -.413$, $p < 0.05$). Despite the majority of female participants, the correlation held true for both genders indicated in Table 02. Consequently, the alternative hypothesis stating, "There is a statistically significant relationship between mental well-being and social isolation among final year undergraduates during the COVID-19 pandemic," is accepted for both genders while the null hypothesis was rejected for both genders. This suggests that gender composition did not exert a discernible influence on the established relationship.

**Table 02**

*Pearson Correlation Coefficient Between Mental Well-Being and Social Isolation in Males and Females*

| Gender | Measure | SI | MW |
| --- | --- | --- | --- |
| Female | SI | | -.446** |
| Male | MW | -.413* | |

*Note.* **$p < 0.01$; $n = 87$ (Female); *$p < 0.05$; $n = 33$ (Male)

    *SI*= Social isolation; *MW*= Mental well-being

**Discussion**

The present study delves into the mental well-being and social isolation levels of final-year undergraduate students during the unprecedented COVID-19 pandemic. The findings indicate a statistically significant negative correlation between mental well-being and social isolation, substantiating the pressing need for a nuanced understanding of the intricate interplay between these variables. Descriptive analyses showed that females reported lower mental well-being compared to males, aligning with research by Liu et al. (2021) and O'Connor et al. (2020), where females exhibited more pronounced psychological distress. This gender-based divergence warrants further exploration to unveil underlying causes and effective interventions.

The results affirm the negative association between social isolation and mental well-being, aligning with findings by Clair et al. (2021) and Al Issa and Jaleel (2021). The significance of these results gains prominence in the context of the pandemic's lingering effects on individuals across different age groups and educational levels, consistent with broader literature highlighting the pervasive impact of social isolation on life satisfaction (Clair et al., 2021). Notably, both male and female participants reported moderate loneliness, debunking the stereotype that males are less susceptible to the adverse effects of social isolation. This echoes the studies by Hamza et al. (2021) and Spasovski and Kenig (2020), emphasizing the universality of the impact of social isolation on diverse demographic groups, irrespective of gender.

Contradicting Spasovski and Kenig's (2020) findings, the results of the present study indicated low mental well-being during social isolation. It is imperative to recognise the diverse situational contexts; the present study focused on final-year undergraduates potentially facing unique stressors. This divergence underscores the multifaceted nature of the relationship between social isolation and mental well-being, influenced by myriad factors such as available social support and engagement in meaningful activities.

The findings bear implications for higher education policies, urging institutions to prioritise students' mental well-being. The revelation of low mental well-being among final-year undergraduates underscores the need for targeted interventions and support mechanisms. Academic authorities should consider implementing psychology referral interventions, fostering a holistic approach to student well-being. The strengths of this study lie in its pioneering effort to explore mental well-being and social isolation among final-year undergraduates in the Sri Lankan context during the pandemic. The adoption of the WEMWBS scale as a standardized tool enhances the study's robustness, allowing for cross-cultural comparisons. However, the limitations, such as the exclusion of participants from other provinces and the cross-sectional nature of the research, necessitate caution in generalising the results.

The present study draws on an array of literature and contextualising findings within the unique Sri Lankan landscape, setting a precedent for future research in the field. The nuanced understanding of gender-specific disparities, the intricate relationship between social isolation and mental well-being, and the implications for higher education policies provide a robust foundation for shaping mental health discourse. The findings beckon policymakers, educators,

and researchers to collaboratively address the nuanced challenges students face, fostering a conducive environment for academic success and holistic well-being.

**Conclusions and Recommendations**

In conclusion, this study offers robust evidence supporting a statistically significant negative relationship between mental well-being and social isolation among final-year undergraduates in Sri Lanka during the COVID-19 pandemic. The gender-based nuances in mental well-being highlight the imperative for gender-specific interventions to cater to the diverse needs of the student population. Recommendations for future research encompass the necessity for a more diversified sample, longitudinal studies to unravel the long-term effects, and the cross-cultural validation of loneliness scales within the Sri Lankan context. The implications of this research extend beyond academic discourse, emphasizing the urgency of awareness campaigns and institutional reforms to alleviate the adverse impact of social isolation on the mental well-being of university students.

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# SELF-STIGMA AND NEGATIVE BELIEFS IN MENTAL ILLNESS AS PREDICTORS OF ATTITUDES TOWARDS SEEKING PSYCHOLOGICAL HELP

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**Abstract**

The underutilization of psychological services in South Asia has been largely attributed to attitudinal barriers. The current study aimed to determine the relationship between negative beliefs in mental illness, self-stigma of seeking help, and attitudes towards seeking professional psychological help among Sri Lankan adults. A volunteer sample of 115 Sri Lankans above the age of 18 *(men=41; women= 74)* participated in an online survey to complete standardized questionnaires employing three pre-existing Likert type scales measuring attitudes, beliefs, and self-stigma. It was found that negative beliefs and self-stigma significantly predicted participants' attitudes towards seeking professional psychological help, with evidence of a weak positive relationship between beliefs and self-stigma. It was further revealed that men and women did not differ in their attitudes towards psychological help seeking. Findings suggest that help seeking attitudes may be culturally defined.

**Keywords:** Attitudes, Negative Beliefs, Self-stigma

**Introduction**

It is revealed that one in seven South Asians suffer from a mental illness (Kakhramonovich, 2022). Contrary to the expectations of such circumstances, cumulative evidence of a depletion in people's psychological help seeking behaviour and the underutilization of mental health services among sufferers of mental illness over the recent years is a cause for concern (Mckenzie et al., 2014). Several studies demonstrate attitudes towards seeking psychological help as the best predictor of intention to seek mental help and is thereby predictive of actual help seeking behaviour (Codd & Cohen, 2003). Empirical evidence portrays a reciprocal relationship between beliefs, self-stigma and help seeking attitudes owing to their codependent qualities (Chandrasekara, 2016; Wijesuriya & Gunasekara, 2018). Consequently, reducing self-stigma of seeking help is shown to reduce negative beliefs about mental illness, thereby cultivating more positive attitudes towards help seeking (Hantzi et al., 2018).

Literature further posits that negative beliefs and stigma towards mental illness- both which position themselves under the cultural umbrella, is significantly higher in the south Asian region (Arora et al., 2016). Despite the demand reflected in recent research, research on the relationship between psychological factors and attitude towards seeking professional psychological help in South Asia remain largely unexplored. Moreover, most of the existing attitudinal research have been conducted in the West, overlooking important cultural aspects and thereby reporting mixed results. In such regard, Sri Lanka's cultural diversity makes for

an ideal setting for attitudinal research. In order to bridge the gap in the existing literature, the present study aimed to explore the relationship between negative beliefs toward mental illness, self-stigma of seeking help and attitudes towards seeking professional psychological help driven by two hypotheses.

*H1*. Negative Beliefs and Self stigma will significantly predict Attitudes Towards Seeking Professional Psychological Help.

*H2*- There will be a difference between men and women in their Attitudes Towards Seeking Professional Psychological Help.

## Methodology
### *Participants*

A voluntary sampling method was utilized in participant recruitment to gather cost effective easily accessible data (Murairwa, 2015). Recruitment was carried out through an advertisement circulated via email and multiple social media platforms. 289 participants attempted the survey out of which 133 incomplete responses were removed to maintain credibility. A further 41 responses were removed for failed attention checks, bringing the total sample to 115.

### *Design and Procedure*

A quantitative correlation study design was selected to determine the prevalence and relationship between Negative Beliefs, Self-stigma and Attitudes (Curtis et al., 2016). The survey explored participants' psychological help seeking behaviour using three standardized questionnaires. Independent variables Beliefs toward Mental Illness (Cronbach's alpha .920) and Self-Stigma of Seeking Help (Cronbach's alpha .745) were measured against the Dependent variable Attitudes Towards Seeking Professional Psychological Help. (Cronbach's alpha .669)

### *Materials*
### *Negative Beliefs*

Beliefs toward mental illness was measured by the Beliefs toward Mental Illness scale (BMI), developed by Hirai and Clum (2000) to evaluate stereotypical beliefs towards mental illness among various cultures with three subscales measuring 1) Dangerousness 2) Poor social skills and 3) Incurability. It is a 6-point Likert scale containing 21 items ranging from (0) Completely agree to (5) Completely Disagree. Higher scores indicate more negative beliefs toward mental illness. BMI has been cross culturally validated, especially in studies conducted across Asia (Segal et al., 2005).

### *Self-Stigma*

Self-stigma was measured using the Self Stigma of Seeking Help Scale (SSOSH) designed by Vogel et al. (2006) to measure personal loss of self-esteem in deciding to seek professional psychological help (SSOSH), It is a 10-item scale assessing responses on a 5-point Likert scale varying from 1(Strongly Disagree) to 5 (Strongly Agree). Higher scores indicate greater self-stigma. SSOSH has been cross culturally validated and have been previously utilized in attitudinal research (Sezer & Kezer, 2013).

***Attitudes***

Likelihood of seeking psychological help was measured by the short form of Attitudes Towards Seeking Professional Psychological Help scale (ATSPPH-SF) by Fischer and Farina (1995), which contains 10-items rated on a 4-point Likert scale varying from (1) Disagree to (4) Agree. Higher scores indicate more positive attitudes towards seeking professional psychological help. ATSPPH was found to have high validity and reliability across multiple studies, particularly in Asia and South-east Asia (Mudunna et al., 2022).

## Results

### Testing for assumption of Normality

Given that normality of data in the Shapiro Wilks test (Table 1) is indicated by a non-significant value of $p > 0.05$ (Razali & Wah, 2011), evidence for normal data distributions for the total scores of Self-stigma ($p =.299$) were present, thus failing to reject the null hypothesis. However, data for Attitudes variable ($p =.002$) and Negative Beliefs ($p =.013$) significantly departed from normality, thus rejecting null hypotheses.

***Table 1***
*Sapiro-Wilks test analysis*

|  | Shapiro-Wilk | | |
| --- | --- | --- | --- |
|  | *Statistic* | *Df* | *Sig.* |
| Total_Attitude | .959 | 115 | .002 |
| Total_Selfstigma | .986 | 115 | .299 |
| Total_Negativel_beliefs | .971 | 115 | .013 |

### Predicting Attitudes based on Self-stigma.

A simple linear regression was calculated to predict Attitudes based on Self-stigma (see tables 2, 3, 4 and Figure 1). A significant regression equation was found ($F(1,113) = 37.841$, $p < .001$), with an $R^2$ of .257. Participants' predicted Attitude is equal to 31.019 + -.486 (Self-stigma) when Self-stigma is measured as 1=Male, 2=Female. Participants Attitude decreased -.486 of measure for each unit of self-stigma measure. A 25.1% influence on Attitudes towards seeking psychological help was established.

***Table 2***
*Model Summary of Self-stigma and Attitudes*

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate |
| --- | --- | --- | --- | --- |
| 1 | .501ᵃ | .251 | .244 | 4.222 |

a. Predictors: (Constant), Total_selfstigma
b. Dependent Variable: Total_attitude

*Table 3*

*Regression analysis between Self-stigma and Attitudes*

| Model | | Sum of Squares | Df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| 1 | Regression | 674.430 | 1 | 674.430 | 37.841 | <.001[b] |
| | Residual | 2013.953 | 113 | 17.823 | | |
| | Total | 2688.383 | 114 | | | |

*Table 4*

*Coefficients* analysis of Self-stigma and Attitudes

| Model | | Unstandardized Coefficients | | Standardized Coefficients | T | Sig. |
|---|---|---|---|---|---|---|
| | | B | Std. Error | Beta | | |
| 1 | (Constant) | 31.019 | 1.764 | | 17.588 | <.001 |
| | Total_selfstigma | -.486 | .079 | -.501 | -6.152 | <.001 |

a. Dependent Variable: Total_attitude

*Figure 1*

Scatterplot chart for regression analysis between Attitudes and Self-stigma
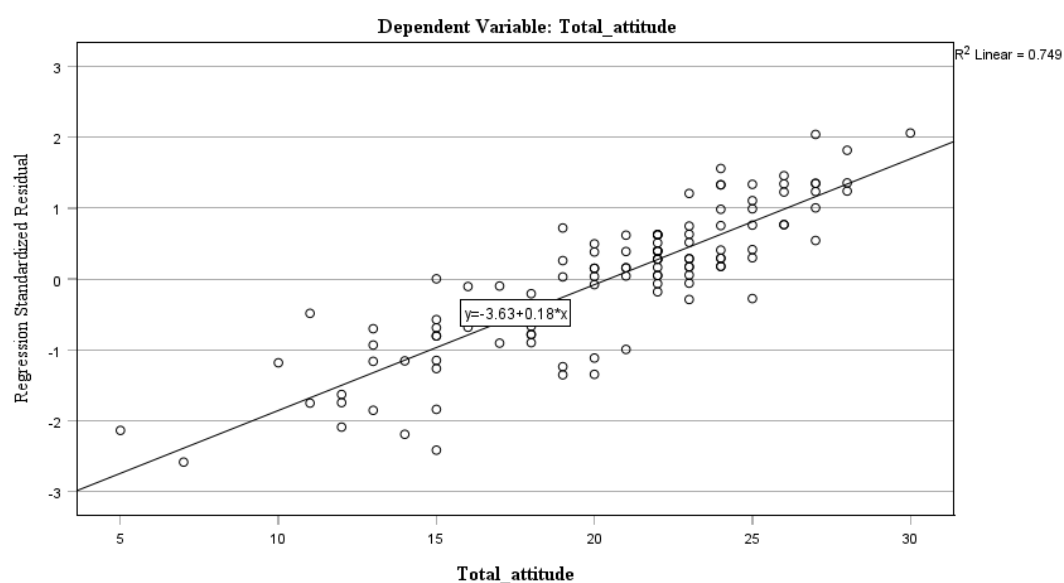
***Predicting Attitudes based on Negative Beliefs***

A simple linear regression was calculated to predict Attitudes based on Negative Beliefs (see tables 5, 6, 7, and Figure 2). A significant regression equation was found ($F(1,113)= 10.561, p < .002$), with an $R^2$ of .085. Participants' predicted Attitude is equal to 23.843 -.081 (Negative Beliefs) when Negative Beliefs is measured as 1=Male, 2=Female. Participants Attitude decreased -.081 of measure for each unit of Negative Beliefs measure. An 85% influence on Attitudes towards seeking psychological help was found.

*Table 5*

*Model Summary* of Negative beliefs and Attitudes

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate |
|---|---|---|---|---|
| 1 | .292<sup>a</sup> | .085 | .077 | 4.664 |

a. Predictors: (Constant), Total_negativebeliefs

b. Dependent Variable: Total_attitude

*Table 6*

*Regression analysis between Negative Beliefs and Attitudes*

| Model | | Sum of Squares | Df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| 1 | Regression | 229.787 | 1 | 229.787 | 10.561 | .002<sup>b</sup> |
| | Residual | 2458.596 | 113 | 21.757 | | |
| | Total | 2688.383 | 114 | | | |

a. Dependent Variable: Total_attitude
b. Predictors: (Constant), Total_negativebeliefs

*Table 7*

*Coefficients* analysis of Negative Beliefs and Attitudes

| Model | | Unstandardized Coefficients | | Standardized Coefficients | | |
|---|---|---|---|---|---|---|
| | | B | Std. Error | Beta | t | Sig. |
| 1 | (Constant) | 23.843 | 1.133 | | 21.045 | <.001 |
| | Total_ Negative_beliefs | -.081 | .025 | -.292 | -3.250 | .002 |

a. Dependent Variable: Total_attitude

*Figure 2*

*Scatterplot chart for regression analysis between Attitudes and Negative Beliefs*
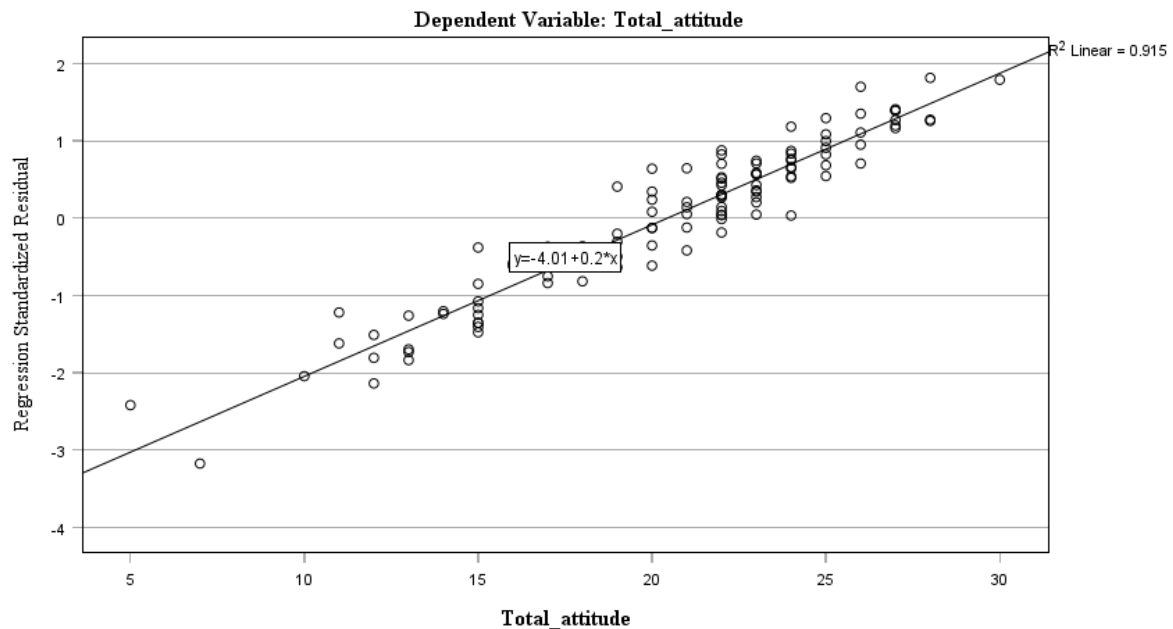


## Measuring the difference in attitudes between males and females

A Mann-Whitney-U test was employed to test the difference between males and females in their Attitudes Towards Seeking Professional Psychological Help (see tables 8 and 9). Results indicated that Males did not significantly differ in their attitudes ($Mdn$ =21, $n$ = 41) compared to females ($Mdn$ = 22, $n$ =74; U=1214.000, z= -1.775, p = .076, with a weak effect size r= 0.165 (less than 0.3 as cited in MacFarland et al., 2016).

*Table 8*

Mann-Whitney U *Test Statistics for differences among genders*

|  | Total_attitude |
| --- | --- |
| Mann-Whitney U | 1214.000 |
| Wilcoxon W | 2075.000 |
| Z | -1.775 |
| Asymp. Sig. (2-tailed) | .076 |

Grouping Variable: Gender.
The significance level is at .05.

*Table 9*

*Mean ranks according to gender*

|  | Gender | N | Mean Rank | Sum of Ranks |
|---|---|---|---|---|
| Total_attitude | Male | 41 | 50.61 | 2075.00 |
|  | Female | 74 | 62.09 | 4595.00 |
|  | Total | 115 |  |  |

**Discussion**

The present study explored the influence of self-stigma and negative beliefs as predictors of attitudes towards seeking professional psychological help, and the differences in attitudes towards seeking professional psychological help between genders. It was established that both negative beliefs and self-stigma significantly predicted participants attitudes towards seeking professional psychological help, with self-stigma influencing help seeking attitudes by 25.1% and negative beliefs influencing help seeking attitudes by 85%. Thus, it can be deducted that psychological help seeking attitudes of Sri Lankan adults are significantly influenced by negative beliefs and self-stigma (Amarasuriya et al., 2018), although negative beliefs employ a greater influence on help seeking attitudes compared to self-stigma.

The prevalence of self-stigma and negative beliefs towards seeking psychological help can be explained through Hofstede's (2001) cultural dimension model which categorizes Sri Lanka as a feminist, collectivistic culture. Persons hailing from such cultures display a strong sense of shared identity with one's in-group, where insubordination to the social norms is met with disapproval (Savani et al., 2010). This explains the adoption and endorsement of negative beliefs regarding mental illness as an act of mirroring societal stereotypes. Results from the present study thus concurs with empirical evidence from South Asian literature on help seeking that stereotypical beliefs, and self-stigma dissuade individuals from seeking psychological help (Jayawardena & Gamage, 2022). Consequently, Hofstede's model can be used to validate similar findings across the region owing to geographical proximity, identical political systems, shared philosophical influence, religious beliefs and practices that contribute to overall likeness among cultures (Hofstede, 2011).

However, contrary to hypotheses 2, the current study found no evidence in support of differences in attitudes between men and women. Such results oppose findings by Chandrasekara (2016) which established that Sri Lankan women portrayed more positive attitudes towards help seeking among Sri Lankans.

The present study was subject to a few citable limitations. One such limitation is being available only to those with access to technology which may have imposed constraints on the study sample, such as being inaccessible to computer illiterate individuals, the elderly and those without web access. It is also taken into consideration that limitations that typically accompany survey methodology may have influenced participants responses, such as response bias due to fear of judgement or self-disclosure, and survey fatigue in answering multiple questionnaires. However, steps were obtained to minimize these effects by informing participants of their

anonymity before obtaining consent and by adopting the short form versions of two out of three scales (ATSPPH-SF and SSOSH-SF). Furthermore, it is worth entertaining the possibility that the limited number of response options available on the survey may not always accurately capture participant sentiments (Tourangeau et al., 2000). Finally, given that the current study was conducted with region and culture specific aims, findings may not be generalizable to populations and sociodemographic groups dissimilar to the sample adopted.

## Conclusion and Recommendations

The findings of this study revealed that negative beliefs and self-stigma are significant predictors of attitudes toward seeking professional psychological help among Sri Lankan adults. The results also indicated that there was a positive relationship between negative beliefs and self-stigma which confirms that they may be culturally defined. It is believed that these findings may have significance for intervention, assessment and outreach for psychologists, educators, various professionals and community leaders in the region.

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# THE INFLUENCE OF PERSONALITY TRAITS ON THE TYPE OF SPORT SELECTED AMONG UNDERGRADUATES IN COLOMBO, SRI LANKA

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**Abstract**

Understanding Introversion and Extraversion is a key aspect to understanding personality, yet it is less understood within the sport psychology setting- especially in the Sri Lankan context. This research aimed to investigate the relationship between personality traits (Introversion/Extraversion) and the type of sport selected (Team/Individual) among athletes in the Colombo region of Sri Lanka. The study was cross-sectional in design and a sample of undergraduate athletes (n=378) were recruited via snowball sampling from selected universities - both state (n=144) and non-state (n=234) universities. A pre-tested questionnaire based on the Big Five personality inventory's Extraversion-Introversion domain was used to collect data online. The results of an independent sample T-test revealed that there is no significant variation between introversion and extraversion related to sport selection. The findings suggest that those playing individual sports were not more likely to be introverted than those engaged in team sports.

**Keywords:** Extraversion, Individual sports, Introversion, Personality, Team sports

## Introduction

Do you thrive when you are the center of attention in a large group, or do you turn shy and try to avoid a crowd? An individual's responses to life situations are characterized by distinctive and enduringways of thinking, feeling, and acting which is also known as one's personality (Smith, 2008). In keeping with the focus of this, the current research will discuss personality related to sport psychology. Physical education includes training in the development and care of the human body and maintaining physical fitness whilst sharpening overall cognitive abilities and motor skills via athletics, exercise and various other physical activities. Being involved in sports has proven to not only physically benefit a person, but it also carries a battery of psychological benefits such as enhanced mood, stress reduction, positive self-concept and higher quality of life (Berger, 1990). Sport involvement has also showed a decrease level of depressive symptoms and an increase level of social support and self- esteem (Babiss & Gangwisch 2009). In addition, higher levels of socialfunctioning, mental health, happiness, and stress reduction has been observed amongst adolescent athletes when compared to non-athletes (Eime et al., 2013).

Dichotomizing sports into team and individual sports is one of the most frequently used classification systems (Schurr et al.,1977). For the purpose of the current study, the sport type will be conceptualized using the same classification system. The common stereotype of the introverted individual sport athlete versus the extraverted team sport athlete is a result of this classification model (Cratty, 1973). A team sport is broadly defined as a sport that requiresa team of players who train together and compete in events that require frequent interaction between members to achieve a group objective. To contrast that, an individual sport can be

characterized as: a group of athletes who train together and may contribute to total team performance but compete individually and often in opposition to their teammates (Jerez, 2020). Regarding sports, one of the major dimensions that needs to be looked into is the type of sport played by an individual. Some sports are highly individualistic, such as long-distance running, or archery, while others are clearly team activities, like football or cricket. Seemingly, the personalities of individuals playing sports vary according to the type of sport played although in a somewhat unpredictable pattern (Newcombe & Boyle, 1995). It cannot be speculated that identical personality patterns will be probable in participants in these two sporting activities that are quite different (Eysenck et al.,1992).

If a person knows more about their own individual potentials regarding their capabilities and what they are intended in accomplishing, there will be a much greater chance of the individual accomplishing success (Dobersek & Bartling, 2008). The Big Five Personality Factorsis a hierarchical model which is descriptive and taxonomic and is basedon personality traits. Modified by Lewis Goldberg, the Big Five Model summarizes the most human personality differences into five dimensions: namely, Neuroticism (N), Extraversion (E), Conscientiousness (C), Agreeableness(A) and Openness (Goldberg, 1990).

The current study focuses on the Extraversion dimension. The two facets of extraversion include high and low extraversion where scoring low extraversion refers to as introverts (John & Srivastava, 1999). Extraversion and Introversion was mainly introduced and popularized by Swiss psychologist and psychiatrist, Carl Jung (1875-1961) in 1921. Whilst introversion refers to one's movement of energy inwards towards more solitary, thoughtful activities, extroverts direct their energy outwards, towards other people and gain energy from such encounters as well (Jung, 1921). Sport participants are no different as there can be personality differences among athletes in various sports as well (Wrisberg et al., 1988). For example, it was found that compared to team sport athletes, individual sport athletes generally do appear to be less anxious, less dependent on others and more self-sufficient (Cratty, 1973). Theoretically, it would seem reasonable to assume that the more introvert individuals would tend to gravitate more towards selecting individual sports and the extroverted individuals towards selecting team sports (Steen & Huntington, 2013).

### Significance and Justification

Research on personality traits and mood states have been extremely imperative in the Sports Psychology field as the process of discovering talented athletes for the participation of sport activities is one of the most crucial issues in sports nowadays (Niaa & Besharat, 2010). The only research conducted on the background of personality and sport in Sri Lanka, investigated the personality characteristics of athletes to a general group of non-athletes (Ramanayaka et al., 2018). Similar to this research, most of the previous research conducted on personality and sport also focus only on comparing athletes to non-athletes (Newcombe & Boyle, 1995). There is also less agreement found on how personality varies from each sport (Wann, 1997). No further research has been conducted on the background of personality among athletes and sport in Sri Lanka. As mentioned in the introduction and background, the importance of sport involvement can clearly be seen. Therefore, we, as researchers must ask ourselves whether the link between sport type and personality serve a useful purpose such as

potential positive sport related outcomes (Jerez 2020). That is, can catering to one's personality have an effect on the type of sport predicted and it turn bring success to the sport industry as well as to the athlete.

In the field of Sports Psychology, the identification and measurement of predictable behavior functionality of athletes and distinguishing athletes from other athletes based on factors such as performance, skills, personality and others are extremely imperative and necessary to help athletes and people in general to decide which sport would favor them more (Ramanayaka et al., 2018). Based on the lack of research on personality and sport in Sri Lanka, investigating both sport type (Individual vs Team sport) and personality (Extraversion vs Introversion) may bring light to which dimension carries more predictive power or if the interaction between the two together is associated with larger associated benefits.

### *Objectives of the Study*

The study's general objective includes assessing the influence of personality traits on sports selection and among Undergraduates in the Colombo region. Research Hypothesis for the current study predicts that team sports are mostly selected by Extroverts.

## Methodology

### *Participants*

Using the convenient sampling method, the current study utilized a sample of undergraduate athletes (N= 378) from the Colombo region from both State (N = 144) and Non-state (N = 234) universities.

### *Measures*

The present research collected data through a closed-ended questionnaire via an online platform. The questionnaire consisted of two sections; namely, Section I consisted of the demographic information inclusive of the duration of the sport played/playing was asked in order to filter out the athletes that does not match the study criteria. The current study's inclusion criteria involved athletes who have played a sport for one year or more. Section II consisted of the personality questionnaire. In addition, attached to the questionnaire was also the consent form and the information sheet. The questionnaire was translated into Sinhala and Tamil and validated before the administration process.

### *Procedure*

Data collection procedures began as soon as the current Research's study proposal was approved by the Ethics Review Committee and after the survey was validated. Undergraduates were accessed via a Google form to administer the questionnaire in all three languages. Along with the general electronic survey that was asked to fill, the participants also filled an electronic consent form before completing the survey. Following consent, the participants had access to the information sheet. The clinical population, non-athletes as well as athletes who have had to quit a sport due to an injury were thereby excluded from the above study.

**Results**

Questions asked in the demographic sections acted as independent variables of our research. Age was considered as undergraduates from the age of 19 to 30 (19 ≤ 30) and this was coded into 3. 19 ≤ 22 age range was coded as 1, 23 ≤ 26 age range was coded as 2 and 27 ≤ 30 age range was coded as 3 in the variable view (Figure 1).

*Figure 1: Age Frequency Variable*
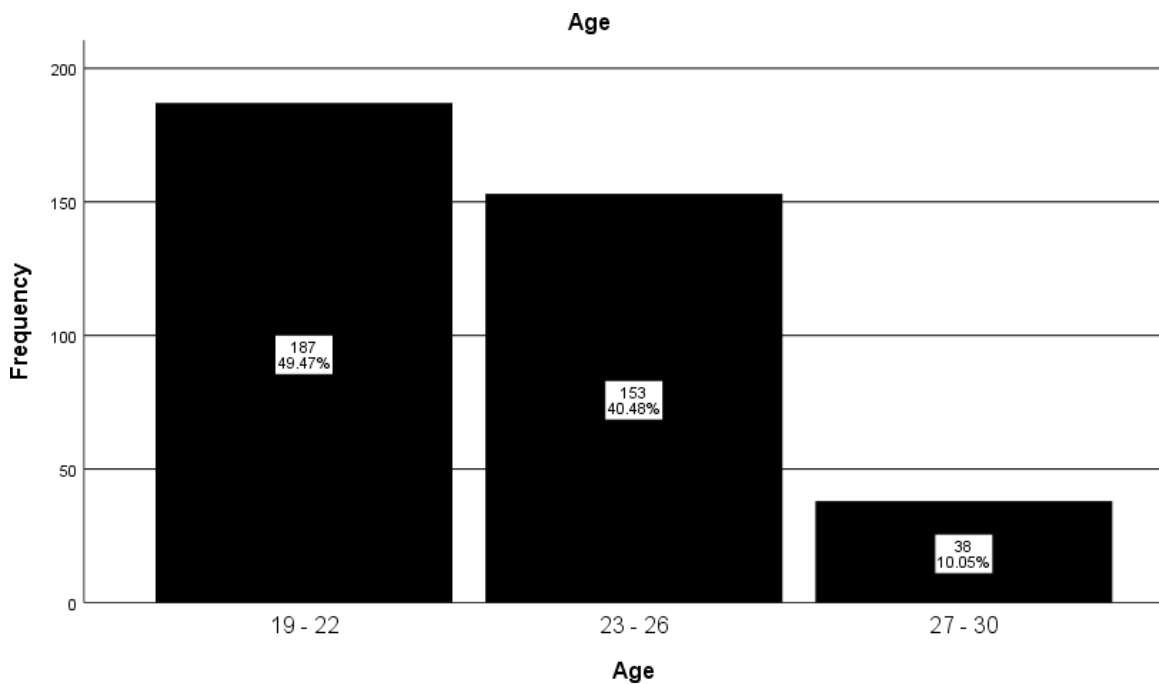


**Table 1**

*Type of Sport*

|            | Frequency | Percent |
|------------|-----------|---------|
| Individual | 191       | 50.5    |
| Team       | 187       | 49.5    |
| Total      | 378       | 100.0   |

**Figure 2**

*Name of Sport*
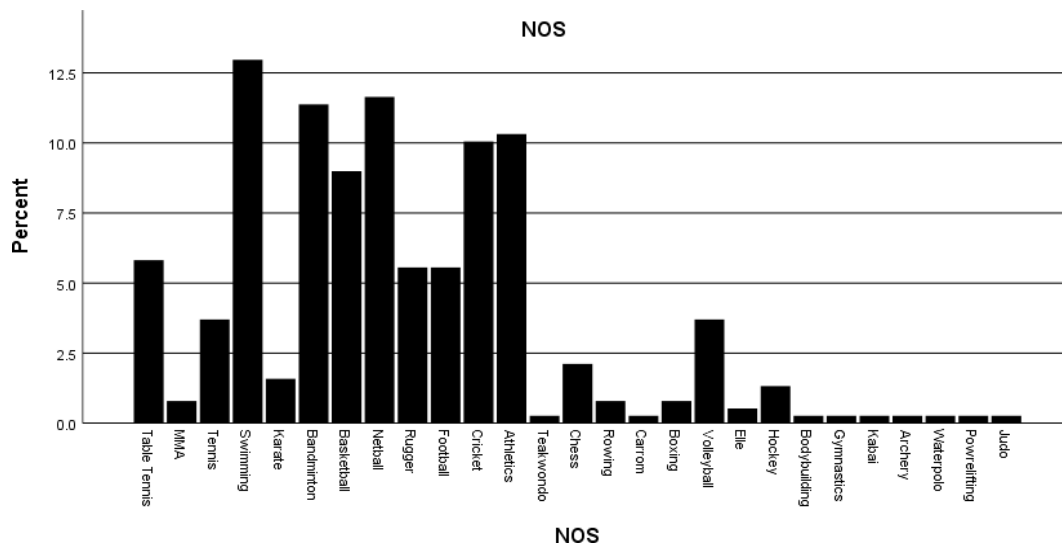


Figure 2 indicates the names of the sports played by the undergraduate athletes in order to understand if they had understood the concept of team and individual sport. And below Table 2 indicates the number of females and males that participated in team and individual sports and according to the table, majority of the males tend to select more team sports than the females.

**Table 2**

*Gender * TOS Crosstabulation*

|        | Individual | Team | Total |
|--------|-----------|------|-------|
| Female | 126       | 86   | 212   |
| Male   | 65        | 101  | 166   |
| Total  | 191       | 197  | 378   |

*Hypothesis testing*

An independent sample t test was run to investigate the hypothesis and the results of the analysis indicated the statement of significance as .139 ($p > 0.05$), which suggests that the null hypothesis is accepted which means that there is no significant variation shown between personality traits and the type of sport selected. Overall, suggesting that those playing individual sports were not more likely to be introverted and vice versa, that those engaged in team sports were not more likely to be extraverted as shown in table 4.

**Table 4**

*Independent sample T test*

| Levine's test for equality of variance | | | |
|---|---|---|---|
| | | F | Sig |
| Extraversion | Equal variance assumed | 2.195 | .139 |
| | Equal variance not assumed | | |

**Discussion**

Do extroverts select more team sports than introverts? Our analysis did not find results suggestive of a relationship. This could be due to college athletes using other criteria such as parents' role. For example, the parents' role in encouraging participation during childhood over and above personality to choose their sport (Strandbu et al., 2019).

However, the lack of a significant relationship between personality and sport type is still noteworthy in terms of understanding the role of each in Eysenck's optimal arousal theory (Eysenck, 1981). These results would suggest that in our sample, extroversion (or introversion) was not linked with the type of sport played, and hence, that this factor may not matter in terms of choosing one's sport. With the psychosocial benefits of sport involvement, it is important for researchers to explore factors that may harvest sport enjoyment and physical improvement and decrease sport-devaluation and attrition.

What factor identifies the "good from the great" or what makes an athlete a champion is not only dependent on the healthy genes, innate talent and physical strength but also depends on an athlete's mental powers, certain personality traits such as their killer instincts and sharpened skills to correctly anticipate an opponents' moves, mental toughness, mood and positive attitude and also the right decision made. Although the current research worked on investigating these factors, significant findings were not obtained, and the study was not able to conclude certain areas and points. In terms of sport type approximately 50% of the athletes selected team and individual sport equally which made the analysis much easier. All in all, the same research must be conducted using a larger sample size to obtain effective results.

*Limitations and Recommendations*

The total number of responses obtained was from 456 participants, however, only 378 responses were accepted due to the filtering of exclusion criteria and irrelevant answers. This caused a discrepancy in both the projected sample size as well as the originally planned analysis. Due to the limited sample size the reliability statistics were also mildly average. This factor could have been caused due to certain factors affecting the athlete's responses. For instance, we approached undergraduate athletes who are usually busy with a study and work

schedule that they simply could not find the time to do. Also, these surveys were completed online due to the pandemic situation. This factor adds a layer of accountability and also the motivation to participate in the study as the researcher was not present in the same room as the participants. To improve the sample size in the future, researchers must work directly with the athletes in a hands-on experience, to foster a greater sense of involvement for the study.

In terms of the age group, most undergraduate athletes have participated in a sport for an extended period of time, ideally from childhood or adolescents. As a result, it could be assumed that their respective guardian was also involved in selecting their sport and thus, this would stand in contrast to the idea of sport selection, where the athletes chose their sport based on the characteristics of their personality. Future researchers may explore this avenue to understand if in this avenue, do athletes really choose the sport that best fits their personality.

Among the most significant problems, a consistent issue is the failure to test for the presence of response distortions, where there is a tendency for some individuals to respond falsely psychological assessments. Social desirability could have been prevalent in the current study as well, just like most personality questionnaires. Therefore, when exploring one's personality, future researchers can conduct qualitative research methods such as interviews or observations, whist maintaining anonymity, rather than quantitative methods, to get in-depth information of one's personality.

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# THE RELATIONSHIP BETWEEN SOCIOECONOMIC STATUS AND PSYCHOLOGICAL WELL-BEING AMONG UNIVERSITY STUDENTS DURING AN ECONOMIC CRISIS IN SRI LANKA

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**Abstract**

This study assessed the relationship between socioeconomic status and psychological well-being among university students during an economic crisis in Sri Lanka. The sample consisted of 97 university students who were selected through convenience sampling. Data was collected through a self-report facilitated by Qualtrics software. Psychological well-being was assessed using the DASS-21, while socioeconomic status was evaluated using the Family Affluence Scale and a Likert-scale question measuring monthly household income. Spearman's rank correlation coefficient was chosen to explore the relationship between socioeconomic status and Psychological well-being. Kruskal Wallis test was used to analyze the significant differences in the mean scores of depression, anxiety, and stress across categories of classes of income. Results indicated a non-significant negative correlation between socioeconomic status and Psychological well-being, and university students belonging to the middle socioeconomic status had greater levels of depression, anxiety, and stress during the economic crisis.

**Keywords:** socioeconomic status, psychological well-being, university students, economic crisis

**Introduction**

Sri Lanka (SL) is experiencing the greatest EC in its history. The 2019 Easter bombings and COVID-19 lockdown escalated the crisis (George et al., 2022). The country's economy is at its worst due to a lack of foreign currency, impending debt obligations, excessive inflation, and shortages of essential goods. These deficiencies led to widespread demonstrations creating an unsteady political structure, which contributed strongly to the economic decline (Vivekanantharasa & Blanco, 2022).

The education system faced significant challenges in meeting the needs of the student population. The fuel crisis and the massive rise in transport costs hindered the students' and educators' access to their institutes (Raveenthiran, 2022), and this allowed the rise of online learning. However, lower-middle-class families, especially those living in rural areas were adversely impacted, as more than 70% of students experienced challenges due to an unstable power grid, and lack of access to the internet or efficient electronic devices (Vivekanantharasa & Blanco, 2022).

During an EC, university students especially, struggle with economic and material resources, such as an increased cost of living and steep in tuition fees (Vivekanantharasa & Blanco, 2022). Certain institutions minimized expenses by raising class sizes, offering limited

course options, and reducing student support services, which caused significant distress among students. Students experienced fewer part-time employment alternatives while in university due to a highly competitive job market, which could reduce their chances of full-time employment after graduation (Stein et al., 2013). These demands have made students less resilient and overwhelmed, further impacting their psychological well-being (PW).

The current study examined PW through the prevalence of depression, anxiety, and stress levels. The study exclusively examined income levels as a measure of SES due to their direct correlation with resource accessibility. University students' mental health is directly influenced by their income, determining their financial ability to access mental health treatment (Chandrasekara, 2020).

### *Socioeconomic status and Psychological wellbeing*

Multiple studies have shown that low SES decreases PW (Mohammad et al., 2020; Saleem et al., 2013; Wahed & Hassan, 2017), but there have been contradicting findings in the literature. For example, Agberotimi et al. (2020) found that depression and anxiety symptoms were higher among middle SES participants in comparison to lower and higher SES.

Conversely, Salami and Walker (2014) found increased depression and anxiety symptoms among higher SES participants. Another study highlighted that students hailing from high SES who have had adverse psychological experiences can be prone to mental health conditions after enrolling in university (Li et al., 2019 cited in Mofatteh, 2021). However, Cao et al. (2020) found, majority (75.1%) of the students without any anxiety symptoms credited a stable family income (SES indicator) as a protective barrier.

These conflicting findings support research on the relationship between SES and PW among university students. However, there is minimal research on the SES-PW link among university students in SL during an EC, indicating a research gap. Further exploration is warranted, given the high trend of pursuing higher education during economic crises, with the belief that a degree can enhance living standards (Varghese, 2001). Amid economic stressors, students are admitted to universities, exposing them to PW issues.

Despite EC disproportionately affecting low- and middle-income countries, there is limited research from these nations (Frasquilho et al., 2016). SL, a low-middle-income country, requires special attention, given the impact of the EC on individuals across various SES, ultimately influencing students' PW.

The current study aimed to contribute to the existing body of literature by assessing the relationship between SES and PW among university students during an EC in SL.

The study hypothesized that;

(H1) Higher SES tends to relate to increased levels of PW.

(H2) Lower SES will relate to significant psychological impact during an EC.

### Methodology
### *Design*

The study employed a quantitative correlation research design to determine whether there is a significant relationship between independent variable SES and dependent variable PW. The study was presented as a Qualtrics self-report survey. Data was analyzed using SPSS

version 29 (IBM Corp, 2021). The study's ethics received approval from the Cardiff School of Sport and Health Sciences' ethics committee (reference no; UG-7494)

### Sample and Procedure

A priori analysis using G* Power version 3.1 (Faul, et al., 2009) required minimum sample size for both linear bivariate regression (medium effect and power value 0.95) and Multivariate Analysis of Variance (medium effect size and power value 0.80) was $N$ = 113. The study, advertised through social media advert, required participants to be 18 or older, enrolled in an SL university, and proficient in English Language. Participants, upon survey access, received an information sheet. Following informed consent and demographic details, they proceeded to complete the DASS-21 and SES measures, including the FAS scale and a Likert scale question on income levels.

Out of 166 attempts, 66 incomplete and 1 incorrect response were removed to maintain data accuracy, avoiding imputation methods. Two underage participants were excluded. This left 97 valid responses, all of whom rigorously satisfied the established criteria. Participants, aged between 18 to 49 years (M=24.56, SD=5.84), included 71 females, 24 males, and 2 who preferred not to say, with educational backgrounds, comprising 45.4% bachelor's, 35.1% diploma, 13.4% Master's, 3.1% post-graduate, 2.1% post-graduate, and 1% Ph.D. programs

### Materials

#### DASS-21

DASS-21, 21-item scale, was used to evaluate the symptom severity of the sub-scales of depression ($\alpha$ = .83), anxiety ($\alpha$ = .79), and stress ($\alpha$ = .79; Overall scale $\alpha$ = .91). For each statement, "I felt that life was meaningless," participants were asked to rate their symptoms on 4-point scales. Scores in each subset were calculated and doubled to accommodate the DASS-21's condensed form from DASS-42. For depression, anxiety, and stress, normal scores ranged 0-9, 0-7, and 0-14, while the highest scores ranged from 10-28, 8-20, and 15-34 respectively.

#### SES Measures

Family Affluence Scale (FAS) is a 6-item scale used to evaluate the socioeconomic position of a family through the measure of family wealth such as vehicles, computers etc. (e.g., "Do you have your own bedroom?"). Scores from combining indicators determine affluence: higher scores indicate greater affluence, while lower scores suggest reduced affluence (Chzhen et al., 2016). The overall scale reliability was $\alpha$ = .55.

Additionally, participants were requested to select a range from 5 options that best represents their monthly household income. These options ranged from upper class to lower class. Each range represented a SES. (e.g., less than Rs. 48, 000 was classified as lower class). The income levels were evaluated based on the data provided by the Department of Census and Statistics (2019). The inflation-adjusted income equation was used to modify the 2019 income levels to the 2022 income levels by integrating the inflation rates. Finally, the figures were rounded off to the nearest thousandth.

### Ethical Consideration

Participants received detailed information covering study aims, withdrawal rights, confidentiality, and data storage. Support pathways for mental health and investigator contact details were also provided.

**Results**

*Psychological well-being among university students*

Descriptive analysis of depression (Figure 1), anxiety (Figure 2), and stress (Figure 3) demonstrated the severity distribution of PW among university students.

**Figure 1**

*Severity Distribution of Depression among University Students*
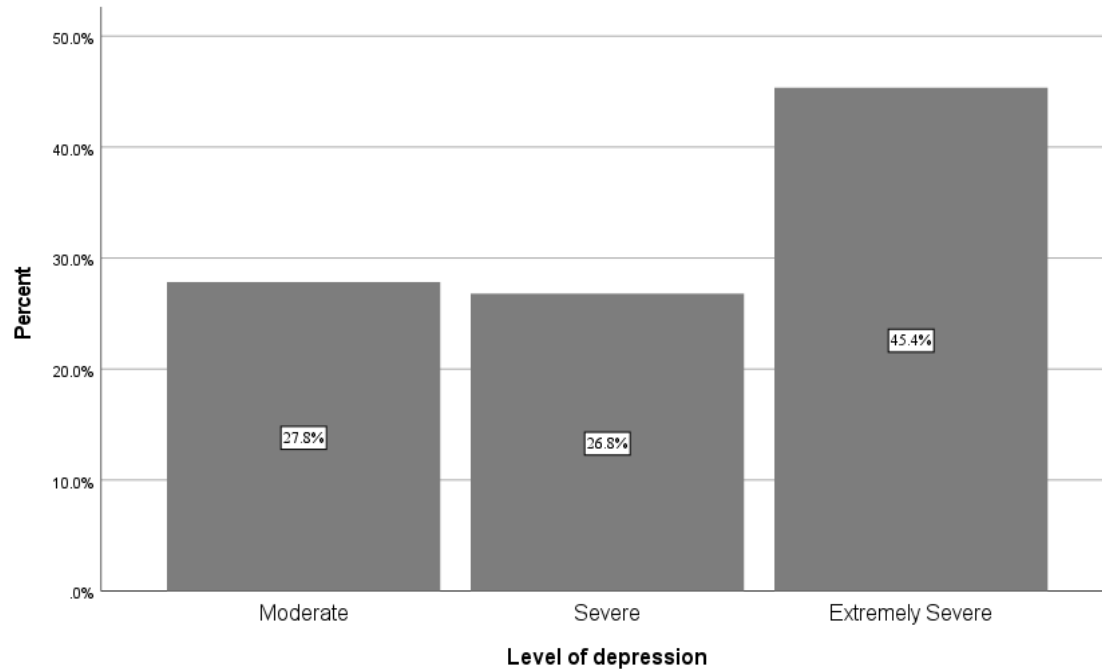


**Figure 2**

*Severity Distribution of Anxiety among University Students*
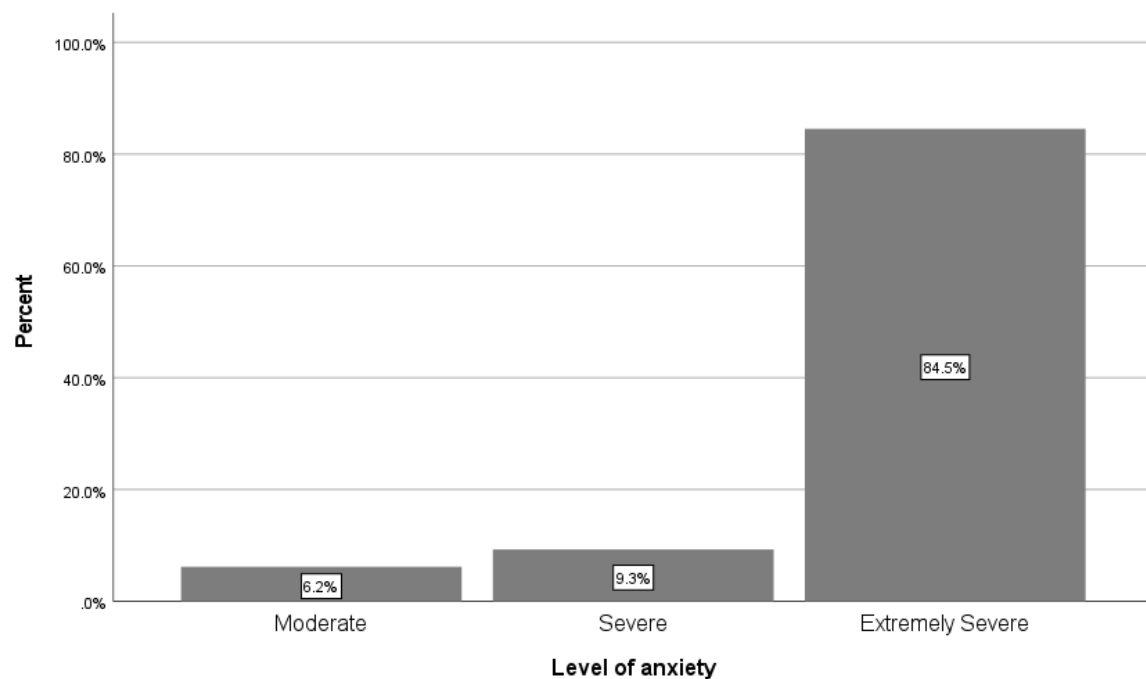
**Figure 3**

*Severity Distribution of Stress among University Students*
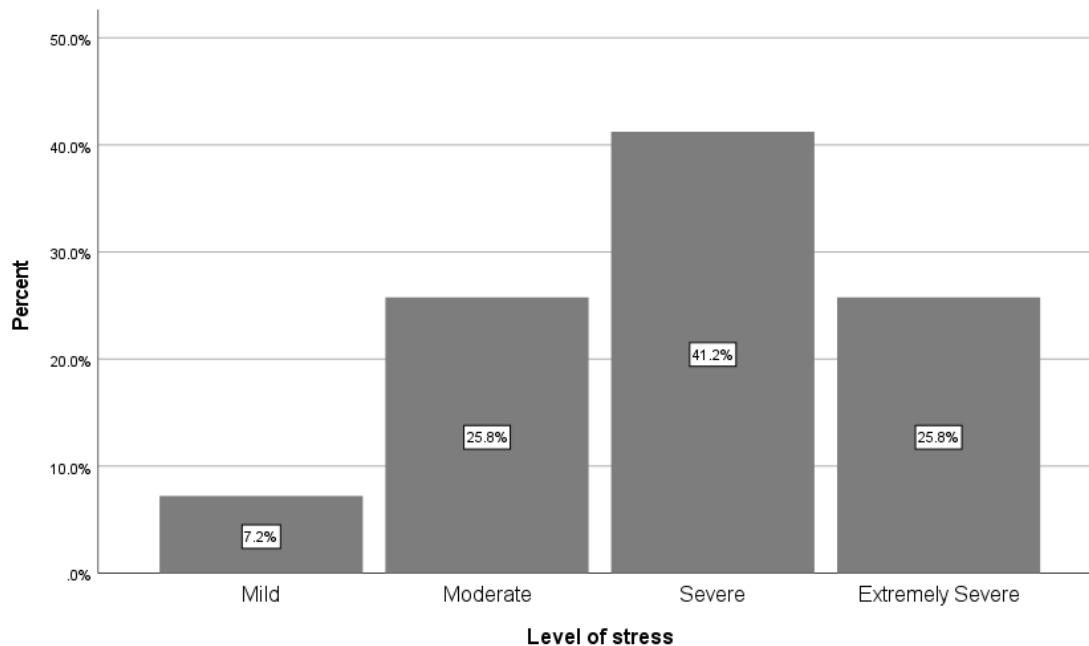


*Socioeconomic classes of university students*

Descriptive analysis demonstrated that, most participants were from lower-income class (*n*=37), with an equal distribution between middle (*n*=30) and high-income classes (*n*=30).

*Relationship between psychological well-being and socioeconomic status.*

Spearman's rank correlation coefficient was chosen to explore the direction and significance of the relationship between the independent variable SES (FAS scale) and dependent variable PW (DASS-21). The results indicated that there was a non-significant negative correlation between the two variables, $r (95) = -.19$, *p*= .067

*Effects of socioeconomic status on Psychological well-being*

Kruskal Wallis test (non-parametric) was used to analyze whether there are significant differences in the mean scores of depression, anxiety, and stress across categories of classes of income. The test yielded significant findings for depression (H= 8.407, df= 2, *p*= 0.015) and stress (H= 9.986, df=2, $p = 0.007$) and demonstrated partial significance for anxiety (H= 5.966, df=2, $p = 0.051$) across categories of classes of income.

The post hoc test (Bonferroni corrected) was carried out to determine which specific SES groups demonstrated significant differences in depression, anxiety, and stress scores.

**Table 1**

*Pairwise Comparisons of Classes of Income*

| | Sample 1- Sample 2 | Test Statistic | Sig. | Adj. Sig. [a] |
|---|---|---|---|---|
| **Depression** | High Income Class-low Income Class Low | 9.697 | .159 | .478 |
| | High Income Class-Middle Income Class | 20.967 | .004 | .011 |
| | Income Class-Middle Income Class | -11.270 | .102 | .305 |
| **Anxiety** | High Income Class-low Income Class | 10.760 | .118 | .354 |
| | High Income Class-Middle Income Class | 17.500 | .016 | .047 |
| | Low Income Class-Middle Income Class | -6.740 | .328 | .983 |
| **Stress** | High Income Class-low Income Class Low | 10.076 | .144 | .431 |
| | High Income Class-Middle Income Class | 22.817 | .002 | .005 |
| | Income Class-Middle Income Class | -12.741 | .064 | .193 |

*Note.* Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same. Asymptotic significances (2-sided tests) are displayed. The significance level is $p <.05$.

a. Significance values have been adjusted by the Bonferroni correction for multiple tests.

Descriptive analysis was carried out to ascertain which of the two categories (high-income classes or middle-income classes) had the greatest number of PW issues.

The second hypothesis—that university students from lower SES face greater PW impact will be rejected.

**Figure 4**

*Distribution of Depression, Anxiety, and Stress across Different Classes of Income*
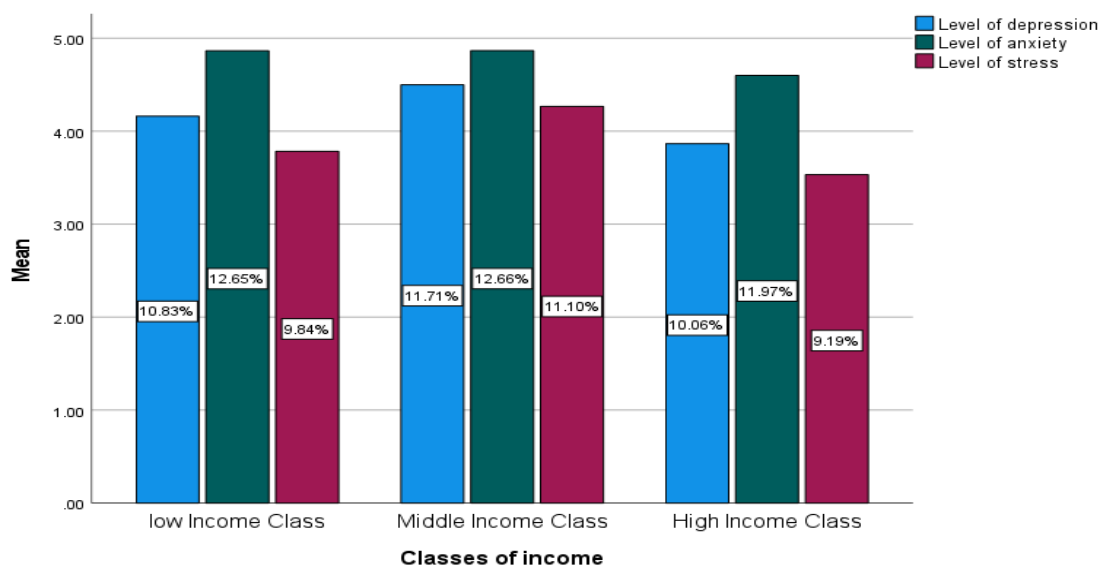
**Discussion**

The study findings indicated a non-significant negative correlation between SES and PW, leading to the rejection of the study's initial hypothesis. This shows a complex relationship between the two variables, suggesting factors beyond SES influenced students' PW significantly. The economic crisis has led to challenges like larger class sizes, limited programs, reduced support services, and fewer job options post-graduation, affecting Sri Lankan students' mental well-being. Academic stress, interpersonal relationships (family expectations, romantic and peer relationships), campus conflicts, and hostel conditions compound these issues, impacting students' psychological health (Mahees, 2020). Additionally, the FAS's lower scale reliability might have influenced unexpected findings that contradicted the study's first hypothesis. The reduced reliability could be attributed to social desirability bias (Angel et al., 2019), affecting respondents' honesty about family affluence.

This finding is consistent with, Cook (2014) study, which found a non-significant negative relationship between SES and PW among university students. Parallel to the current study, Cook (2014) also utilized DASS-21 to assess PW and classified participants into three socioeconomic classes (lower, middle, and upper), with a sample size of 95 participants. Cook (2014) validated findings indicating students' reluctance to disclose family finances and highlighted typographical errors and language ambiguities in the scale, potentially impacting study outcomes. Cook's survey-based approach could introduce social desirability bias, contributing to unexpected results. This underscores the need for cautious interpretation due to methodological limitations. Aligning with the current findings, Sakshi and Baloria, (2023) and Wang and Geng (2019) found similar results but within different populations: college lecturers and participants from the Chinese general social survey.

The study's second finding reveals that SL university students in the middle SES experienced higher levels of depression, anxiety, and stress during the EC, resulting in the rejection of the second hypothesis. Despite the findings differing from the study hypothesis, it is acceptable to assume that during an economic crisis, the middle SES suffers the most. In contrast to high-income persons who have savings and low-income people who receive government assistance, (Jayathilaka et al., 2022), the middle class does not have equivalent financial buffers or support. During the EC, they experienced increased job uncertainty and income loss, which was exacerbated by government policy changes affecting their financial responsibilities and capacity to support their children's education. Due to economic difficulties, middle-class students felt obligated to work part-time or contemplate student loans (Shanthaarchch, 2022).

Additionally, the study's unexpected findings might relate to middle-SES students prioritizing education more than high or low-SES peers (Azaria et al., 2019). Due to financial constraints, economically disadvantaged students might consider dropping out or prioritize job hunting, hindering their educational pursuits. High-SES students from more affluent households, on the other hand, may be less motivated to pursue additional qualifications due to their already high SES (Azaria et al., 2019). However, middle SES students prioritize education, especially during economic distress, seeing it as a way to improve their quality of life (Varghese, 2001). However, their commitment to education amid financial pressure may have lowered middle SES students' psychological well-being, as evidenced by the study.

This finding is consistent with, Agberotimi (2020) study, which found that people in the standard (middle) income class had greater levels of depression, but found no statistically significant results for stress or anxiety. This could be because the middle SES, which in Nigeria comprises the majority of business owners and employees earning higher salaries in both the private and public sectors, represents the largest percentage of the population, contributing to the results. Although the economic crisis and COVID-19 were separate circumstances, both studies had the same underlying causes, such as economic uncertainty and income loss, which are likely responsible for the increased prevalence of depression demonstrated in individuals from middle SES. While the study aligned with prior research on health workers, it's essential to note the scarcity of research on middle SES in the context of SES and PW among university students.

The present study has a few limitations including reliance on self-reported measures, reduced sample size limiting generalizability, FAS's lower reliability scores, and the limited availability of published non-significant findings on this topic posed challenges in interpreting the study findings with existing research. The unavailability of a validated SL SES questionnaire and measuring SES with only income levels will be viewed as yet another limitation of this study.

## Conclusion and recommendations

Despite limitations, the study questions the established link between SES and PW. Many studies with non-significant results go unpublished due to publication bias, hindering a complete understanding. The study, though non-significant, reveals a noteworthy impact on middle-SES students. This emphasizes the value of publishing non-significant findings to avoid redundancy, refine hypotheses, and advance research more efficiently. It underscores the need for transparency in research to enhance the overall literature.

Future studies can focus on supplementing this quantitative research with a qualitative approach, delving into specific stressors like academic pressure, financial strain, and employment insecurity affecting middle-income university students during crises. Expanding the sample size and enhancing scale reliability would offer a more robust foundation for further research. When determining SES, considering additional variables like education and occupation could provide a more comprehensive evaluation.

Amid SL's EC, PW among university students is a universal concern. This study serves as a crucial reminder to educators and relevant organizations that students from all SES, not just those traditionally considered at risk, can experience PW concerns.

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# THE RELATIONSHIP BETWEEN INTRINSIC MOTIVATION AND ACADEMIC PERFORMANCE AMONG UNDERGRADUATES IN SRI LANKA

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## Abstract

The current study explored the relationship between intrinsic motivation and the academic performance of Sri Lankan undergraduates. The participants were 80 undergraduates (*13 males; 65 females; 2 prefer not to say*) attending both government and private universities in Sri Lanka within the age range of 18 to 30 years. The responses were collected using an online survey that included the subscales of intrinsic motivation from the Academic Motivation Scale to evaluate their intrinsic motivation levels. Their academic performance was measured using their average percentage scores from the last performed module. Spearman's rank-order correlation was used to test the relationship between intrinsic motivation and academic performance. According to the results, there is a significant weak positive correlation between the two variables of this study ($r_s = .22$, $p = .047$). It was concluded that when the level of intrinsic motivation is high, the level of academic performance also increases.

**Keywords:** intrinsic motivation, academic performance, university, undergraduates

## Introduction

A common goal of university students around the world is to achieve academic success. Therefore, their academic performance plays a crucial role in determining their academic success. One of the factors that influences academic performance is motivation. When students are enrolled in a university for the first time, they display a sense of freedom, which makes them realize that academic motivation plays a major role in determining the choices made by them; whether or not they meet the requirements (Clark & Schroth, 2010). There is also a general conclusion that a prominent learning motivation has the ability to promote academic performance among students (Schick & Phillipson, 2009). Thus, it has become a topic of discussion in the field of psychology due to its connection with biological, cognitive, and social aspects and their impacts on how an individual demonstrates behavior (Tariq et al., 2011).

When considering the types of motivation, intrinsic motivation plays a crucial role in academic performance (Vallerand et al., 1992), as it makes it effortless to overcome academic challenges within the education sector (Ibrahim et al., 2017).

In terms of university education, intrinsic motivation is typically displayed in the form of active engagement in the selected course of study, enjoying lectures, and interest in the relevant course materials. Hence, being intrinsically motivated while pursuing a particular course at a university or college impacts performance as well as assists in maintaining a sense of motivation ahead of that course (Harackiewicz et al., 1998). On the other hand, academic performance is both objective and subjective. The objective aspect is a student's numeric score

in an examination, while the subjective sense is a student's attitude towards learning (Coetzee, 2011). At the university level, subjective academic performance is known to bring about a noticeable difference (Bakar et al., 2010).

The majority of the previous research studies indicate that there is a significant relationship between motivation and academic performance, with a few studies proving that there is no significant relationship, particularly between intrinsic motivation and academic performance. Thus, to address this research gap, the current study aimed to examine the relationship that exists only between intrinsic motivation and the academic performance of Sri Lankan undergraduates.

Based on previous research, the following hypotheses were generated:

$H_0$ – There is no significant positive relationship between intrinsic motivation and academic performance

$H_1$ – There is a significant positive relationship between intrinsic motivation and academic performance

## Methodology

### Sample and Design

After excluding a null response, the final sample consisted of 80 participants who were recruited using a convenience sampling method via a social media advertisement. They were within the age range of 18-30 and were both employed and unemployed. A quantitative, correlational design was utilized for this research to measure the relationship between intrinsic motivation and academic performance and the survey was presented online with the help of Qualtrics software.

### Materials

After obtaining informed consent, the questionnaire of this study collected demographic details such as age, gender, year of study, and type of university.

To measure the intrinsic motivation of students, the Academic Motivation Scale (AMS) developed by Vallerand et al. (1992) was used. This is a 28-item scale including 7 subscales that measure intrinsic, extrinsic, and amotivation. However, as this study's focus was only on intrinsic motivation, the subscales only relevant to intrinsic motivation were included in the questionnaire to assess the intrinsic motivation of undergraduates. These subscales consist of 4 items each with 12 items in total namely; Intrinsic Motivation to Know (IMTK), Intrinsic Motivation to Accomplish (IMTA), and Intrinsic Motivation to Experience Stimulation (IMTES). The internal consistency values of each subscale indicated by Cronbach's alpha were .78, .76, and .67 respectively. These subscales were considered reliable for this study according to Gliem and Gliem's (2003) Cronbach's alpha reliability coefficient for the Likert scales.

To determine the academic performance of students, their scores (in percentage) of the last completed module were assessed.

### Analysis

The collected data was analyzed using SPSS version 29.0. Descriptive statistics were calculated to determine gender and age, whereas a correlational analysis was conducted to determine the type of relationship between intrinsic motivation and academic performance. In

addition, a simple linear regression was run to determine if intrinsic motivation has an impact on academic performance.

## Results

### Hypotheses testing

As per the results of the Shapiro-Wilk normality test, the distribution of Intrinsic Motivation deviated significantly from normality ($W = .94$, $p = .001$), and the distribution of Academic Performance did not depict a non-normality ($W = .98$, $p = 0.25$). However, on the whole, as the test of normality demonstrated that the data was skewed, Spearman's rank-order correlation analysis was computed to investigate the correlation between intrinsic motivation and the academic performance of the undergraduates employed for this study.

The results revealed that there is a significant weak positive correlation between intrinsic motivation and academic performance ($r_s = .22$, $p = .047$) as denoted in Table 1. Hence, the results supported $H_1$ which stated that there is a significant positive correlation between intrinsic motivation and academic performance, and $H_0$ was rejected. Overall, the results suggest that when the level of intrinsic motivation is high, the academic performance level also increases.

**Table 1**

*Spearman's correlation between Intrinsic Motivation and Academic Performance*

| | | | IM_mean | What is your average percentage in the last performed module of the semester? |
|---|---|---|---|---|
| Spearman's rho | IM_mean | Correlation Coefficient | 1.000 | .223[*] |
| | | Sig. (2-tailed) | . | .047 |
| | | N | 80 | 80 |
| | What is your average percentage in the last performed module of the semester? | Correlation Coefficient | .223[*] | 1.000 |
| | | Sig. (2-tailed) | .047 | . |
| | | N | 80 | 80 |

*. Correlation is significant at the 0.05 level (2-tailed)

### Exploratory analysis

A simple linear regression was further conducted to check the impact of Intrinsic motivation on Academic performance as shown in Table 2 below. According to the results, intrinsic motivation significantly predicts academic performance ($\beta = .23$, $t = 2.072$, $p = .042$).

**Table 2**

*Regression Coefficients of Intrinsic Motivation on Academic Performance*

| Variable | B | β | t | SE |
|---|---|---|---|---|
| Constant | 56.49*** | | 7.898 | 7.15 |
| IM_mean | 3.52* | .228 | 2.072 | 1.69 |
| $R^2$ | .05 | | | |

*Note.* $N = 80$, ***$p < .001$, *$p < .05$

**Discussion**

Based on the findings of this study, the alternative hypothesis was supported because even though weak, a significant positive relationship was found between intrinsic motivation and academic performance, with the rejection of the null hypothesis. The findings of this study are also in line with previous research as that of Amrai et al. (2011) and Yarin et al. (2022) in which a weak, positive, and significant correlation was found between academic motivation and academic achievement as well as between intrinsic motivation and students' academic performance respectively by running correlational analyses. Similar results were drawn from the study of Buzdar et al. (2017) and Muhammad et al. (2015) which identified a significant positive relationship between intrinsic and extrinsic motivation and academic performance.

Furthermore, according to the study of Shillingford and Karlin (2013), a need for competence, self-determination, and satisfaction from college life are elements of intrinsic motivation that contribute to the increase in academic performance. Hence, it can be stated that the selected sample of this study may also have displayed a sense of self-determination and a satisfactory college life that potentially enhances their academic success. This may be the reason for the positive correlation and linking to the self-determination theory that highlights the need for autonomy in a psychological aspect (Ryan et al., 1997) as well as examining the positive impacts of intrinsic motivation on academic success (Trevino & DeFreitas, 2014).

It is also noteworthy that the results of this study are contradictory to the findings of Bengtsson and Teleman's (2019) study that claimed both intrinsic and extrinsic motivation and academic performance are negatively correlated and there is an insignificant correlation between academic motivation and academic performance accordingly. Thereby, this study was able to address the research gap of these studies that concluded the correlation of both variables to be either negatively or insignificantly correlated.

There are, however, some limitations of this study. The use of the convenience sampling method has affected the external validity of this study due to the unequal representation of gender making the findings less generalizable. However, the findings can be fairly generalized to the younger population who are between the ages of 18 to 30 years. Additionally, confounding variables such as the personality traits of the participants were not controlled. Thus, there would have been a significant impact of such variables in the results of the study.

**Conclusion and Future Recommendations**

The results of this study offer the latest insights into the relationship of intrinsic motivation with academic performance among undergraduates in Sri Lanka indicating that when the level of motivation is high, the academic performance is also high. This highlights that intrinsic motivation alone can determine the academic success of university students. Future research should consider using a stratified sampling method to have an equal number of individuals to represent each gender so that the generalizability of the findings can be improved. Moreover, factors such as personality traits should be considered when examining how the intrinsic motivation levels and academic performance of undergraduates can be impacted by their personality traits. In addition, qualitative studies can be conducted to explore and understand the experiences of undergraduates concerning their college life more comprehensively with the aid of open-ended questions by also shedding light on the experiences of online learning that became widespread during the prevalence of COVID-19. Educators around the world could focus on implementing strategies to enhance the motivation of students toward their studies as well, via various educational programs. This can subsequently assist in improving the quality of teaching and methods of assessing students' performances to make university life a valuable experience for the students.

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# RELATIONSHIP BETWEEN PERCEIVED STRESS, BURNOUT AND TURNOVER INTENTION AMONG SRI LANKAN VOLUNTEERS

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**Abstract**

Volunteering is important for a productive economy and society, however, when a volunteer quits, it impacts the organization and the community. This study examined the relationships between perceived stress, burnout, and volunteers' turnover intention in Sri Lanka. This study used a quantitative cross-sectional design utilizing 128 Sri Lankan volunteers who were 19 to 52 years. The Perceived Stress Scale (PSS-10), Oldenburg Burnout Inventory (OLBI) and the Turnover Intention Scale were used to measure perceived stress, burnout and turnover intention respectively. The participants demonstrated moderate levels of perceived stress, high levels of burnout, and moderate negative levels of turnover intention. The results revealed a significant relationship between perceived stress and turnover intention ($r_s$ (126) = .28, $p$ = .002), a significant relationship between burnout and turnover intention ($r_s$ (126) = .50, $p < .001$) and a significant relationship between perceived stress and burnout ($r$ (126) = .42, $p < .001$).

**Keywords:** Burnout, Perceived Stress, Turnover Intention, Volunteers

## Introduction

Sri Lanka has a rich culture and a long history of volunteering that was shaped by socio-cultural practices (United Nations Volunteers Sri Lanka, 2023) and it is the country with the highest rate of volunteering in 2019, with an overall participation rate of 46% of the general population (Charities Aid Foundation, 2019). Research has demonstrated that engagement in volunteering activities is strongly predictive of improved happiness (Borgonovi, 2008; Musick & Wilson, 2003) and decreased psychological distress (Greenfield & Marks, 2004; Thoits & Hewitt, 2001). However, while the above-mentioned statistics and benefits are encouraging, research has also demonstrated that highly intense volunteering can also lead to anxiety (Thornton & Novak, 2010), burnout (McNamee & Peterson, 2015), stress, and psychological and emotional exhaustion (Heldman & Israel-Trummel, 2012; Jones & Williamson, 2014). As a result of these negative impacts, one of the primary challenges experienced by volunteer organizations is the individual's intention to quit, also called as turnover intention, which then later leads to quitting the volunteer organization (Garner & Garner, 2011).

According to research, perceived stress has a significant relationship to turnover intention among different types of populations (Ahn & Chaoyu, 2019; Al-Mansour, 2021; Arshadi & Damiri, 2013; Sewwandi & Perera, 2016; Yin-Fah et al., 2010). Additionally, ample research has provided evidence that burnout has a positive relationship with a volunteer's turnover intention (Allen & Mueller, 2013; Chen & Yu, 2014). It should be highlighted that

the studies by Allen and Mueller (2013) and Chen and Yu (2014) are the sole investigations that experimentally explored the impact of burnout on volunteer turnover intentions, and both demonstrated a positive relationship between burnout and turnover intention (Scherer et al., 2016). This indicated that not much research has discussed the link between volunteer burnout and turnover intention. Moreover, research also suggests that a relationship exists between perceived stress and burnout among different populations (Abdollahi et al., 2021; Brubaker & Beverly, 2020; Rey et al., 2016; Santen et al., 2010). Although not many studies have looked into the relationship between perceived stress and burnout among volunteers, the research conducted by Akintola et al. (2013), demonstrated a positive relationship between stress and burnout among volunteers.

The objectives of this study were to determine if there is a relationship between perceived stress and turnover intention, burnout and turnover intention, and perceived stress and burnout.

H1- There is a significant relationship between perceived stress and turnover intention among volunteers.

H2- There is a significant relationship between burnout and turnover intention among volunteers.

H3- There is a significant relationship between perceived stress and burnout among volunteers.

## Methodology

### Participants

According to calculations made using the G-power software version 3.1.9.4, a minimum sample size of 46 was required to conduct a bivariate Pearson correlation. 248 participants who were 18 years of age or older, in an active volunteering experience of at least 6 months or more were recruited using a convenience sampling strategy and a snowball sampling strategy from several Sri Lankan volunteers. After eliminating missing responses and failed attention checks, the sample consisted of 128 participants with a response rate of 51.61% (74 males, 54 females). Participants' age ranged from 19 to 52 years ($M$= 25.31, $SD$= 5.32).

### Design and Procedure

This was a quantitative cross-sectional design study that was pre-registered on the Open Science Framework registry. The study collected data using an online survey approach with the use of scales which were administered via Qualtrics. The link to the online form created was incorporated into an advert that was designed to access participants. The advert specified the eligibility criteria to participate in the study and if potential participants were interested and met the criteria, he or she was able to click on the link to access the study. This advert was circulated across social media platforms such as WhatsApp, Instagram and LinkedIn for data collection. Upon giving consent, the participants filled out the demographic questionnaire, followed by the PSS-10, the OLBI, and the turnover intention scale.

*Materials*

*The Perceived Stress Scale-Version 10 (PSS-10)*

The PSS-10 is a 10-item questionnaire with a 5-point Likert scale ranging from 0 (never) to 4 (very often) that was developed by Cohen et al. (1983) and is used to measure perceived stress (overall scale α = .78).

*The Oldenburg Burnout Inventory (OLBI)*

The OLBI is a 16-item questionnaire with a 4-point Likert scale ranging from "strongly agree" to "strongly disagree" that was originally developed by Demerouti and Nachreiner (1998) to measure burnout and contains 2 subscales disengagement (α = .58) and emotional exhaustion (α = .78; overall scale α = .815).

*The Turnover Intention Scale*

The Turnover Intention Scale is a 3 item questionnaire with a 6-point Likert scale ranging from "strongly disagree" to "strongly agree" (overall scale α = .58) which was developed by Michaels and Spector (1982) and was used to assess a volunteer's intention to leave, or turnover intention (Michaels & Spector, 1982).

*Demographic Questionnaire*

Age, gender, marital status, employment status, highest level of educational qualification, number of hours of volunteering per week and the number of years of volunteer experience, were among the demographic data that was gathered.

**Method of Analysis**

The IBM-SPSS version 29 was used to analyze the data. To test if there was a relationship between perceived stress, burnout and turnover intention, a correlational analysis was used.

**Results**

*Descriptive Statistics*

**Table 1**

*Demographic Characteristics of the Volunteers*

| Demographic characteristics | n | % |
|---|---|---|
| Sex | | |
| Male | 74 | 57.8 |
| Female | 54 | 42.2. |
| Marital status | | |
| Single – never married | 118 | 92.2 |
| Married with children | 4 | 3.1 |
| Married without children | 5 | 3.9 |
| Divorced | 1 | .8 |
| Employment status | | |
| Employed – full time | 60 | 46.9 |

| | | |
|---|---|---|
| Employed – part-time | 6 | 4.7 |
| Unemployed – looking for a job | 6 | 4.7 |
| Unemployed – not looking for a job | 2 | 1.6 |
| Student – studying and working | 27 | 21.1 |
| Student – studying and not working | 23 | 18.0 |
| Self-employed | 4 | 3.1 |
| **Highest level of educational qualification** | | |
| Ordinary level | 2 | 1.6 |
| Advanced level | 13 | 10.2 |
| Certificate | 2 | 1.6 |
| Diploma | 8 | 6.3 |
| Advanced diploma / Higher national diploma | 18 | 14.1 |
| Bachelor's degree | 67 | 52.3 |
| Postgraduate studies | 7 | 5.5 |
| Master's degree | 11 | 8.6 |
| **Number of volunteer hours per week** | | |
| 0-5 hours | 39 | 30.5 |
| 6-10 hours | 38 | 29.7 |
| 11-15 hours | 15 | 11.7 |
| 16-20 hours | 11 | 8.6 |
| 21-25 hours | 5 | 3.9 |
| 26-30 hours | 5 | 3.9 |
| 31-40 hours | 7 | 5.5 |
| 40+ hours | 8 | 6.3 |
| **Number of years of volunteering experience** | | |
| 6-9 months | 12 | 9.4 |
| 1 year | 14 | 10.9 |
| 2 years | 18 | 14.1 |
| 3 years | 11 | 8.6 |
| 4 years | 15 | 11.7 |

| | | |
|---|---|---|
| 5 years | 14 | 10.9 |
| 6 years | 12 | 9.4 |
| 7 years | 12 | 9.4 |
| 8 years | 3 | 2.3 |
| 9 years | - | - |
| 10 years | 3 | 2.3 |
| 10 + years | 14 | 10.9 |

**Table 2**

*Descriptive Statistics for Age, Total Scores of Perceived Stress, Burnout and Turnover Intention*

| | N | range | minimum | maximum | M | SD |
|---|---|---|---|---|---|---|
| Age | 128 | 33 | 19 | 52 | 25.31 | 5.32 |
| Perceived Stress | 128 | 30 | 4 | 34 | 19.41 | 5.84 |
| Burnout | 128 | 32 | 19 | 51 | 35.73 | 6.15 |
| Turnover Intention | 128 | 4.33 | 1.00 | 5.33 | 2.55 | 1.19 |

**Table 3**

*Spearman's Rank Correlation Between Perceived Stress, Burnout and Turnover Intention*

| | M | SD | 1 | 2 | 3 |
|---|---|---|---|---|---|
| 1. Perceived stress | 19.41 | 5.84 | - | | |
| 2. Burnout | 35.73 | 6.15 | | - | |
| 3. Turnover Intention | 2.55 | 1.19 | .28** | .50*** | - |

*Note.* ***$p < .001$, ** $p < .01$

Table 3 demonstrates the results of Spearman's rank correlation between perceived stress and turnover intention (hypothesis 1), and burnout and turnover intention among volunteers (hypothesis 2). The results indicated that there was a significant weak, positive correlation between perceived stress and turnover intention, $r_s (126) = .28$, $N = 128$, $p = .002$, resulting in rejecting the null hypothesis, and a significant, moderate, positive correlation between burnout and turnover intention, $r_s (126) = .50$, $N = 128$, $p < .001$, resulting in rejecting the null hypothesis.

**Table 4**

*Bivariate Pearson Correlation Between Perceived Stress and Burnout*

|  | M | SD | 1 | 2 |
|---|---|---|---|---|
| 1. Perceived stress | 19.41 | 5.84 | - |  |
| 2. Burnout | 35.73 | 6.15 | .45*** | - |

*Note*. ***$p < .001$.

Table 4 demonstrates the results of the bivariate Pearson correlation between perceived stress and burnout among the volunteers (hypothesis 3). The results indicated that there was a significant moderate, positive correlation between the two variables, $r(126) = .45$, $N = 128$, $p < .001$, resulting in rejecting the null hypothesis.

**Discussion**

This cross-sectional study investigated the relationship between perceived stress, burnout, and turnover intention among Sri Lankan volunteers. It was observed that the participants demonstrated moderate levels of perceived stress, high levels of burnout, and moderate negative levels of turnover intention. This observation is consistent with past studies conducted on volunteers and employees of various sectors where it was made evident that stress, burnout and turnover intention are experienced simultaneously (Allen & Mueller, 2013; Brubaker & Beverly, 2020). According to the study perceived stress and turnover intention had a positive relationship with each other. Though research on volunteers is scarce, it is consistent with research conducted on the relationship between perceived stress and turnover intention among firm employees (Arshadi & Damiri, 2013), and healthcare workers (Al-Mansour, 2021).

It was also determined that there was a positive relationship between burnout and turnover intention among volunteers. These findings are consistent with the findings of studies conducted by Allen and Mueller (2013) and Chen and Yu (2014). It is worth noting that these past research were also done with volunteers, which adds to the validity of the current study findings.

In addition, it was demonstrated that perceived stress had a positive relationship with burnout among volunteers which is consistent with past findings (Abdollahi et al., 2021; Rey et al., 2016). Although the target groups for these studies were not volunteers, the results support the notion that perceived stress and burnout are experienced simultaneously. The participants may have experienced stressors related to volunteering similar to stressors experienced by medical students such as exams (Santen et al., 2010) which may have led them to experience perceived stress which may have led to burnout. However, further exploration would strengthen this finding by understanding what causes perceived stress leading to burnout.

*Limitations*

Although, more than the target sample size was achieved with a 51.61% response rate, 48.39% of participants who attempted to participate had discontinued the survey midway. One of the reasons could have been the length of the questionnaire, however, research has shown that administering scales online leads to a low response rate (Nayak & Narayan, 2019). Moreover, employing convenience (Devebakan, 2018) and snowball sampling technique to

recruit participants was adapted from past research as this combined technique was feasible and economical. However, both these techniques reduced the degree to which the obtained sample represented the target population (Jager et al., 2017; Parker et al., 2019).

**Conclusion and Recommendation**

Through this study, it is evident that perceived stress, burnout and turnover intention have a relationship with each other. Therefore, it can be concluded that volunteer organizations need to assist their volunteers in maintaining a balanced mental state through healthy work environments, monthly assessments, and awareness sessions. By doing so, not only will they have efficient volunteers but also a successful volunteer organization which could thereby support the society.

Based on the limitations, future research can incorporate a mixed methods approach to analyze the impact of other factors such as volunteer hours, number of years of volunteering experience, marital status and educational qualifications of the volunteer on perceived stress, burnout and turnover intention as these were not investigated in this study. By doing so, in-depth insights can be gained as to what causes perceived stress and burnout and what drives them to continue volunteering even though they possess turnover intentions. Secondly, factors such as lack of voice, role ambiguity (Allen & Meuller 2013), and poor volunteer fit (Scherer et al., 2016) have been major contributors to turnover intention in volunteers. Exploring these aspects will also increase the generalizability and validity of the study.

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# COVID-19 FEAR AND GENERAL SELF-EFFICACY AMONG EMPLOYED AND UNEMPLOYED SRI LANKAN MOTHERS

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## Abstract

The current study aimed to examine the relationship between fear of coronavirus and general self-efficacy of employed and unemployed Sri Lankan mothers. Out of 135 online survey responses, data from 75 eligible participants, after excluding missing responses and attention check failures, were analysed in this quantitative study. The sample consisted of 38 employed and 37 unemployed mothers. The scales used were Fear of COVID-19 Scale and General Self-Efficacy Scale. The results derived from Spearman correlation test indicated that there is a weak, negative relationship between fear of coronavirus and general self-efficacy. The Mann-Whitney U test and Independent T-test revealed that there are no significant differences in general self-efficacy and fear of coronavirus, respectively, among employed and unemployed mothers. The study suggests that providing psychological support to help cope with such adverse situations may improve the quality of life of vulnerable populations such as mothers.

**Keywords:** Employment Status, Fear of Coronavirus, General Self-Efficacy, Mothers, Sri Lanka

## Introduction

The global COVID-19 pandemic, declared by the World Health Organization (WHO) in March 2020, has had profound repercussions, resulting in thousands of fatalities worldwide. Sri Lanka, after confirming its initial COVID-19 case on January 27, 2020, implemented various health protective measures. Despite efforts, as of July 9, 2023, there have been 672,552 confirmed cases and 16,880 reported deaths in the country, emphasizing the persistent public health concern (Epidemiology Unit, 2023).

The impact of the pandemic extends beyond physical health, affecting mental well-being. Studies have unveiled a spectrum of psychological challenges, from fear to anxiety and depression, indicating potential long-term effects that demand psychological interventions (Chew et al., 2020; Sanyaolu et al., 2020; Wang et al., 2020).

Research on mothers highlights their heightened vulnerability. Traditional gender roles in Sri Lanka, coupled with the demands of balancing work and family responsibilities, accentuate challenges faced by women, particularly in a pandemic context (Meegaswatta, 2021). Most mothers who are the primary caregivers for their infants and school-age children face unique stresses, impacting their mental health and well-being (Pierce et al., 2020). Due to mothers' central role in family, this could have a detrimental impact on psychosocial family

functioning (Cameron et al., 2020), indicating that growth and development in community will be strongly impeded by overlooking the seriousness of the situation.

This study aims to address gaps in the literature by exploring the General Self-Efficacy (GSE) of employed and unemployed mothers in Sri Lanka during the pandemic. GSE, a crucial aspect of an individual's belief in their ability to navigate challenging situations, is expected to play a role in mitigating the psychological impact of the pandemic (Bandura, 1986). While studies have investigated GSE among mothers, this research seeks to contribute by examining GSE in the specific context of Sri Lankan mothers during the COVID-19 crisis.

Additionally, the study delves into the Fear of COVID-19 (FCV-19) among employed and unemployed mothers, recognizing the potential correlation between fear levels and mental health outcomes (Bandura, 1995). By addressing these aspects, the research aims to shed light on the intricate relationship between GSE, FCV-19, and the association of Sri Lankan mothers' employment status during the pandemic.

The central research questions guiding this study are:

1. What is the relationship between FCV-19 and GSE?

2. Are there differences in GSE and FCV-19 between employed and unemployed mothers?

The study proposes three hypotheses:

H1: A negative relationship exists between FCV-19 and GSE.

H2: The GSE of employed mothers and FCV-19 of unemployed mothers are higher.

Through addressing these questions and hypotheses, this research seeks to contribute valuable insights to the understanding of the psychological impact of the COVID-19 pandemic on mothers in Sri Lankan context with a focus on their employment status.

## Methods

### Participants

The inclusion criteria were, 1) Sri Lankan nationality, 2) must be 18 years or above, 3) have at least one child between the ages of 0-18 years, and 4) proficient in English language. Participants and their children with mental and/or physical health conditions were excluded as these characteristics were found to effect the variables studied considerably (Benzies et al., 2013; Byra et al., 2017). In addition to having limited financial resources and time constraints, convenient sampling method was utilised to recruit participants because the study primarily aims to generalise the findings only to employed and unemployed mothers in Sri Lanka fitting the criteria. Thus, reducing the risk of affecting external validity that is otherwise present in this sampling method (Andrade, 2021).

The priori analysis conducted using G* Power version 3.1. (Faul et al., 2009) for correlation analysis, power .80, $\alpha = .05$ and Pearson's r = .30, and independent sample t-test, power .95, $\alpha = .05$ and effect size, d = .80, recommended a sample size of N = 70, with 35 participants in each independent variable groups.

### Design and Procedure

The study used quantitative correlational design which measured the variables, employment status of participants, their age categories, number of children, GSE, and FCV-19. Qualtrics software was used to create the online questionnaire. The Ethics Committee of

Cardiff School of Sports and Health Sciences provided the ethics approval. The participant information sheet and informed consent form were used to debrief and inform the potential participants about the study's purpose, participants' privacy and confidentiality and their rights to withdraw from the study.

The participants were advised to reconsider their participation if they felt distressed while responding to the questionnaires and mental health help centres contact details were provided for support. As a precaution to reduce missing responses, participants were notified to respond to unanswered questions to continue with the survey.

## *Materials*

Demographics questionnaire was utilized to collect information about the participants' employment status, age category, and number of children. Additionally, the validated scales used to measure the variables of the study are, Ahorsu et al.'s (2020) Fear of COVID-19 Scale (α = .90) which consists of 7 items and Schwarzer and Jerusalem's (1995) General Self-Efficacy Scale (α = .87) with 10 items. An attention check question that required to select 'Strongly agree' out of 3 other options was included to determine participants' attention.

## *Data analysis*

The data was cleaned and analyzed using SPSS version 26.0. Pearson Correlation and Independent sample *t*-tests were planned to be employed to determine the first and second hypotheses, respectively, after meeting the tests' assumptions. If the assumptions are not met, the alternative non-parametric tests, Spearman Correlation and/or Mann-Whitney U test were to be utilized to test the study's first and second hypotheses accordingly.

## Results

Out of 135 participants' responses, 40 randomly incomplete responses that was found by Little's MCAR test, $X^2$ = 24.03, *p* = .771, and 20 responses that selected the wrong option in the attention check question demonstrating poor reliability, were removed. The data collected from remaining eligible participants (*N* = 75) were used for this study. To avoid instrumental representations, the minimum outliers detected were not excluded or analysed.

## Table 1
*Demographic Characteristics of the Participants*

|  | Employed Mothers *n* = 38 | | Unemployed Mothers *n* = 37 | |
|---|---|---|---|---|
|  | n | % | n | % |
| Age Category |  |  |  |  |
| 18-25 | 11 | 28.95 | 15 | 40.54 |
| 26-33 | 6 | 15.79 | 9 | 24.32 |
| 34-41 | 13 | 34.21 | 6 | 16.22 |
| 42-49 | 6 | 15.79 | 3 | 8.11 |
| 50+ | 2 | 5.26 | 4 | 10.81 |
| Number of Children |  |  |  |  |
| 1 | 19 | 50 | 20 | 54.05 |

| | | | | |
|---|---|---|---|---|
| 2 | 9 | 23.68 | 8 | 21.62 |
| 3 | 7 | 18.42 | 7 | 18.92 |
| 4+ | 3 | 7.89 | 2 | 5.41 |

Table 1 shows that the majority of employed mothers belonged to the age category 34-41 whereas unemployed mothers were mostly 18-25 years old. However, it showed that both employed and unemployed mothers predominantly had 1 child.

To test the first hypothesis, the normality test indicated that FCV-19 was normally distributed, however, the GSE was found to be violating the normality assumption of the Pearson Correlation test (see Table 2). Therefore, the alternative non-parametric test, Spearman Correlation test was utilised. The results indicated a weak negative, significant correlation between FCV-19 and GSE, $r_s = -.039$, $n = 75$, $p = .039$.

**Table 2**
*Tests of Normality for FCV-19 and GSE*

| | Kolmogorov-Smirnovᵃ | | | Shapiro Wilk | | |
|---|---|---|---|---|---|---|
| | Statistic | df | Sig. | Statistic | df | Sig. |
| FCV19 | .082 | 75 | .200* | .975 | 75 | .140 |
| GSE | .110 | 75 | .026 | .964 | 75 | .031 |

*. This is a lower bound of the true significance.
a. Lilliefors Significance Correction

The GSE were normally distributed in employed mothers, $W = .96(38)$, $p = .250$, and unemployed mothers, $W = .95(37)$, $p = .105$. Mann-Whitney U test was conducted as the homogeneity of variance was not met, $F = 2.85$, $p = .003$. It was found that there was no significant difference in the GSE between employed mothers ($Mdn = 31.00$, $n = 38$) and unemployed mothers ($Mdn = 31.00$, $n = 37$), $U = 652.50$, $z = -.54$, $p = .295$, with a small effect size of $r = .06$.

The FCV-19 were normally distributed in employed mothers, $W = .97(38)$, $p = .519$, and unemployed mothers, $W = .96(37)$, $p = .141$. The homogeneity of variance assumption of independent T-test was met, $F = 9.70$, $p = .096$. The results revealed no significant difference in the FCV-19 between employed mothers ($M = 18.92$, $SD = 7.49$) and unemployed mothers ($M = 18.78$, $SD = 6.13$) groups, $t(73) = .087$, $p = .466$, with a very small effect size of $r = .02$.

**Discussion**

This study aimed to investigate the relationship between FCV-19 and GSE among Sri Lankan mothers during the pandemic. With a focus on the employment status, the research sought to understand whether it affected their FCV-19 and GSE. The results and implications of the study are discussed below. The first hypothesis was supported by the findings. The study revealed a significant, weak negative correlation between these variables, aligning with Bandura's (1995) social cognitive theory. This indicates that as fear of COVID-19 increases, the general self-efficacy of individuals tends to decrease. The results are consistent with a prior study that reported a similar negative association (Okan, 2021).

Contrary to the second hypothesis, no significant difference in GSE was found between employed and unemployed mothers. This unexpected result contradicts previous literature suggesting higher GSE in employed mothers. It is possible that that the participants are from similar educational background as it is evident by their participation in the English medium online survey influenced the finding. However, it emphasizes the need for further exploration into the nuanced factors affecting GSE.

Additionally, the second hypothesis predicting higher FCV-19 in unemployed mothers, did not align with the study's results. No significant difference in FCV-19 was found between employed and unemployed mothers. The study posits that participants presumed educational background and fluctuating nature of COVID-19 news during the period may have contributed to this outcome. However, the FCV-19 mean in employed mothers was slightly greater than that of unemployed mothers, consistent with findings from other studies (Ergün et al., 2022).

### Strengths, Limitations, and Future Recommendations

This study contributes to the literature by exploring the unique context of Sri Lankan mothers during the COVID-19 pandemic. While strengths include being the first of its kind in this context, limitations, such as the educated and tech-savvy sample, risk response bias, and the inability to establish causation, must be acknowledged. Future research should consider a broader range of demographic factors and employ experimental designs to enhance causal understanding.

### Research Implications and Conclusion

The study highlights the importance of mental health care initiatives for vulnerable populations, particularly mothers, amid the pandemic. Government and private organizations should implement intervention programs addressing emotional regulation and provide literacy programs to counter misinformation. Telepsychiatry and online platforms can enhance accessibility to mental health support. The study concludes by emphasizing the necessity of psychological support to enhance the well-being of mothers during the global pandemic, as it impacts the family and community.

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# THE INFLUENCE OF SELF-EFFICACY AND EXPERIENCE OF SRI LANKAN TEACHERS ON THEIR EXPERIENCE OF OCCUPATIONAL STRESS AND RESILIENCE.

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**Abstract**

The study examined the relationship between self-efficacy and occupational stress and to understand whether work experience influences resilience of Sri Lankan teachers. A questionnaire with few demographic questions and three scales which assessed the efficacy, stress and resilience were presented via Qualtrics. Participants were attracted through a social media advert. A total number of 113 responses were collected where 89 responses were used for analysis. Spearman's correlation test results indicated a moderate negative relationship between teacher's sense of efficacy and occupational stress, *r=-0.56, n=89, p<.001*. A strong positive relationship was indicated between years in service and resilience, *r=0.70, n=89, p<.001*. Thereby, it was suggested that teachers with greater self-efficacy perceived less occupational tress and teachers with more work experience had higher levels of resilience.

**Keywords:** Occupational stress, Resilience, Self-efficacy, Work experience

## Introduction

Awareness and belief of an individual's strengths and weaknesses are necessary in order to achieve better outcomes. Bandura et al., (1997) suggested that the belief of an individual's own abilities on executing and organising actions which lead to produce required outcomes is Self-efficacy (SE). In the profession of teaching, teachers' SE is defined as the individual's belief on his or her own capabilities to achieve desired learning outcomes even among unmotivated and difficult students (Moran & Hoy, 2001).

Stress is another widely investigated topic and is known for causing many illnesses. Stress is a physiological and psychological responses to external and internal stimuli, resulting changes in the human body's system, influencing behaviour, and feeling (American Psychological Association, 2023). Work environment is one of the most stress generating environments. Occupational stress (OS) is a response of an individual when his or her ability and knowledge cannot cope when challenged with work pressure (World Health Organisation, 2020). An individual's work experience is considered important as it may help both the individual and the institution. Work experience is explained as the events an individual encounters while engaging in the job (Quinones et al., 1995). Resilience is widely studied in management, psychology, education, and sociology. The capacity of an individual to adopt accordingly to adverse effects of work and withstand work pressure is considered as workplace resilience (Kossek & Perrigino, 2016).

A study undertaken in Sri Lanka examined a sample of 393 undergraduates from a Sri Lankan higher educational institute, on their SE levels and perceived stress. The results indicated that higher SE resulted in lowering stress (Walpola et al., 2020). The findings of an Indian study suggested that teachers at private schools showed higher stress levels compared to government schoolteachers. A sample of 90 (25 males and 65 females) teachers from private, semi-government and government schools were selected for the study (Bhrigu et al., 2021). A study done in Philippines on 48 academic personal, suggested that SE, as a mediator between emotional intelligence and OS, has a significant negative effect on OS. All recruits for the study had been obtained from local college faculties (Wapano, 2021). A cross cultural study which had a participation of 1187 teachers from Canada, England, Hong Kong, and Thailand proposed that SE influences to lower OS levels. The findings also suggested that effectiveness and commitment towards work improves as individuals with higher SE tend to react well towards stress (Klasen et al., 2012). Further, a study conducted in Australia on resilience and work stress suggested that individuals with higher resilience levels perceived less work stress. A sample of 1048 were included in the study. The participation covered over 15 job categories (McCormac et al., 2018).

Past studies conducted in Sri Lanka have not examined work experience's impact on resilience. The present study aimed to investigate how a Sri Lankan teacher's SE influences OS and whether the work experience influences resilience. The following two hypotheses were tested in the study.

H1: There is a significant negative relationship between a teacher's self-efficacy and the perceived occupational stress.

H2: There is a significant positive relationship between a teacher's work experience and resilience.

## Methodology

### *Participants and Sample*

It was mandatory for all the participants to be over 18 years of age. Participation was open for teachers in primary, secondary or tertiary levels of schools and educational institutions. However, self-employed individuals were excluded as such individuals do not expose themselves to an organisational environment. G*power calculation for 80% power with medium effect and 0.05 significant level, indicated a minimum sample size of 84. Participants were recruited through an advert which was circulated on social media. Convenience sampling method was used in the study as it was understood to be cost effective and comparatively less time consuming.

### *Design and Procedure*

None of the variables were manipulated by the researcher. The study examined the relationship between variables focussing on the direction and the strength. Considering the mentioned factors, it was decided to use a correlation design. The study used a survey designed on Qualtrics platform. The questionnaire was designed using three scales and four demographic questions. A social media advert was used to attract participants. Prior to participations information on the study was presented and the consent was taken. The survey took between 10 to 15 minutes.

## Materials

Teachers' sense of efficacy scale by Moran & Hoy, the workplace stress scale by Marlin company & American institute of stress and the Brief Resilience Scale by Smith et al was used in the study.

## Ethical Considerations

The study was approved by the ethics panel of Cardiff School of Sport and Health Sciences. Participation was solely voluntary. No personal details in any form were collected. In the event of a participant felt stressed and understood that he or she needed mental support, contact details of mental health helplines were stated on the information sheet as well as the study advert.

## Analysis Plan

The collected responses were exported from Qualtrics to SPSS version 29.0.1.0. Data cleaning was carried out initially followed by Descriptive statistics. Normality tests were carried out and participant demographics were analysed. Reliability tests for all scales were undertaken and inferential statistics were carried out thereafter.

## Results

### Descriptive Statistics

### Data Cleaning

A total of 113 responses were recorded in the exported dataset. However, 24 responses had to be removed due to various errors in answers leaving 89 responses to analyse. Shapiro-Wilk tests were carried out, where significance values for all variables were less than 0.05 (see table 1).

**Table 1**

*Tests of Normality*

| | Kolmogorov-Smirnov[a] | | | Shapiro-Wilk | | |
|---|---|---|---|---|---|---|
| | Statistic | df | Sig. | Statistic | df | Sig. |
| TESS sum | .121 | 89 | .003 | .941 | 89 | <.001 |
| WSS sum | .169 | 89 | <.001 | .902 | 89 | <.001 |
| Years of experience | .178 | 89 | <.001 | .856 | 89 | <.001 |
| BRS sum | .123 | 89 | .002 | .942 | 89 | <.001 |

[a] Lilliefors Significant Correction

*Participant Demographics*

The recorded minimum age was 20 and the maximum was 59 among the participants with a mean of 33.78. Forty-four were female and 45 (50.6%) were male. It was also found that the participants' work experience ranged from 1 year to 39 years, with a mean of 10.47.

Reliability Tests

TSES consisting of 12 items (α=.95), WSS consisting of 8 items (α=.92) and BRS containing 6 items (α=.94).

### *Inferential Statistics*

Spearman's correlation analyses were carried out and the results indicated a moderate negative correlation between teacher's sense of efficacy and workplace stress, r=-0.56, n=89, p<.001, and a strong positive correlation between work experience and resilience, r=0.70, n=89, p<.001. In conformity with the results of the Spearman's tests, higher levels of SE resulted in low levels of OS, and greater work experience resulted in higher levels of resilience. Thereby, the results supported the tested hypotheses.

### Discussion

The study's results indicated that teachers with higher levels of SE, perceived less OS. Further, the results indicated that teachers who possessed more work experience had higher levels of resilience. It was noticeable that many studies conducted in the past on SE's relationship with OS, supported the findings of the present study (Betoret, 2006; 2014; Klasen et al.,2012). A review done in 2022, which examined data from 6 countries suggested that higher SE resulted in increasing resilience and lowering stress (Baluszek et al.,2022). A study which was carried out in Spain on 308 nurses during the COVID-19 pandemic period, suggested that higher SE resulted in increasing resilience (Penacoba et al., 2021). As per the mentioned review and the study, it was noted that work experience increased SE of workers, and SE increased resilience of workers. Considering the link between the three factors, it could be suggested that work experience influences resilience positively.

### *Limitations*

The participants were collected through a social media advertisement, where the even distribution of the advert can be questioned. Further, much older individuals may not use social media as much, compared to the younger individuals. The mentioned fact was a concern as the study also inquired about work experience, which is predominantly determined by age. The comment made here is not wholly based on ideation, as the data indicated a participation of only 17(19.1%) individuals over 45 years of age. The figure reflected the impact on experience, as only 11(12.3%) individuals possessed work experience over 25 years. The survey was carried out only in English. There were no translated versions of questionnaires in the main two local languages resulting limited participation.

### Conclusion and Recommendations

The present study examined the relationship between SE and OS and how years in service influence resilience among Sri Lankan teachers. The results indicated a moderate negative relationship between SE and OS and a strong positive relationship between work experience

and resilience. These suggested that Teachers with higher levels of SE perceived less OS and teachers with more work experience had greater levels of resilience. The study's results supported majority of the past research findings on SE and OS. However, experience and resilience were not examined in previous studies carried out in Sri Lanka. Therefore, it may convince researchers to conduct more studies on the related field. For better understanding on the topic, future studies may examine primary, secondary, tertiary level teachers separately. This may provide insight as to whether two teachers with similar efficacy levels perceive different levels of stress depending on the level they work. Further, there might be instances where teaching certain subjects generate more stress. Therefore, subject wise examining can be conducted.

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**EFFECT OF MENTAL HEALTH ON UNEMPLOYMENT WITH EFFECT OF ECONOMIC CRISIS: A STUDY IN CONSTRUCTION INDUSTRY OF SRI LANKA**

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**Abstract**

This study investigated the effect of mental health on unemployment with effect of economic crisis in the construction industry of Sri Lanka. The study was conducted using quantitative approach with a sample size of 162 unemployed individuals in the construction industry. Data collection was done using a structured questionnaire that included questions on unemployment and mental health. The results show a significant impact on mental health of individuals in the construction industry when unemployed during the economic crisis. Overall, this study highlights the importance of addressing unemployment and people's mental health, particularly during the period of economic crisis. Finally, the report draws conclusions and recommends strategies to mitigate unemployment for the construction industry during the economic crisis.

**Keywords:** Depression, Distress, Low self-esteem, Mental health, Unemployment

**Introduction**

Construction industry has contributed immensely to develop the economy of Sri Lanka. It has been recognised that the construction industry has faced difficulties when it comes to socioeconomic stress, resource shortages, institutional weakness, investment planning failures, and changing priorities in different governments due to political, economic, and sociological constraints. In the Sri Lankan economy, construction industry is the fourth highest industry after services, manufacturing, and agriculture (De Silva et al., 2008). In 2019 and 2020, the negative impacts resulted to a GDP contribution of 7.4% and 6.2%. The construction industry employs 650,000 direct and 325,000 indirect employees. According to Secretary General/CEO Chamber of Construction Industry (2022), the main causes for unemployment delay in payments to contractors by the government, fluctuations in the exchange rates, lack of construction materials and difficulty in importing, the increase in interest rates, suspension of capital expenditure, recovery actions by bank and unprecedented cost escalations.

The government of Sri Lanka is discontinuing proposed projects and postponing the start of projects set to begin. Furthermore, the recent price hike and the shortage of raw materials have made small construction firms to go bankrupt. This has resulted unemployment of skilled labour in the industry. The workforce in the construction industry, in which the majority are unemployed, are determined to migrate in hopes of finding work overseas (Perera, 2022). Previous researchers have identified that unemployment leads to mental disorders (Achdut & Refaeli, 2020; Axelsson & Ejlertsson, 2002; Breslin & Mustard, 2003; Crowe & Butterworth, 2016; McGee & Thompson, 2018). Unemployment is said to have several negative consequences that affect mental health. The idea of being unemployed has caused

anxiety and distress within the individuals. Having feelings of depression due to unemployment damages the self-esteem of individuals (Axelsson & Ejlertsson, 2002). The rising cost of living has not made it easy on people, putting them in further distress and ultimately resulting a depression (Frese & Mohr, 1987).

The objective of this study is to identify the main factors influencing unemployment in construction industry with effect of economic crisis, to identify the relationship between unemployment and mental health effect of economic crisis and to identify the strategies which can be introduced to mitigate the unemployment.

**Methodology**

The conceptual framework of this research is identified by using the past researchers' work done during an economic crisis or after unemployment. The author has developed the following conceptual framework to collect primary data for this research.
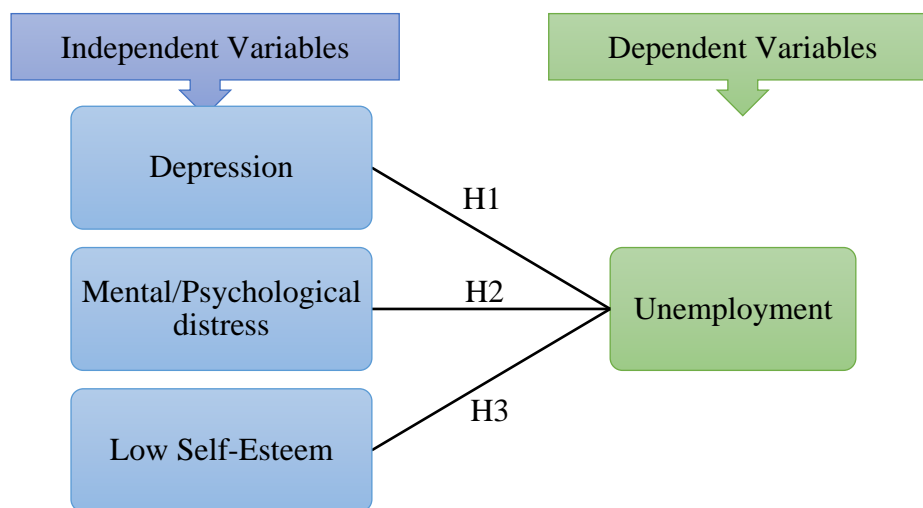


*Figure 1 : Conceptual Framework*

As this is a quantitative analysis research, the data collection method was done through a survey. The author used a questionnaire through Google forms to collect data from the participants. The questionnaire consisted of 25 questions based on multiple choice answers using Likert scale from 1 to 5. This questionnaire contained questions from past studies to identify the effect of mental health on unemployment. The questionnaire includes several questions from Beck's Depression Inventory (BDI) to measure depression, Rosenberg Self Esteem Scale (RSES) to measure the Self Esteem of unemployed and questions from Kessler Psychological Distress Scale (K10) adopted from Breslin and Mustard (2003) with 6 questions assessing to measure Distress.

The sampling frame includes unemployed individuals from the construction industry further concentrating on the individuals in water supply, sewerage waste management and remediation activities. According to Department of Census and Statistics (2020), the employed in this industry is 12,723 in 2019. However, this research is conducted on unemployed individuals, therefore the author collected the population off the data from Department of

Census and Statistics (2020) for the year of 2019 resulting in sample size of 162 calculated with 80% confidence level and margin of error at 5%.

The data analysis for this research was done using the SPSS software. To test the reliability of the data set, Cronbach Alpha method was used, the validity testing was done through KMO and Bartlett's Test of Sphericity and the Multicollinearity test was used to ensure the multicollinearity between the independent variables. A data purification was done to identify the outliers in the data set. The linear correlation analysis using the Pearson Correlation Coefficient is done to identify the correlation between the independent variables and the dependent variable. Lastly the data analysis of the study is concluded using the ANOVA model to determine the significance of the model and the regression analysis was done to identify the impact of the independent variable to the dependent variable.

**Data Analysis**
***Reliability, Validity, and Multicollinearity***

The reliability test for all the variables is higher than 0.7 which is acceptable. The validity test showed a significant value of <0.001 which also proved the data set is statistically significant. The tolerance value of each of the variables are all > 0.1, hence there is less multicollinearity between the independent variables.

***Correlation***
**Table 1**
Correlation Analysis

| Factor | Pearson Correlation | Sig. (2-tailed) | N |
|---|---|---|---|
| Independent Variable 1 | | | |
| Depression | .399** | <.001 | 158 |
| Unemployment | .399** | <.001 | 158 |
| Independent Variable 2 | | | |
| Distress | .360** | <.001 | 158 |
| Unemployment | .360** | <.001 | 158 |
| Independent Variable 3 | | | |
| Self esteem | .486** | <.001 | 158 |
| Unemployment | .486** | <.001 | 158 |

**Table 2**

ANOVA Table

| Model | Sum of Squares | df | Mean Square | F | Sig |
|---|---|---|---|---|---|
| Regression | 11.335 | 3 | 3.778 | 18.758 | <.001[b] |
| Residual | 31.018 | 154 | .201 | | |
| Total | 42.353 | 157 | | | |

a. Dependent Variable: Unemployment
b. Predictors: (Constant), Self-esteem, Depression, Distress

**Table 3**

Regression Analysis

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate | Durbin-Watson |
|---|---|---|---|---|---|
| 1 | .517[a] | .268 | .253 | .44880 | 2.374 |

a. Predictors: (Constant), Self-esteem, Depression, Distress
b. Dependent Variable: Unemployment

**Table 4**

Study Outcome

| Variables | Relationship | Results of Hypothesis Testing |
|---|---|---|
| Depression and Unemployment | Weak to Moderate relationship | Alternative hypothesis accepted |
| Distress and Unemployment | Weak to Moderate relationship | Alternative hypothesis accepted |
| Low Self Esteem and Unemployment | Moderate relationship | Alternative hypothesis accepted |
| Overall model fit | 25.3% | |

**Discussion and Conclusions**

The aim of this research was to study the effect of mental health on unemployment during the period of economic crisis in construction industry. According to the past research, depression and distress seem to be the leading factors affecting unemployment followed by the low self-esteem. The conceptual framework was developed with reference to past literature review. Further reviewing of literature enabled to identify the factors that were measured to identify the indicators needed to find the relationship between the independent and the dependent variable. All the independent variables used clinically proven self-assessment tests to measure the depression, self-esteem, and distress.

The data analysis showed a significant relationship between the independent and dependent variables. The regression analysis for the all the independent variables received a

25.3% impact. The results of the ANOVA analysis concludes that the conceptual framework of this study is acceptable. The hypothesis testing for the variables resulted in accepting the alternative hypothesis and rejecting all the null hypothesis as all variables were significant in the model. Therefore, it can be concluded that all the independent variables have a significant relationship with the dependent variable unemployment.

The study conducted by Zuelke et al. (2018) showed that there is a significant impact of depression for unemployed individuals. Unemployment is also linked to psychological distress according to Breslin and Mustard (2003) whose study found that the unemployed are prone to distress two times than the employed individuals. Previous studies on self-esteem and unemployment are limited. Comparing previous studies mentioned above, it was proven that there is an impact on mental health due to unemployment. There is a possibly to conducted further studies in identifying the other 74.7% of variance in the model.

## Recommendations

According to Cai and Chan (2009), vocational training programs for the unemployed to increase the job opportunities. Likewise in Sri Lanka the government can focus on providing local training to start a small business with day-to-day items or farming so that with the period of economic crisis the unemployed individuals will not have food issues and have means of income by farming. Furthermore, providing financial support for the unemployed until they find alternative employment or establish a small business to stay afloat during the economic crisis. Establishing a small business and aiding to develop it will aid the GDP of the country during the economic crisis. Furthermore, this would help keep the individual stay busy and reduce the mental health impact due to unemployment.

Large scale construction companies can focus on establishing subsidiaries to overcome the industry situation and focus on diverting construction industry employees to this subsidiary without downsizing them. Construction corporations too can focus on farming and agricultural business ventures which would result in financial gain for the business, low unemployment rate in the industry and the country. This would also mean that the risk of being unemployed for individuals are low. The government of Sri Lanka can discuss with the International Labour Organization and create a job creation scheme such as green initiatives.

During this economic crisis one of the main issues Sri Lanka faced was long power cuts during the day. The government can encourage new innovations to find alternatives for issues as such. Testing these products and aiding monetarily for research and development for these types of innovations aid establishment of small-scale businesses and bring foreign investments to the country.

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# SRI LANKAN CULTURAL PERSPECTIVES ON ROMANTIC RELATIOSNHIPS

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**Abstract**
It is believed that Sri Lankan culture impacts how people act in public and how they perceive many facets of life. This study uses a qualitative method to determine if there are any cultural influences on the participant's perceptions of romantic relationships. Data for the study was gathered through semi-structured interviews with 8 participants. According to study findings, family and religion have a significant impact on how people see romantic relationships. Both favorable and unfavorable themes were considered. Furthermore, people's perceptions varied greatly depending on whether they came from a collectivistic or an individualistic culture. Future research should investigate toxic masculinity, mental health, and cultural stereotypes of women in romantic relationships.

**Keywords:** Culture, Family, Religion, Romantic Relationships, Sri Lanka

## Introduction

Romantic relationships (RRs) have piqued the interest of civilizations throughout history, although their feelings and behaviours vary according to cultural factors (Karandashev, 2015). Love is universal but culturally distinctive, with three major influences on romantic relationships: individualistic and collectivistic cultures, religion, and societal expectations (Karandashev, 2015). This paper seeks to address research gaps on Sri Lankans' attitudes about romantic partnerships, focusing on the cultural backgrounds and elements that shape these relationships. It is critical to understand what kind of cultural backgrounds Sri Lanka has and what factors can influence these RRs. This will give insight into how Sri Lankans view RRs from a cultural point of view.

### Individualistic and Collectivistic cultures

Markus and Kitayama (1991) and Triandis et al, (1990) studied how individualism and collectivism influence love experiences. Individualistic cultures, like those in the US, UK, Australia, Canada, and Northern and Western Europe, prioritize family interests, freedom of choice, and autonomous judgments. Collective cultures, like those in China, Africa, Latin America, Greece, India, and Pakistan, prioritize group interests and communal decisions over personal ones. Understanding these cultures is crucial as they explain most countries, communities, and identities.

### Religion and its effect on romantic relationships

Sri Lanka's cultural environment is heavily influenced by religion, with Buddhist, Hindu, and other religious temples dominating. Religion influences couples' communication and resolution of difficult situations, promoting healthy communication and preserving

marriages. Couples who recognize the benefits of religion can manage challenges effectively, reducing psychological and emotional suffering. Forgiveness and hope are encouraged by many faiths, making couples feel more valuable. However, certain religious rules can hinder connection and potentially harm relationships, as a person in an abusive relationship may believe their faith forbids divorce.

### Societal standards and their effect on romantic relationships

Family and social groups significantly influence an individual's behavior, often due to their conformity to important expectations. Social standards and cultural norms significantly influence RRs among adolescents (Thoits, 1991). Asians, Hispanic, and African adolescents often avoid romantic relationships, while those of Hispanic and African American descent often hide their first boyfriends from their families. Understanding and addressing cultural norms is crucial in RRs, as they can lead to psychological pressure and emotional distress (O'Sullivan & Meyer-Bahlburg, 2003). In China, adolescent romance can be seen as a social aberration, leading to conflict between self-concept and social identity expectations. This cultural norm can be opposed by families and educational institutions. Adolescents with emotional and psychological issues in their RRs often resist seeking help from family or school (Liu et al., 2020).

The research gap on the impact of culture on RRs in Sri Lanka is significant. There are significantly less studies done on how culture affects RRs, but more on the idea of marriage and divorce in Sri Lanka. However, some studies have investigated dating patterns in the country. A study done by De Silva and colleagues (2022) on dating patterns, found that individuals who choose to do their higher studies prefer to get involved in RRs after they have finished their studies and are stable. This was found to be corelated with independence rather than any cultural effects. The same study discovered a higher rate of love-based marriages and women having more freedom to meet new people without worrying about their families, which presents a different, more modern perspective than Emery's 2013 study on culture and divorce, which revealed that stigma, particularly in collectivist countries, frequently leads to individuals suffering through marriage due to prioritising others' needs. Furthermore, a study done by (Kumarasinghe et al., 2021), shows that it is looked down upon to be in casual RRs unless the end goal is marriage. This is based off societal standards and the need to satisfy other's needs. As a result of this individuals keep RRs a secret and never publicize it.

### Methods

### Participants

The study involved eight Sri Lankan volunteers aged 18-25, chosen through snowball sampling. The demographic that was chosen was ideal for this study because there could be varied views on the topic that could include a combination of traditional and modern views. This is also the ideal age that individuals get into RRs. To recruit individuals, the study used exponential non-discriminative snowball sampling, as random recruitment would have been difficult. This strategy assured that all referrals agreed to participate and was suited for the study's sensitive topic of romantic relationships, as researchers would select individuals eager to speak up and contact appropriate individuals.

*Design*

This study utilized a qualitative, phenomenological technique to understand Sri Lankans' opinions and perceptions on romantic relationships through semi-structured interviews, providing in-depth information on specific themes and allowing for elucidation (Jamshed, 2014).

*Materials*

This study was conducted using a set of eight questions, each focusing on a specific culture segment and RR's.

1. 'What is your view on relationships?'
2. 'To what extent does family have an influence on relationships?'
3. 'To what extent does religion have an influence on relationships?'
4. 'What are the cultural outlooks on long distance relationships?'
5. 'What are the cultural perspectives on breakups?'
6. 'From a cultural standpoint, how does one cope with a breakup?'
7. 'From a cultural standpoint, how do you think individuals deal with toxic relationships?'
8. 'What is your viewpoint on incorporating other cultural norms in a relationship?'

The researcher posed follow-up questions to clarify responses and understand the impact of culture on Relationship Reliability (RR) and its influence on religion, family, and breakup situations. They also explored the benefits of incorporating other cultural norms into RRs.

*Procedure*

Participants were invited to participate in a study after an advertisement was sent via social media. If they volunteered, they were given information sheets and asked to fill out a consent form. Consent was obtained through email and verbal means. Interview times were agreed upon by both the researcher and participants. The study included semi-structured interviews done via Microsoft Teams, recorded with participant consent, and a research briefing. The interviews lasted 10-40 minutes, with no time limit, and participants were free to speak without constraint.

*Method Of Analysis*

Thematic analysis (TA) was utilized in this study to identify patterns in responses related to RR's and to analyze Sri Lankan culture's influence on RR's. This method was chosen for interviews, allowing for in-depth analysis and the extraction of raw data for the most effective results (VandenBos, 2015).

*Ethics*

Five ethical considerations were covered in this study: confidentiality, informed consent, participant safety, debriefing, and withdrawal from the experiment. Following the interview, participants had 14 days to withdraw, and informed consent was acquired via a consent form. In addition to receiving a reference number to protect the privacy of their data, participants were briefed on the purpose of the study. The information gathered will be destroyed after ten years and only the researcher and supervisor will have access to it. Ethics approval was obtained by the ethics panel of Cardiff Metropolitan University, UK before any data was collected.

**Results**

The study investigated Sri Lankans' perceptions of RRs and its influence on culture. Four themes were identified: perceptions of RRs, family perceptions, cultural impact, and negative consequences due to cultural influence and stigma.

*Perceptions of RR's*

Participants focused on the importance of having a partner and also the important characteristics of RRs. Participants spoke about how having a partner uplifts mood and helps create a better atmosphere in their life. Additionally, they discussed how the values in a partner is an important element when being in a RR

"So, I believe like its an important, important aspect in a person's life, like other relationships like, you know, family, friendships, things like that its it I feel like it comes under a very basic need like second to basic, where a person usually like, they do need someone to be there for them. In terms of having the support in terms of having a someone as a source of comfort" (P3, L12 - 34)

"It is also about mainly about trust, mutual trust, actually respect and being there to support each other" (P1, L12)

*Family perceptions on RR's*

Family has a tremendous influence on romantic relationships (RRs), with the ideal RR established by one's upbringing and history. When selecting a partner, families consider factors such as educational background, social class, and religion, demonstrating the importance of family in shaping one's preferences.

"But they do have a certain standard. When it comes to their influence, this person has to be from a well-formed background family and they have to be be well off, they have to have education, they have to have a job, car, house' (P2, 86 - 92).

Two participants even stated that if they don't meet these criteria, they're not allowed to continue the relationship.

*The impact of culture and religious background*

Participants emphasised the importance of having a partner from the same cultural background and incorporating other cultural norms into relationships. They also talked about their perceptions of religion's influence on relationships, emphasising its good impact on developing healthy ones while also emphasising possible areas where religion might be a drawback.

"And when it comes to the western cultures, I like the concept of living together because that giving you the opportunity to decide and you know, get into the comfort zone, seeing the uglier sides of your partner and decide whether you want to be with him or her or like you want to like, you know" (P8, L 731 - 738)

"It could cause some level of maybe frustration or something within that particular person where they kind of like it could be that they become torn between wanting to be stable in their religion, in following their religious conditions versus wanting to be with a particular person who does not fall under that category" (P3, L 238 - 249)

*Negative consequences in RR's due to cultural influences and stigma*

The study emphasises the difficulties women encounter when selecting romantic partners, such as the stress of meeting family expectations and the lack of freedom that typically

results from family participation. Women frequently blame themselves for conflicts and breakups, feeling terrible for failing to make their partner happy or manage the household. The stigma surrounding divorce and breakups makes it difficult for people to leave unfavourable relationships or distance themselves from incompatible companions. Mental health is also a developing issue in Sri Lanka as a result of these unfavourable situations, yet many people are unaware of its significance and why it's important.

"So, like what I said for Muslim cultures, usually they push you to get married early, so we don't have the freedom most of the people have. The freedom to have romantic relationships as such" (P1, L 71 - 77)

"I feel like it creates a lot of strain, a lot of frustration between the partners when family gets involved" (P3, L 591 -593).

"In Sri Lanka, the mental health aspect like there's a long way to go, it's still emerging and developing so people don't really seek mental health you know, they don't go and talk to anyone, they just just keep it inside" (P5, L 131- 140)

**Discussion**

This paper investigates Sri Lankan cultural viewpoints on RRs and its significance for people. In addition to discussing the value of a spouse with a similar background, the participants offered their opinions on adopting other cultural norms into the relationship. Two conventions that might help couples in RRs include living together and having sex prior to marriage, as these are crucial components of closeness and compatibility that are necessary for a happy marriage. While Van Lankveld and colleagues (2018), support the above statements, Fehring and Manhart (2020) demonstrated that chastity before marriage and during RRs are important for an individual's well-being and mentality and the unity of a couple.

Participants' perceptions of RRs are significantly influenced by their family and religion. They claim that what they see and learn about RRs is adapted to what they are searching for in a spouse by virtue of their upbringing and family history. Families attach great importance to the qualities they look for in a potential mate, such as social standing, religion, and educational background. These results are in line with other recent research on the impact of parenting and family expectations on RRs (Amato & Patterson, 2016; Jamison & Lo, 2020).

Religious compatibility is a crucial factor for premarital relationships as well. Participants did, however, voice worries over religion's detrimental effects on people and relationships. It might be challenging for people to get support after a breakup since many religions, including Islam, forbid partners with different religious faiths.

Breakups are another contributing cause to RRs, and stigma around mental health is pervasive in Sri Lankan society. Studies have revealed that culture, particularly collectivistic societies, is a major factor in the development of stigma around mental health.

In Sri Lanka, toxic masculinity and the cultural stigma against women are frequently observed, particularly in marriages and partnerships. Prior studies have demonstrated the detrimental impacts of toxic masculinity, such as physical and sexual abuse in relationships and marriages. preconceptions are a major factor in the continuation of these negative connections and preconceptions (Amin et al., 2018).

**Conclusions and Recommendations**

The study investigates Sri Lankans' perception of RRs and their impact on culture, highlighting the significant role of family and religion in shaping one's upbringing. It also emphasizes the importance of cultural background and the stigma surrounding women, which affects mental health which is important to look into. The study suggests that further research is needed to understand the relationship between RRs and mental health, as well as the impact of different faiths and beliefs on RRs.

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