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Computing and Information Systems



Computer Awareness and Computational Thinking in Sri Lankan Street Vendor Communities

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ABSTRACT

Little is known about computer awareness and computational thinking (CT) skills of street vendors, a common form of informal economy in many developing countries. This research attempts to fill this gap by investigating the digital awareness and CT skills among street vendors in a Sri Lankan urban commercial area. It proposes a multidisciplinary framework to capture CT skills that integrates digital literacy, algorithmic thinking, and problem-solving skills. Using the data collected in a mixed approach, it reveals that street vendors employ a degree of algorithmic thinking in planning, organizing, and optimizing their vending activities, and show problem-solving skills when coping with uncertainties, risks, and conflicts in the context of their business and community. The results also indicate street vendors' positive digital awareness, mainly in digital device usage for purposes ranging from communication, information acquisition, to entertainment. It also indicates that they face barriers in access, affordability, and trust. Conclusively, the study confirmed the existence of computing and CT skills among the participants, and showed how they are valuable and relevant to them. Recognizing and nurturing these skills can enhance their socio-economic inclusion and resilience.

KEYWORDS: Algorithmic Thinking, Computational Thinking, Computer Science Social Topics

1 INTRODUCTION

The research centers on the concept of Computational Thinking (CT), that emphasizes a thought processes involved in formulating problems and represent solutions as step-by-step instructions (i.e. algorithmic steps), that can be executed by a computational agent, preferably a computer (Wing, 2006). Its applicability is later expressed to expand beyond computer science, portraying it as a fundamental skill applicable in various domains (Wing, 2017, Jong et al., 2020). This research extends this perspective to examine the CT within the informal, dynamic community of street vendors in Sri Lanka. Recognizing that CT transcends formal educational boundaries, revealing computational skills in the

practical dimensions as it naturally emerges helps understanding drive to computing and nature of the potential for computational problem solving in non-traditional settings.

The research motivation lies in the belief that CT is not confined to formal education or professional environments but permeates daily life, even in unconventional occupational landscapes, and seeks to contribute nuanced insights into problem-solving, algorithmic thinking, and digital literacy within non-traditional spaces. It explores the relationship between street vendors' educational backgrounds and their CT abilities, based on the distinctive computational skills displayed by them

and their impact on street vending practices.

2 LITERATURE REVIEW

2.1 *Computational Thinking,*

Algorithmic Thinking and Problem Solving

Wing (2006) popularized Computational Thinking as “thinking like a computer scientist to solve problems”, and subsequently clarified the term as: “the thought processes involved in formulating problems and their solutions so that the solutions are represented in a form that can be effectively carried out by an information-processing agent” (Wing, 2017), recognising it as a fundamental skill for all, not just for computer scientists. CT is the mental effort involved in framing a problem in order to admit a computational solution, and is recognised as a skill similar to reading, writing, and math. Aho (2012) further clarifies this by highlighting that finding appropriate models of computation with which to formulate the problem and derive its solutions is an important part of this process. CT includes more than just perceiving solutions as algorithms, but a set of abilities that allows both to enhance things and ponder about the world.

Algorithm is a method to solve a problem that consists of exactly defined instructions, and the thinking pattern required to achieve this is one’s capacity for algorithmic reasoning (Futschek, 2006). Algorithmic thinking is closely similar to CT, yet it emphasizes the applicability in computation as a process to develop code and program applications. It is seen as an individual’s ability to construct new algorithms aiming at solving a given problem (Kanaki and Kalogiannakis, 2022).

‘Problem solving skills’ brings the concepts of CT and algorithmic thinking to a single facet, and is defined as the cognitive processes that aim at reaching a goal when no clear solution approach exists. Often requiring a fresh insight based on a sudden shift in the way the problem is viewed (Scheerer, 1963), problem solving skill has been a popular tool of measuring a person’s skill level in both CT and algorithmic thinking (Baker, 2017, Gok, 2012).

These perspectives indicate the close relationship of these concepts, and consequently how they together can bring an innovative inspiration for people to adapt to an intelligent, changing society.

2.2 *Street Vendors*

Bhowmik & Saha (2012) describe a street vendor as “a person who offers goods for sale to the public at large without having a permanent built up structure from which to sell”. Street vending has been present as an important occupation since ancient times found in virtually every country and major city around the world. (Bromley, 2000, Karunaratna & Tjandra, 2021).

2.3 *Digital Literacy*

The skills needed to ‘survive’ in the digital environment range from software usage know-how in performing a task, to the ability to evaluate trustworthy online sources to construct new knowledge and many other things in between, and such abilities are frequently referred to as ‘digital literacy’ in the literature (Greene et al., 2014). The proliferation of information technologies and digital contents have a significant impact in modern society (Komlayut & Srivatanakul, 2017). This research study considered digital literacy (and the usage

of the underlying technologies) as an indicator of a person's awareness of computing, and thus used it as a parameter to measure CT and algorithmic thinking skills.

3 METHODOLOGY

A pragmatist approach was followed as the overall methodology of this research study, and mixed methods approach as data collection and analysis strategy. Since there were no dominant model or approach in the literature for the measurement and evaluation of CT skills (Ceylan et al., 2023) nor a generally accepted questionnaire to measure computing or digital skills of subjects similar as street vendors, the CT skill levels were determined by measuring the digital literacy, algorithmic thinking, and problem-solving skills of participants, collected using interviews with questions extracted from commonly used survey tools of those areas.

The research questionnaire consisted of four parts namely: demographic information, digital literacy, algorithmic thinking, and problem-solving. The questionnaire also considered the street vendors' day-to-day experiences related to technology usage, their digital literacy and how they solve day-to-day problems. A Sinhala translation of an originally English language questionnaire was used.

3.1 Sample Nature

Twenty-five (25) street vendors, with no permanent shelter/structure surviving as a shop, in a highly urban area of Sri Lanka's commercial capital were approached randomly. Due to the interviewer's limitations, all selected participants were those with the ability to communicate meaningfully in Sinhala. Eleven (11) interviews were removed due

to their incompleteness and inadequacy in administering. The researcher cum interviewer's observations were also used as a data source.

3.2 Analysis

The quantitative data were analyzed using descriptive statistics methods. The transcripts generated from the voice recordings of interviews were used as the key source of qualitative data. The observational notes gathered during interviews were crucial in providing context to the subject's environment. An open-ended and flexible strategy that can allow emerging themes and patterns to develop was used to identify themes.

4 RESULTS AND DISCUSSION

4.1 Surveys

The selected group of street vendors (12 male and 2 female) sell a variety of goods (e.g. food & beverages, clothing, toys, electronics, books & magazines, arts & crafts). Around 29% were of the age between 20-29 years, 21% between 40-49 and 14% between 30-39, 14% between 50-59 and 14% above 60.

A large proportion of the respondents revealed to have been street vending for a long time (e.g. 28% engaged for over 10 years, 7% over 20 years). Primary education level of the participants is observed to be considerably low (around 78%). The number of hours served in a day seem to vary depending on the products sold, location, sales volume, and terms of trade; majority work from 9 to 15 hours.

4.2 Interviews

Detailed interviews were conducted in three phases. In the first phase, questions were aimed to gain insights into their familiarity with digital tools and

technologies, taking into consideration the extent they integrate such tools in their daily business operations. Participants were asked questions about the digital devices they use as tools of sales, frequency of use, level of confidence in using those digital devices and technology, and the challenges faced in adopting them to their occupation.

All the participants use mobile phones, particularly smartphones. Calculators and digital weight scales were also in use, subject to the kind of product they sell. It was observed that the younger participants opted to use digital scales more than the elderly. It was also observed that the participants do not use calculators regularly, despite owning them. All showed confidence in using digital devices and technologies of their interest. Responding to how they felt about using them, one participant said, "Everything is done with a phone. That's how it works for things dealing with money. I'm sure of it."

The second phase aimed algorithmic thinking to unravel the intricate decision-making processes and problem-solving strategies employed by street vendors in the context of their daily vending activities. These questions delved into the operational aspects of their business, focusing on how they approach tasks such as setting up their stall, responding to various challenges, determining pricing strategy, business decision evaluation, restocking timing, product prioritization, discount decisions, adapting to weather changes, budget-conscious purchasing, handling limited quantities, and dynamic pricing decisions.

The third phase explored the participants' approach to problem-solving and strategies they employed in their daily

vending activities. These questions investigated the general problem-solving strategies employed by street vendors in their day-to-day activities. Problem encounter frequency, confidence in problem-solving skills, and handling customer complaints were also considered here.

5 CONCLUSION

The prevalence of smartphone usage among street vendors underscores the integral role of digital devices in their business operations. The observed confidence in using digital tools, particularly smartphones, suggests a degree of adaptability to the digital age. However, the variance in the adoption of specific tools, such as digital weight scales, raises questions about accessibility and affordability. Strengthening digital literacy among street vendors, tailored to their specific needs, emerges as a crucial avenue for improvement.

The participants exhibited algorithmic thinking in their daily decision-making processes. From setting up stalls to determining pricing strategies, the vendors demonstrated a form of organizational and strategic thinking essential for navigating the challenges of their dynamic environment. The adaptability observed in response to various challenges indicates a dynamic algorithmic approach, often learned through experiential learning. Integrating these skills into formal education and promoting knowledge sharing within the street vending community could contribute to collective improvement in algorithmic thinking.

Recognizing and developing CT skills, digital literacy, algorithmic thinking, and problem-solving talents

may help socio economic empowerment of street vendors, perhaps breaking the cycle of restricted possibilities and financial restraints. However, the limitations identified in the methodology such as time constraints, difficulties in approaching the target community, reluctance to respond, and potential biases should be acknowledged as having an impact on the generalizability of the findings.

A more extensive and diverse sample that incorporates various geographic locations & cultural contexts could provide a more comprehensive understanding of CT skills among street vendors. Longitudinal studies tracking the impact of educational interventions on the CT skills and its relationship to business outcomes of street vendors would offer valuable insights. By recognizing the inherent skills developed in the dynamic environment of street vending and providing avenues for further development can contribute to the socio-economic empowerment of street vendors, enabling them to navigate challenges and seize opportunities in an ever-evolving marketplace.

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Design and Development of a Prototype for Innovative Traffic Light System

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ABSTRACT

With the increasing population, the number of vehicles on the road increases rapidly causing heavy traffic. Traveling during peak hours including office hours, school hours and evenings can be challenging and sometimes, it seems impossible. People wait in the traffic for countless hours. Heavy traffic due to poor traffic management, less road capacity and poor transportation options may be considered as the reasons for that. Traffic lights were invented as the best solution. The traditional traffic light system is based on fixed time regardless of the real-time traffic condition. The biggest problem in the traditional traffic light system is that they keep drivers waiting for a long time even during the non-peak hours. Even though the present traffic management system is well suited to heavy traffic conditions, its performance is not that good during the non-peak hours. Therefore, it is good to enhance the traffic light system. This paper proposes a method to enhance the traffic light system that suits both the peak and non-peak hours.

KEYWORDS: Object Detection, Real-Time, Traffic, Travelling

1 INTRODUCTION

Due to the globalization and development of technology, the number of vehicles on road has been increasing rapidly causing heavy road traffic. The traffic congestion forms long queues of vehicles at intersections leading drivers to lose plenty of valuable time. Apart from these issues, traffic congestion has caused health and environmental issues. Long lines of vehicles emit a considerable amount of carbon and nitrogen oxide which affects the air and sound pollution. Heavy traffic conditions lead to driver frustration and stress resulting in dangerous road accidents. Waiting in the traffic for long hours also results in several economic challenges to the country (Qadri et al., 2020).

As the best solution for the heavy traffic, every country needs a proper traffic management system. The

traditional time-based traffic light system is the best way of controlling the traffic. Keeping drivers waiting for traffic lights to change at intersections, even at non-peak hours, is one of the biggest drawbacks in the present time-based traffic light system. The existing time-based traffic light system works according to a pre-scheduled time interval regardless of the current traffic condition.

Research is carried out by proposing a smart traffic light system which was studied under object detection. The invented traffic light system detects the number of vehicles on each lane and compares the outputs in order to get the maximum number of vehicles out. This system will give the priority for the lane with the maximum vehicle count. The system was built using Python. The YOLOv5 framework was used when training the dataset.

The aim of this research was to give a solution for the heavy traffic by providing a system to get the vehicle count. It will get the vehicle count both at day and nighttime, increasing the accuracy of the system.

2 RELATED WORK

2.1 *An Improved YOLOv2 for Vehicle Detection*

The YOLOv2 model was used by Sang et al.(2018) for detecting vehicles. When clustering the training dataset k-mean algorithm was used collaborating with different-sized anchored boxes. The research has been mainly focused on improving the detection of the bounding boxes but it is less accurate for the data that the model is not trained.

2.2 *A Deep Learning Approach of Vehicle Multitarget Detection from Traffic Video*

A yolo vocRV model was provided by Li et al. (2018) for object detection. Detection of several objects in difficult traffic densities was performed by them. The issue with this is the highest false detection rate in a small dataset, therefore this research requires a large training dataset and it is not trained for low-light conditions.

2.3 *Vehicle Detection on Unmanned Aerial Vehicle Images based on Saliency Region Detection*

An improved YOLOv3 model was proposed by Li et al. (2019) for object detection with high accuracy. This research improved the calling map mechanism to vehicle detection giving the highest accuracy rate. The limitation in this research is that it's less accurate vehicle detection in complex and heavy traffic environments.

3 METHODOLOGY

This work was carried out with a dataset including 6190 images of vehicles. The dataset was separated into three groups namely test with 9% of the data, train with 70% and validate with 20% of the data including a single class of vehicle. When training the dataset to develop the model, YOLOv5 was used due to its fast and accurate real time object detection ability.

3.1 *YOLOv5 (You Look Only Once)*

Yolo is considered as the best model for real time object detection due to its speed, single pass-architecture, detecting multiple objects in one frame, flexibility, ease of use and accuracy. In yolo we can adjust the number of batches and epochs. By changing the number of epochs, the number of times the entire dataset is used to train a neural network. Changing the batch size and the number of images that the algorithm looks at in one go during training can be decided as well.

3.2 *Dataset*

The data set was collected through the internet (Kagel) and each image had to be labeled in order to train the model with YOLOv5. All the images had to be in the same size so that the data were resized for the same size. Finally the dataset was split into three groups of test with 9% of the data, train with 70% and validate with 20% of the data. The data set was trained using version 5 of yolo (YOLOv5s). Labels were made for each image in order to use in Yolo.

3.3 *Object Detection*

Object detection is a computer vision task of identifying and detecting the location of a given image or a video stream. In the object detection process, the

object in the image or the video will be identified and located with a bounding box. Object detection is used in many fields including Autonomous Vehicles, Surveillance Systems, Medical Imaging, Retail, and Augmented Reality. The algorithms such as Yolo use deep learning techniques to recognize patterns in images, allowing accurate and efficient object detection.

3.4 Vehicle Detection and Comparison

The trained model (best. pt) was used to detect vehicles using two cameras. The system was developed to calculate the total count of vehicles on each lane. The output is stored separately in two text files which will be compared to get the maximum vehicle count.

The system will detect and compare the number of vehicles in real time. The system can be used to develop a smart traffic light system that will give the priority for the lane with highest vehicle count. That way, we can reduce the waiting hours in the intersections waiting for traffic lights to change.

4 RESULTS AND DISCUSSION

The model was trained by varying different factors such as the batch size, number of epochs and for YOLOv5s model architectures with T4 GPU runtime



Figure 1: Vehicle Detection at Night Time from Camera Two.

in google colab in order to get the maximum accuracy.

The results were taken using two phone cameras. In order to connect the two cameras to the laptop. Iruin Webcam was used to record the vehicles on the road. By executing two cameras parallelly, the vehicle count was saved in two files separately. Then after real-time comparison of the two outputs, the maximum number of vehicles was obtained and then the lane which consist of the maximum vehicles was detected.

The system was tested both at night and day time. When capturing the vehicles, two mobile cameras were used. Night time testing was done at Athurugiriya junction where the day time testing was done near the highway intersection at Athurugiriya.

4.1 Vehicle detection at Night Time

The Fig. 1 and Fig. 2 given below represent the output taken by two mobile cameras in the night time. The test was done at Athurugiriya town where there is a heavy traffic and controlled by a traffic police officer. The vehicles were clearly located with the bounding box that include the class label and accuracy. The Fig. 3 and Fig. 4 are the representation of vehicle detection tests done during day time. As presented in the above figures the



Figure 2: Vehicle Detection at Night Time from Camera One.



Figure 3: Vehicle Detection at Day Time from Camera One.

efficiency and the accuracy of the detection process are higher at day time than night.

The output vehicle count from two cameras are saved in two text files separately. When there are no vehicles on the road, it will be detected as “no detection”. The maximum vehicle counts that outputs after comparing the two text files will be displayed on the terminal.

As presented in Table 1 The data set was trained for three epochs with batch size of 1 and 25. The model trained with epochs three and batch size of 1 was selected when developing the system as it had the highest accuracy of 0.993 with 0.99 precision and 0.989 recall values.



Figure 4: Vehicle Detection at Day Time from Camera Two.

Table 1: Output of Trained Models

Topic	Precision	Recall	Accuracy
Epoch 3 with Batch 1	0.999	0.989	0.993
Epoch 3 with Batch 25	0.946	0.977	0.974

5 CONCLUSION

In conclusion, the time-based traffic light system has some problems on both humans and the environment, even though it has been the traditional way of controlling traffic. Real-time traffic management systems produced more effective and flexible ways in managing traffic using object detection technologies. This system has proven the effect to the traffic management by providing a system that adjusts with the real-time conditions.

The developed traffic light system is designed using machine learning to detect vehicles and adjust to the real time situation of the traffic. Using a real time object detecting traffic management system not only reduces waiting time, but also it improves safety of both the drivers and the pedestrians by effectively responding to emergencies, accidents and unusual traffic patterns. By lowering fuel use and carbon emission, this system has contributed to increase the overall productivity of the transportation network.

6 FUTURE WORK

The research can be improved to detect and make conclusions on future traffic. By predicting the future traffic

situations, the relevant steps can be taken in order to prevent the heavy traffic.

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Gemstone Detection and Identification Using Image Processing and Deep Learning

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ABSTRACT

Sri Lanka's gemstone industry faces problems due to a surge in gem purchasers who lack a specialist understanding of jewels and the quick spread of amateur gem dealers. This study uses YOLOv5, a smartphone technology that can recognize characteristics from the images of the gem, to create an automated system for gemstone identification and classification in an effort to counteract this. The system's objectives are to improve classification accuracy and deal with dishonest behavior in the gemstone industry. Based on the image dataset, this study evaluates how well YOLOv5 performs in recognizing different gemstones. The results are encouraging, providing a potential means of thwarting fraud, enhancing the precision of gemstone identification, and opening the door for a more open and reliable gemstone market.

KEYWORDS: Deep Learning, Gemstone, Object Detection

1 INTRODUCTION

Sri Lanka, revered as the 'pearl of the Indian Ocean', boasts a legacy deeply rooted in gemstone mining and trading, with its 65,000 square kilometers harboring an astonishing four-fifths of the world's coveted gems. In the contemporary gemstone market, escalating prices and burgeoning demand underscore the urgent necessity for streamlined, automated gemstone identification processes. Both buyers and sellers now depend on in-depth knowledge to make accurate evaluations because there isn't a reliable automated system in place. The goal of this study is to address the need for action for impartial and reliable gemstone evaluations, which are essential for enhancing accessibility and availability within Sri Lanka's rich gemstone background. This method's key component is the application of

sophisticated image processing methods based on advanced algorithms. These technologies play a pivotal role in swiftly and precisely classifying gemstones, serving as a complement to traditional strategies while fortifying the industry's integrity.

2 LITERATURE REVIEW

A detailed evaluation of the relevant studies has been conducted to understand the existing processes, provide a framework for project development, and address issues that have been encountered.

The paper "Automatic Gemstone Classification Using Computer Vision" by Chow and Reyes-Aldasoro (2022) describes an effective method that makes use of 33 feature extraction techniques and machine learning methods. The Random Forest approach outperformed skilled gemologists with an accuracy rate

of 64.4%, demonstrating the promise of computer vision in the field of gemology. Singh et al. (2022) researched the application of deep learning algorithms for mineral classification, emphasizing the difficulty of mineral identification and the requirement for rapid, accurate processes. Convolutional neural networks (CNNs) were suggested by them as a workable solution.

Amarasekara and Meegama (2021) established a machine-learning technique for classifying different types of gemstones using convolutional neural networks (CNNs) and images of microscopic gemstones. The system's accuracy rates for yellow and blue sapphire were 87% and 77%, respectively, demonstrating the need for high-quality images for accurate color recognition.

Maula et al. (2017) developed a system that uses artificial neural networks and HSV color space to detect different kinds of gemstones. After several training and testing rounds, the system, which could identify three different kinds of gemstones, demonstrated an amazing accuracy of 90.66% in the tough testing.

Zhang and Guo (2021) compared the visual differences between the values from a conventional colorimeter and the Computer Vision System (CVS). The study focused on the evaluation of gem color using a CVS. Notwithstanding the discrepancies, the study showed that CVS is a workable method for determining jadeite-jade hue.

3 METHODOLOGY

The gemstone dataset, which was a custom dataset, was used in this study. It includes images of gemstones categorized into 20 classes, such as blue

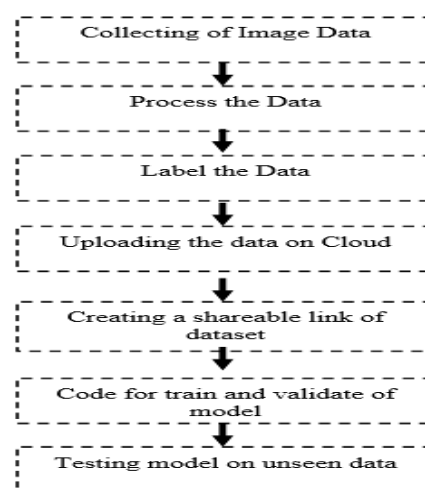


Figure 1: Block Diagram of Gemstone Identification Process

sapphire, chrysoberyl cat's eye, chrysoberyl, and citrine. A software called "Make Sense" was used for labeling the gemstones, and a 4:1 split of the dataset was made into training and test sets. In all, there are 2500 equal-sized images. Fig. 1. indicates the block diagram of the gemstone identification process.

3.1 Object Detection

Image classification is the process of giving an image a single label, whereas object detection is the process of identifying and localizing multiple objects within an image and defining their locations using bounding boxes. The objective of this work is to identify and categorize various objects while establishing their exact positions through the use of segmentation or bounding box techniques. It is a crucial component of computer vision and has a wide range of uses in augmented reality, medical imaging, driverless cars, and surveillance systems. Modern approaches such as Faster R-CNN (regional-based convolutional neural networks) and

YOLO (you only look once) have greatly improved object recognition speed and accuracy, making it possible to identify many objects more reliably and effectively in real-time applications.

3.2 Data Augmentation

Using various transformations, such as rotations, shifts, zooms, and horizontal flips, help expand the training data. By providing the model with multiple angles and angles of the images, this feature improvement helps the model become more robust and flexible. In addition, it provides more data to train and test our model to prevent overfitting.

3.3 Data Balancing

Maintaining data balance is essential for models that handle multiple categories. The dataset used in the study includes 20 different classes. To prevent biases and unequal representation, it is crucial to maintain data balance between multiple categories. This will enhance the model's learning capacity. To guarantee a fair distribution of examples across all classes, balancing entails making necessary adjustments to the dataset. By improving the model's accuracy and preventing it from preferring more common classes over less represented ones, this procedure seeks to improve the model's performance across a range of classification tasks and make it more reliable and equitable.

3.4 YOLOV5 Model

The most recent development in object detection is the YOLOv5 algorithm which is well-known for its high accuracy and speed. There are four different models available in the YOLOv5 framework: YOLOv5s, YOLOv5m, YOLOv5l, and YOLOv5x. The four main components of the

YOLOv5s model—input, backbone, neck, and prediction—are the focuses of this research. Each component is essential to the model's overall performance and makes a distinct contribution to how well it detects objects.

3.4.1 Input

YOLOv5 enhances small object detection by using techniques like CutMix and Mosaic data augmentation in the input component. These methods blend and paste images, enhancing the dataset. Adaptive scaling processing also resizes images for efficient data processing.

3.4.2 Backbone

The YOLOv5 Backbone uses cross-stage partial networks and focus structures to transform original 608x608x3 images into 304x304x32 feature maps, using local cross-layer fusion for richer feature maps and improved object detection performance.

3.4.3 Neck

YOLOv5 uses PANet and SPP in the neck section to integrate image characteristics from layers, blending data from top-down and bottom-up paths for efficient contextual information capture. SPP performs maximum pooling with four different-sized nuclei and tensor splicing, enhancing object identification at various scales.

3.4.4 Prediction

YOLOv5 uses the GIOU (Generalized Intersection over Union) Loss function in its Prediction component to address the limitations of the standard IOU Loss. This refinement considers minimal exterior rectangles of real and predicted boxes, resulting in a more resilient loss function. YOLOv5 also employs NMS (Non-Maximum

Suppression) to localize redundant detection boxes and retain the most suitable ones, specifically using DIOU_NMS (Distance IOU Non-Maximum Suppression) to improve object identification outcomes.

4 RESULTS AND ANALYSIS OF THE EXPERIMENTS

The PyTorch framework was used in this research, and the model was trained on a Tesla T4 GPU using the CUDA 12.0 experimental environment. The training parameters were set as follows: the input image size was 640x640 pixels, and the batch size was 16.

This experiment uses Precision (P), (R), and Recall mean Average Precision (mAP) as evaluation indicators. The results of the detection contained four cases, namely True Positive (TP), False Positive (FP), True Negative (TN), and False Negative (FN).

Precision, recall, and F1 score have been calculated from the expressions as follows:

$$\text{Precision} = \frac{TP}{(TP+FP)} \tag{1}$$

$$\text{Recall} = \frac{TP}{(TP+FN)} \tag{2}$$

$$\text{F1} = \frac{2 \times \text{Precision} \times \text{Recall}}{(\text{Precision} + \text{Recall})} \tag{3}$$

4.1 Confusion Matrix

The normalized confusion matrix serves as a vital tool applicable to both binary and multiclass scenarios and is extensively employed in addressing classification issues.

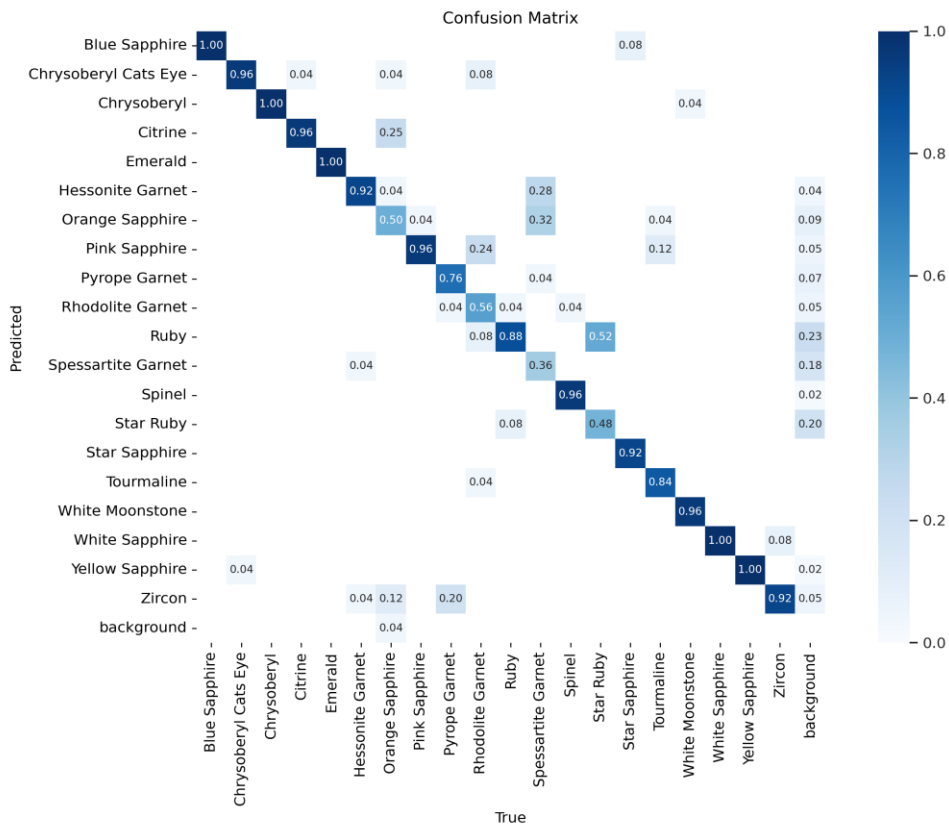


Figure 2: Confusion matrix of the model for the twenty classes

Its utilization allows for a thorough assessment of model performance, thereby facilitating insightful research outcomes. Fig. 2 visually represents the normalized confusion matrix, plotted using Scikit-Learn and Matplotlib. This matrix effectively tabulates the comparison between correct and incorrect predictions across twenty categories.

4.2 Test Results and Analysis

Fig. 3 illustrates the experimental results. The proposed model can correctly detect and classify gemstone images from the detection results.

In the evaluation of the YOLOv5 model's performance, tests were conducted to assess its efficacy and accuracy across different batch sizes. The model's efficacy and accuracy were evaluated by changing the batch sizes while taking into consideration how this would affect the outcomes of object detection. This experiment was to establish the optimal batch size for the YOLOv5 model. Fig. 4 illustrates the variation in results with different batch sizes.



Figure 3: Test results

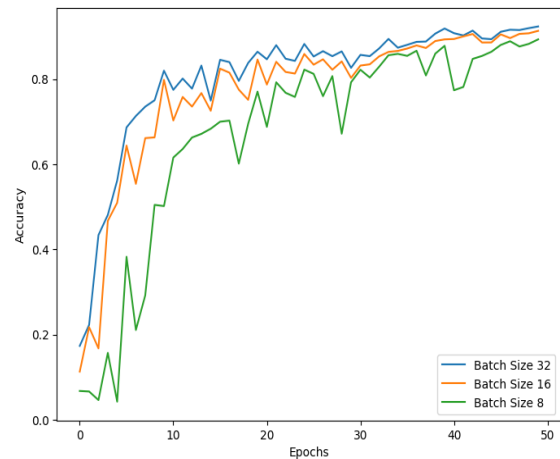


Figure 4: Result variation with Batch Size

In this study, an extensive evaluation of parameter variations on the YOLOv5 model was conducted, as outlined in Table 1. Notably, the experiment revealed noteworthy trends. When the batch sizes were increased to 816 and 32 the training accuracies rose to 88%, 89%, and 91% respectively. These results highlight a clear correlation between larger batch sizes and improved training results. Conversely, it was noted that the number of steps per epoch had an impact on the ultimate training performance.

5 CONCLUSION

The gem export market in Sri Lanka has seen substantial growth, but it faces escalating issues of fraud and corruption due to the absence of reliable gem identification procedures. This lack has resulted in considerable financial losses. In this work, a mode was proposed to identify Gems.

Table 1: Comparison of the accuracy with different Batch Sizes

Batch Size	Accuracy
8	88%
16	89%
32	91%

By adjusting various parameters, including dataset size, annotation quality, augmentation techniques, model architecture modifications, and hardware resources, a target accuracy of 0.922 was achieved with YOLOv5. The study underscores the importance of accurate gem identification and proposes that this developed model can significantly contribute to resolving the prevalent issues in the industry.

6 FUTURE WORK

The current research successfully addressed the need for accurate gemstone identification using a model that demonstrated high accuracy across various gem classifications. However, incorporating factors like carat weight, color, clarity, and market trends could enhance the application's predictive capabilities. Such an innovation would cater to gem enthusiasts, collectors, and industry professionals, providing a convenient tool for precise gemstone evaluation. Thus, warranting further exploration and research in the domain of gemstone assessment technology.

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Optimizing Plant Selection for Location-Specific Environmental Conditions

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ABSTRACT

Today most people, including farmers, encounter considerable challenges when selecting the plant best suited for their geographical locations. Due to selecting the wrong plant, many issues occur such as diminished harvest yields, heightened susceptibility to diseases, and increased vulnerability to pest infestations. This study is based on finding the best plant for the location and selecting suitable locations for given plants. Machine learning techniques were used in this work. The data set was trained using five machine learning models KNeighbors, Logistic Regression, Naive Bayes, Support Vector Machine, and Decision Tree. Each model's performance was evaluated based on Accuracy, Precision, recall, and f1 score values. The model with the highest values of performance indicators was identified as the best model. When finding the crop for the given location the model that was trained using the dataset "Crop Nutrient Requirements and Environmental Conditions Dataset" the model KNeighbors was used. To find the best location for the given plant, the model was trained using the dataset "Agricultural Soil Quality and Environmental Conditions Across Districts". Finally, a web application was developed using two selected models.

KEYWORDS: Agriculture, Crop, Location, Machine Learning

1 INTRODUCTION

With the increasing population and economic crisis, agriculture is becoming an important growing sector all over the world (Mondal & Rehena, 2018). With the developed technology many areas in the agriculture field have been developed and modified. The modern agriculture sector has to face several challenges including increasing population, climate changes, natural resources reduction, and also the safety and health concerns (Benos et al., 2021).

Today many people are tending to gardening due to the economic challenges as it provides fresh and cost-effective products. In gardening, people face several challenges such as getting the highest harvest, protecting the plants, and protecting from diseases among other

factors. The main reason for most of those issues is selecting the plants that are not suitable for a location. When planting, consideration of temperature, weather conditions in the area, and soil condition (amount of carbon, magnesium, and potassium in the soil) are really important (Mondal & Rehena, 2018).

Different plants grow based on different conditions. Optimal harvest yield is achieved by situating it in the right place with the right conditions. Selecting the correct plant is a doubting task. In the research, a web application is developed using the model that is trained using five machine learning models.

2 RELATED WORK

2.1 *Crop Prediction Using Machine Learning*

The research "Crop prediction using machine learning" done by Rao et al. (2022) used several machine learning algorithms accounting for climate, soil, fertilizer, and seed quality, to forecast crop selections and agricultural yield. By evaluating various algorithms, such as KNN, Random Forest, and Decision Tree, the research has demonstrated the efficiency of using metrics like Entropy and Gini Index on a dataset with 22 crop types. They were able to achieve high recall, accuracy, precision, and F1 values in their prediction.

2.2 *Prediction of Crop Yield Using Machine Learning*

The "Prediction of Crop Yield using Machine Learning" in the study by Ghadge et al. (2018) divides soil into organic, inorganic, and real estate kinds using both supervised (Back Propagation Network) and unsupervised (Kohonen Self Organizing Map) learning methods. By evaluating the accuracy of several network learning techniques the system provides users accurate results. Priority has been given to variables such as soil composition, soil type, and pH value in order to achieve excellent classification accuracy in contrast to other methods that rely on crop output and market pricing for crop sequencing.

2.3 *Evaluation of Predictive Data Mining Algorithms in Soil Data Classification for Optimized Crop Recommendation*

The research study which was carried out by Arooj et al. (2018) looked at the viability of classifying soil types in Pakistan's Kasur area using a variety of

classification methods, including Decision Trees, Naïve Bayes, Rule-Based classification, Neural Networks, Support Vector Machines, and Genetic methods. The research evaluates the importance of data mining in managing huge datasets, identifying relationships, classifying information, and forecasting results using pattern recognition. A better understanding of soil types might increase agricultural output, decrease the need for fertilizer, and improve the accuracy of yield predictions. The study's ultimate goal is to provide the framework for a future soil management system.

2.4 *A Scalable Machine Learning System for Pre-Season Agriculture Yield Forecast*

Oliveira et al. (2018) invented a machine learning method for the early prediction of soybean output. They make use of a recurrent neural network (RNN) that has been trained using information from many sources, such as temperature, rainfall, and soil characteristics. Historical corn and soya bean yield data collected from 1500 towns in the US and Brazil has been used in the training labels deriving process. It uses meteorological information from seasonal forecasts to make predictions as far ahead as seven months. The results suggest that this strategy is successful or perhaps superior to models that rely on remote sensing data, which can only offer early season forecasts during the opening weeks or months of the crop cycle.

3 METHODOLOGY

3.1 *Machine Learning*

The Fig. 1 given below is a representation of the mechanism of machine learning. The data is trained

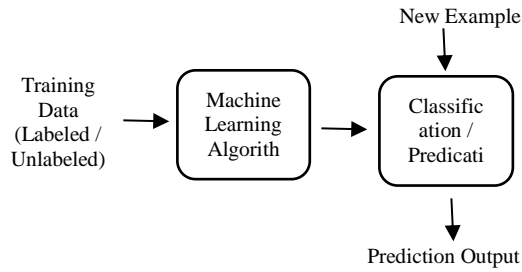


Figure 1: A machine learning approach.

using machine learning algorithms and develop the prediction model. Which is then used to predict new data.

3.2 Data Preprocessing

The dataset was loaded to the code and started the preprocessing process. After referring to the description of the two data sets, duplicate values were dropped. Then the correlation heat map was developed separately for two datasets.

After referring to the heat map diagram, the dependent variables that increase the correlation by 0.7 were selected and removed from the dataset. By removing the highly correlated variables the multicollinearity was reduced and secured from redundant data enhancing computational efficiency.

3.3 Model Training

The model was developed by training the datasets with five machine learning techniques including KNeighbors, Logistic Regression, Naive Bayes, Support Vector Machine, and Decision Tree. The model with the highest accuracy, precision, recall, and f1 score (f1 score is a machine learning metric that calculates model accuracy that measures how many times the model made correct predictions. It's a combination of precision and recall scores of the model.) values was selected when developing the web application.

3.4 Web Application Development

After selecting the best model with highest accuracy, it was used to develop the web application.

The application was developed using CSS, html and Flask framework. The users can easily select the suitable location for the selected plant and also the best-suited plants for the selected location as well.

4 RESULTS AND DISCUSSION

The web application required two models to find the crop for the location (Crop Nutrient Requirements and Environmental Conditions Dataset) and to find the location for the crop (Agricultural Soil Quality and Environmental Conditions Across Districts). So two datasets were collected and trained separately for five models KNeighbors, Logistic Regression, Naive Bayes, Support Vector Machine, and Decision Tree. Accuracy, precision, recall and f1 score values were calculated for each model and selected the model with the highest accuracy.

This experiment uses Precision (P) and Recall (R) as evaluation indicators. The results of the detection contained four cases, namely True Positive (TP), False Positive (FP), True Negative (TN), and False Negative (FN).

Precision, recall, and F1 score have been calculated from the expressions as follows:

$$\text{Precision} = \frac{TP}{(TP+FP)} \quad (1)$$

$$\text{Recall} = \frac{TP}{(TP+FN)} \quad (2)$$

$$\text{F1} = \frac{2 \times \text{Precision} \times \text{Recall}}{(\text{Precision} + \text{Recall})} \quad (3)$$

Table 1: Training Results for "Crop Nutrient Requirements and Environmental Conditions Dataset"

Topic	Accuracy	Precision	Recall	F1
KNeighbors	0.991	0.992	0.991	0.991
Logistic Regression	0.978	0.980	0.978	0.978
Naive Bayes	0.961	0.964	0.961	0.961
Support Vector Machine	0.983	0.984	0.983	0.983
Decision Tree	0.983	0.983	0.983	0.983

Confusion matrices were developed for each dataset. The confusion matrices were drawn to find the crop for the location (Crop Nutrient Requirements and Environmental Conditions Dataset). The confusion matrices were drawn to find the location for the crop (Agricultural Soil Quality and Environmental Conditions Across Districts).

As shown in Table 1, when finding the crop for the given location the model that was trained using the dataset "Crop Nutrient Requirements and

Because of the accuracy of the data, size of the dataset, and the proper machine learning model we could get the output with better accuracy.

5 CONCLUSION

In this study, a system was developed to select the most suitable plants for the location and also to select the best location for the selected plant. A proper dataset was selected and trained using five machine learning models. When

Environmental Conditions Dataset" the model KNeighbors was used as it was having Accuracy of 0.991, precision 0.992, recall 0.991 and f1 with 0.991.

As shown in Table 2, when finding the best location for the given plant the model was trained using the dataset "Agricultural Soil Quality and Environmental Conditions Across Districts". The Support Vector Machine was used as it was having an accuracy of 0.808, precision of 0.832, recall of 0.808, and f1 of 0.794.

developing the system the model with the highest accuracy was selected. In this study, the model that was trained under KNN classification model holds the highest accuracy and it was used for the development purposes of the web application. The developed website was used for the convenience of the people allowing them to easily select the plant that is the best suited for their lands.

Table 2: Training Results for "Agricultural Soil Quality and Environmental Conditions Across Districts"

Topic	Accuracy	Precision	Recall	F1
KNeighbors	0.768	0.768	0.768	0.763
Logistic Regression	0.646	0.646	0.646	0.645
Naive Bayes	0.649	0.685	0.649	0.643
Support Vector Machine	0.808	0.832	0.808	0.794
Decision Tree	0.744	0.743	0.744	0.742

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Perception and Knowledge of Information Technology Ergonomics Among Sri Lankan Students: A Study

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ABSTRACT

Ergonomics is a branch of science that aims to study the abilities and limitations of humans and then apply this study to improve human interaction with systems and working environments. The unexpected shift to online learning challenged the students to set up proper work areas with available resources and space. The objective of this research was to explore the ergonomic perception of school students to create awareness of ergonomics among these students. The study was conducted through a questionnaire on ergonomics knowledge and its practices, screen time, breaks during the study, and devices they use. Data was collected during the first quarter of 2023. A total of 252 students responded to the questionnaire. With the frequency distribution and descriptive statistics, the study revealed that the students were unaware of ergonomics and its effects on their health. The majority of the students had pain or discomfort in their online study activities (84%), and very few students used the correct screen-brightness ergonomics (11%), surface ergonomics (9%), and (13%) importance of breaks. About 37% of subjects suffered neck pain, 18% had upper back or lower back pain, 28% had hand or shoulder pain, and 6% had sleep difficulties. In one year, many of them have developed significant problems, which may increase the risk of health issues in the future. There is a need for the inclusion of ergonomics in the school curriculum, and students need training in the subject. The study endorses promoting IT health education for proper ergonomics in schools effectively.

KEYWORDS: Education, Ergonomics, Post-pandemic, Perception

1 INTRODUCTION

The global declaration of the pandemic by the World Health Organization on the month of March 2020 due to the Coronavirus Disease, and a year after some quarantine procedures were loosened, many organizations continued to work remotely (Puljak et al., 2020). Consequently, educational environments affect students' development, growth, concentration, performance, and learning efficiency. The paradigm shift in the learning conditions of millions of students has undergone some substantial ergonomic complications. The shift towards a "home-schooling" approach was considered beneficial as it reduced

the spread of the infection and mitigated teaching and learning loss. Accordingly, almost all the education institutes followed a "new normal" or a "hybrid reality" within the post-COVID world (Bakry et al., 2022). Despite all these challenges, Sri Lankan Education organizations have responded positively and succeeded in ensuring the ongoing provision of teaching and learning, research and contribution to society with contemporary techniques and tools during and post-pandemic. As a result, most of the school students have shifted to online learning, therefore ergonomics may be required to ensure the learners remain healthy. This is essential to set up a work

area with tools and resources they had at home, such as a dining table and chairs or alternative desks without external monitors or input peripherals. These home environments may not fit the ergonomic features of the students.

2 LITERATURE REVIEW

Due to the COVID-19 pandemic, education shifted to e-learning, moving away from traditional classrooms typically adhering to traditional ergonomic standards (Bakry et al., 2022). According to Yan et al. (2021), ergonomics might be necessary to maintain the health of learners in the context of remote learning following the pandemic. Ergonomics aims to mitigate injuries like musculoskeletal disorders (MSD), impacting productivity and performance, as highlighted by Dianat et al. (2016). Khan et al. (2012) suggested that the design and adjustment of computer workstations are crucial in diverse settings, as these modifications can enhance efficiency and comfort by reducing the visual demands of the users of their tasks (Soltaninejad et al., 2021). Teachers and students enhanced their utilization of electronic media and devices, such as WhatsApp, Google Drive, Telegram, etc., and Smartphones, tablets laptops and desktops to facilitate the sharing of information (Jena 2020). Jena (2020) suggests digitizing learning as a strategy to mitigate the threat posed by the pandemic.

3 METHODOLOGY

Poor ergonomics can lead to adverse consequences on students' health, both physically and psychologically. The study was conducted in 9 schools located in the Uva Province during January/February 2023. The selected schools were teaching

ICT as a subject without considering city-based or rural schools. Data was collected through an online questionnaire that included 22 questions grouped under five segments. The first one is about the demographic characteristics of the students, which accessed the socio-demographic variables precisely age category on the level of study and the usage duration of electronic devices the type of devices used generally. Ergonomic perceptions were assessed in the second section, which included five questions to precisely assess the perceptions of the influence of the environment, extended sitting and maintaining a good posture of the musculoskeletal system, perception of the consequences of environment lighting on the eyes, and the position of the screen and its brightness, break-rest characteristics and sleep status of online learning. The following section assesses their health complaints and issues experienced during e-learning. Furthermore, the last section examines the effectiveness of their devices and virtual learning.

4 DATA COLLECTION AND ANALYSIS

A total of 252 responses were received through an online questionnaire. Frequency of distribution, descriptive statistics, and correlation tests were utilized to analyze the data. This study examined comprehensive school students' attitudes toward information technology-based teaching and learning environments. This statistical approach enabled the investigation of potential relationships between specific ergonomic behaviors or attitudes and students' overall understanding of information technology ergonomics.

Table 1: Ergonomic Practices of students with their devices

Questions	N	(%)
Upon which surface do you position your smartphone/tablet/laptop?		
Appropriate surface (table or desk)	201	79.8
Inappropriate surface (ground, sofa, bed or pillow)	51	20.2
What level of brightness does the device have?		
Appropriate (moderate)	208	82.5
Inappropriate (low/high)	44	17.5
What distance do you maintain between your eyes and the screen for viewing?		
Appropriate (more than 40 cm)	193	76.6
Inappropriate (less than 40 cm)	59	23.4
How do you evaluate the size of your device's screen?		
Appropriate (medium)	187	74.2
Inappropriate (small/large)	65	25.8

5 RESULTS AND DISCUSSION

To devise the study objective, descriptive data on ergonomic perception and practices in online education were presented as numbers and percentages. The study encompassed 132 (52.4%) male and 120 (47.6%) female students aged 15-19 years. Among them, 24.4% reported using laptops, 45% used smartphones, and only 2.9% used desktops. The students' screen time for the online education activity was as follows: 65.5% of the respondents used devices for more than 4 hours for educational purposes. 24.1% of the students used devices for 2–4 hours, and approximately 10% reported using them for less than 2 hours for educational purposes.

Table 1 shows the ergonomic practices of students with the devices they use. Approximately 20% of the respondents placed the devices on an inappropriate surface, such as a sofa, bed, or the ground. In addition, 23% of them

had an inappropriate distance between their eyes and the screen, which contrasts the reported optimal distance between the screen of the device and their eyes (Black et al., 2022). Also, 17% had a suitable brightness level. Poor ergonomics practices may cause discomfort and pain for the students. The students were questioned if they experienced any kind of discomfort or pain.

Table 2: Localization of different symptoms, percent of the students

Localization of symptoms	(%)
Neck	39.8
Elbow/Forearm	5.8
Shoulder	19.5
Hand/Wrist	11.1
Ankle/Foot	4.0
Upper Back/Lower Back	19.9

The analysis indicated that all the students experienced pain, discomfort, aches, or

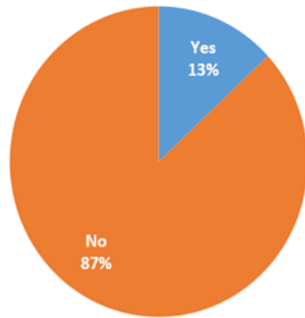


Figure 1: Students' responses for the breaks

swelling in the neck, shoulder, back, or arm areas (Table 2). The most indicated health effect experienced by students was neck pain (39.8%). This could be ascribed to improper postures or extended sitting without breaks while studying (Akulwar-Tajane et al., 2021). To prevent extended poses in the same position for hours taking breaks should be considered to follow.

The Pearson correlation coefficient represents the strength and direction of the linear relationship between the independent variables and the dependent variable. In our study, the value of the correlation coefficient (R) is 0.68, indicating a strong positive correlation between inappropriate ergonomic practices and the health issues that arise from those practices.

Furthermore, the study reveals that most students skipped the much-needed breaks (Fig.1). It is suggested that for every two hours of continuous computer work, a 15-minute break should be taken (Shikdar & Al-Kindi, 2007).

Table 3: The correlation coefficient

R	R Square	Adjusted R Square
0.68	0.46	0.19

Table 4: Cronbach's Alpha Test

Cases	N	Percent
Valid	243	96.4%
Excluded	9	3.4%
Cronbach's Alpha		N of Items
0.33		2

Cronbach's Alpha is a crucial metric in assessing the reliability of measurement likelihood. We conducted the correlation coefficient test and the reliability test using PSPP, 2.0.0-pre2 software. The questions included in the questionnaire on the satisfaction with online learning and the likelihood of continuing virtual learning.

The low Cronbach's Alpha value of 0.33 suggests that the satisfaction with online learning and the likelihood of continuing virtual learning may not be highly internally consistent.

This low reliability indicates that discomfort resulting from poor ergonomic practices may be perceived and reported differently among students, emphasizing the need for targeted interventions to improve overall well-being and mitigate the adverse effects of suboptimal ergonomic habits.

This study shows that the students were unaware of ergonomic properties and practices. The lack of ergonomic knowledge and lack of preparation for the novel approaches may result in adverse effects on the health of the students.

6 CONCLUSION

This study pursued to survey the ergonomic perceptions after the COVID-19 pandemic resulted from online education. Knowledge of ergonomics is an essential requirement today due to the increased online mode of knowledge dissemination. Ergonomically sound

components should enhance students' well-being and comfort while learning. This study emphasizes a requirement to guide good practices regarding ergonomic properties of viewing content, adjusting the screen brightness, device distance, the correct sitting position, and posture when using a device at a desk for school students.

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Pose Estimation Comparison to Identify Technical Issues during Athletic Coaching

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ABSTRACT

As the intersection of technology and sports continues to evolve, pose estimation emerges as a pivotal tool in addressing technical issues during athletic coaching. This report explores and compares various pose estimation techniques, ranging from computer vision-based, with the primary objective of enhancing the coaching process. We delve into the background of pose estimation and its significance in providing real-time feedback to athletes. Identifying and addressing technical issues in sports coaching scenarios is paramount for improving athlete performance. By leveraging pose estimation technologies, coaches can gain insights into body movements, postures, and techniques, thereby refining their training methodologies. The report analyzes the advantages and limitations of different pose estimation approaches, providing a comprehensive overview of their applicability in diverse sports settings. Through a comparative analysis, we evaluate factors such as accuracy, real-time processing, and cost-effectiveness, offering insights into the strengths and weaknesses of each technique. Additionally, we discuss specific technical issues in athletic coaching and demonstrate how pose estimation can play a pivotal role in addressing these challenges. The report concludes with a discussion of the current challenges and limitations of pose estimation in athletic coaching, along with potential future directions for research and technological advancements. As we navigate this rapidly evolving field, this report aims to inform coaches, researchers, and technology developers about the potential of pose estimation in revolutionizing the coaching landscape and enhancing athlete performance.

KEYWORDS: Athletics, Coaching, Image Processing, Media Pipe, Tkinter

1 INTRODUCTION

In the dynamic realm of athletic coaching, the pursuit of precision and excellence has led to a paradigm shift in methodologies, with technology emerging as a formidable ally. Among the transformative technologies, pose estimation, a computer vision technique, stands out as a promising tool for dissecting athlete movements and identifying nuanced technical issues. This research endeavors to explore the intersection of pose estimation and athletic coaching, specifically examining its efficacy in discerning and rectifying technical challenges faced by athletes.

Our focus is directed towards [E.g. Athlete player, Weight trainers], where precision in movement and posture is paramount.

2 METHODOLOGY

The OpenPose algorithm's implementation enables precise athlete pose capture, which is the foundation of this study. A state-of-the-art computer vision system called OpenPose is well known for its accuracy in identifying important body joints and their spatial relationships. Using a picture or a video, this device can quantify any single joint angle in the human body. The OpenPose algorithm's implementation enables

precise athlete pose capture, which is the foundation of this study. A state-of-the-art computer vision system called OpenPose is well known for its accuracy in identifying important body joints and their spatial relationships. Using a picture or a video, this device can quantify any single joint angle in the human body.

2.1 Data Collection

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2.1.1 Open Pose Algorithm

OpenPose serves as the fundamental tool for data collection, providing a robust framework for capturing and analyzing athlete poses. The algorithm excels in its capability to identify key body joints, enabling the measurement of various joint angles crucial for biomechanical analysis (Nath et al., 2018).

2.1.2 Data Source

For this research project, data related to athlete poses and joint angles was collected from an already-existing real-time image and video set. This dataset comprises a diverse range of real-time images and videos capturing athletes in different angle statuses. Specific focus was placed on measuring joint angles such as the right-arm elbow angle, the left-hand elbow angle, and other relevant joint configurations.

2.1.3 Real-time Images and Videos

The dataset encompasses a variety of scenarios, including different sports,

exercises, and movement patterns. Each image or video in the dataset corresponds to a specific angle measurement, allowing for a comprehensive analysis of joint angles across various athletic contexts.

2.1.4 Angle Statuses

The data collection process involves systematically measuring and documenting the angles of interest, ensuring a detailed representation of the athletes' poses. Angle statuses include but are not limited to the measurement of the right-arm elbow angle, the left-hand elbow angle, and other pertinent joint configurations that are crucial for understanding biomechanical movements.

2.1.5 Existing Real-time Image and Video Set

To ensure a diverse and representative dataset, the research leverages an existing real-time image and video set. This set captures the natural variability in athlete poses and movements, reflecting the complexity and diversity inherent in athletic activities.

2.1.6 Data Validation

Quality control measures are implemented to validate the accuracy and reliability of the collected data. This involves cross-referencing angle measurements from Open Pose with manual annotations or other established benchmarks to ensure the precision of the dataset.

2.2 Data Preprocess

To guarantee the quality of the dataset and its compliance with the pose estimation technique, a thorough data pretreatment step was conducted before the start of the training phase. Video frame alignment, resolution standardization, and the elimination of any artifacts or outliers that would have

affected the pose predictions' accuracy were all included in this picture frame alignment process (Mündermann et al., 2006).

2.2.1 Video Frame Alignment

The dataset contained videos with varying frame rates and resolutions. To ensure consistency, all video frames were aligned using the Open Pose algorithm. This step involved synchronizing frames across different videos and establishing a uniform temporal structure for accurate pose estimation.

2.2.2 Resolution Standardization

Standardizing the resolution of the video frames was crucial for maintaining consistency in the dataset. The Open Pose algorithm operates optimally with a standardized resolution, enhancing the accuracy of joint detection and angle measurement. The resolution standardization process involved resizing frames to a predetermined resolution suitable for the pose estimation model.

2.2.3 Artifact and Outlier Removal

Artifacts and outliers in the dataset could lead to inaccuracies in pose estimations. A comprehensive cleaning process was implemented to identify and remove any irregularities. The Open Pose algorithm, with its ability to robustly handle occlusions and noise, played a vital role in mitigating the impact of artifacts and outliers.

2.2.4 OpenPose Integration

The Open Pose algorithm was seamlessly integrated into the preprocessing pipeline to facilitate accurate pose estimations. Leveraging its advanced capabilities, Open Pose assisted in aligning video frames, standardizing resolutions, and effectively handling artifacts, ensuring the dataset's readiness for subsequent training phases.

2.2.5 Quality Control Checks

After preprocessing, quality control checks were conducted to verify the effectiveness of the alignment, resolution standardization, and artifact removal processes. These checks involved visual inspection of sample frames, comparing them before and after preprocessing to ensure that the essential features and details were preserved while unwanted elements were successfully eliminated.

2.2.6 MediaPipe Integration

In conjunction with Open Pose, the preprocessing pipeline integrated Media Pipe, another robust library for pose estimation and tracking. Media Pipe provided additional tools for refining pose estimations, contributing to the overall enhancement of data quality and accuracy.

2.3 Pose Estimation Model Selection

2.3.1 OpenPose Algorithm

Open Pose is a state-of-the-art computer vision library renowned for its accuracy in detecting and estimating the positions of key body joints in real-time. It excels in capturing the spatial relationships between joints, enabling precise pose estimations.

Selection Rationale:

The decision to choose Open Pose as the pose estimation model was rooted in its proven capabilities to handle diverse athletic movements and its robustness in real-time scenarios. Open Pose's ability to accurately identify and track body joints aligns with the research goal of capturing nuanced athlete poses.

2.3.2 Model Fine-Tuning

Dataset Annotation:

An annotated dataset was prepared, providing the model with labeled examples of various athlete poses. Each

image or video frame in the dataset was annotated with corresponding joint positions, allowing the model to learn the relationships between body parts.

Training Process:

The Open Pose model underwent a fine-tuning process using the annotated dataset. This involved adjusting the model parameters to optimize its performance for the specific movements and postures prevalent in the chosen sport or athletic activity (Guo et al., 2010).

Performance Optimization:

During fine-tuning, the model was optimized to handle variations in body shapes, clothing, and movement speeds commonly encountered in athletic scenarios. This process aimed to enhance the model's accuracy and robustness in capturing athlete poses across diverse contexts.

2.3.3 Validation and Iterative Refinement

Validation:

The fine-tuned model underwent rigorous validation using a separate dataset not used during the training phase. This ensured that the model generalized well to new data and maintained accuracy in pose estimations.

Iterative Refinement:

Based on validation results, the model underwent iterative refinement. Adjustments were made to address any challenges or limitations identified during validation, further enhancing the model's overall performance.

3 RESULTS

Employing a combination of Python, image processing techniques, and the MediaPipe algorithm, we tailored our approach for pose estimation in athletic coaching scenarios.

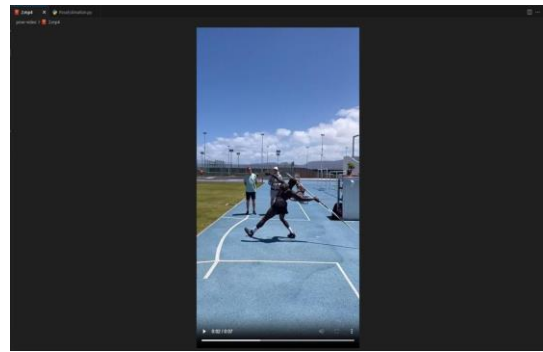


Figure 1: before getting the angle of the left elbow and right elbow angle.

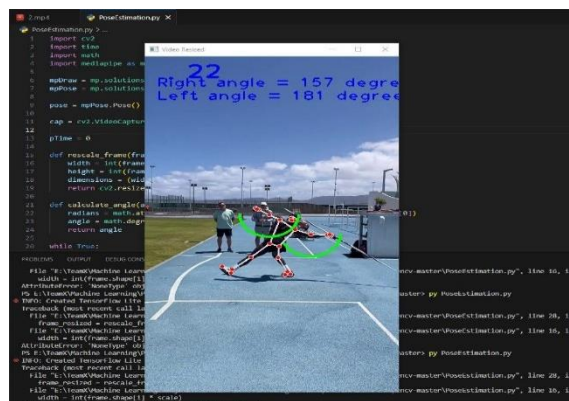


Figure 2: After getting the angle of the left elbow and right elbow angle.

The methodology leverages the power of MediaPipe for accurate pose estimation and further enhances it through custom image processing techniques. The user interface is developed using the Tkinter framework, providing an interactive platform for coaches. This integrated solution not only utilizes advanced algorithms but also ensures a seamless and user-friendly experience for effective technical issue identification during athletic training.

4 CONCLUSION

In the pursuit of refining athletic coaching methodologies, this research embarked on an exploration of the intersection between pose estimation technologies and coaching effectiveness.

Through the lens of [e.g. Running, jumping, throwing], our investigation sought to compare traditional coaching methods with modern approaches enhanced by real-time pose estimation feedback. The culmination of our study has provided nuanced insights into the potential impact of technological integration on athlete development and training practices.

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Understanding the Actual Usage of Block Coding Platforms Among Secondary Level College Students in Sri Lanka

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ABSTRACT

In the dynamic landscape of the digital age, the significance of computer science education is paramount, particularly at the secondary level. While developed nations have seamlessly integrated coding into their school curricula, recognizing its pivotal role in fostering digital competency and innovation, challenges persist in developing countries like Sri Lanka. Here, limited resources hinder the effective implementation of comprehensive computer science education. This research focuses on the intriguing phenomenon of the underutilization of free coding platforms among college students in Sri Lanka. Despite the accessibility of these resources, a palpable lack of interest is observed among students. The study takes a comprehensive approach to investigate various factors contributing to this trend. It delves into the intricacies of educational practices, curriculum design, student motivation, and teacher training, seeking to unravel the complexities that underlie the apparent disinterest in coding education. The relevance of bridging this gap becomes evident in the context of the escalating demand for coding skills in the contemporary job market. As technology-driven industries continue to dominate, proficiency in coding is increasingly becoming a prerequisite for meaningful participation in the global economy. Therefore, this research not only unveils critical insights to enhance computer science education in Sri Lanka but also proposes evidence-based interventions. These interventions, tailored to the specific challenges faced by developing nations, can potentially revolutionize coding education, offering valuable lessons for educational policymakers and practitioners worldwide.

KEYWORDS: Block-coding, Coding Education, Secondary Level School Children, Technology Acceptance Model

1 INTRODUCTION

Developed nations have prioritized computer science education in secondary schools, recognizing its role in fostering digital literacy and innovation. Initiatives like Code.org, backed by governments, underscore the pivotal role of coding in the modern world. Statistical data highlights the increasing demand for computer science skills in technology-driven industries, emphasizing the employability of individuals with coding expertise (Yadav et al., 2011). However, developing countries face challenges, including limited resources and trained educators, creating a digital divide. Despite these obstacles, the importance of

bridging the digital divide and empowering students with computer science skills remains paramount. To address this, organizations offer free online learning platforms in countries like Sri Lanka. Despite these efforts, interest in coding among Sri Lankan students remains low, prompting the need for investigation. This research aims to uncover factors hindering engagement, providing insights not only for Sri Lanka but also for other developing nations seeking to enhance computer science education. Understanding these challenges is crucial for optimizing the effectiveness of free coding platforms and promoting digital literacy among

secondary school students in developing countries.

2 LITERATURE REVIEW

A systematic examination of the literature was undertaken to discern the factors influencing the active utilization of block coding platforms among secondary-level college students in Sri Lanka. The PRISMA methodology was employed to conduct this comprehensive literature review. The procedure suggested by Chathuranga et al. (2023), Jayasinghe et al. (2022), Jayasinghe et al. (2023) and Jayasinghe et al. (2023) was also utilized when systematically examining the literature. Throughout this process, the Technology Acceptance Model (TAM) was strategically utilized as a framework to thoroughly explore the research problem within the wider context of information system adoption. By incorporating these models, commonly employed in the assessment of new technologies, the review aimed to provide in-depth insights into the variables that impact the acceptability and usage of information systems (O'Dell & Sulastri, 2019).

2.1 Article Inclusion Criteria

To ascertain pertinent literature for this study, a set of criteria was employed, focusing on peer-reviewed journal articles and conference papers published in English between 2016 and 2023. The chosen sources were sourced from Google Scholar. A meticulous three-step screening process ensued. In the identification phase, articles were sought using keywords related to e-learning and the Technology Acceptance Model (TAM). Recognizing the potential for diminishing relevance beyond the first ten pages of search results, emphasis was

placed on the initial ten web pages containing 200 articles. Following the screening of titles and abstracts, 100 articles were shortlisted, and cross-referencing was performed with Scimago for indexing confirmation. Ultimately, 62 papers met the criteria for inclusion in the review.

2.2 Factor Identification

In the realm of e-learning, perceived ease of use is a critical factor, reflecting students' personal assessments of the technology's simplicity in navigating course contents (van Raaij & Schepers, 2008). Similarly, perceived usefulness is pivotal, indicating individuals' beliefs regarding how technology adoption can enhance their job performance (Burton-Jones & Hubona, 2006). Moreover, enjoyment emerges as a significant determinant, with studies highlighting its influential role in e-learning adoption (Fu et al., 2007). Notably, individuals' experiences significantly shape their perceptions of ease of use and usefulness of e-learning systems (Lee et al., 2013). This underscores the importance of considering prior experiences when evaluating technology acceptance. Furthermore, attitudes play a central role in influencing students' learning experiences, as evidenced by research on instructional technology adoption. The constraining impact of computer anxiety on attitudes, willingness to use, learning capacity, and performance during system utilization has been consistently observed, emphasizing the need to address this barrier in technology adoption efforts (Gilbert et al., 2003). Collectively, these factors underscore the multifaceted nature of technology acceptance and its implications for effective e-learning implementation.

Identified factors that affect Actual Usage (AU), including Perceived Ease of Use (PEOU), Perceived Usefulness (PU), Experience (EX), Perceived Enjoyment (PE), Computer Anxiety (CA), and Attitude (ATT), underwent a rigorous assessment, considering their frequency across the literature. Additionally, insights from a senior lecturer in the Department of Industrial Management and input from industry professionals helped with the shortlisting process. These factors were selected based on their prominence in existing research and their relevance to understanding the complexities of block coding platform adoption among secondary-level college students.

3 METHODOLOGY

3.1 Conceptual Framework

The primary goal of this research was to pinpoint the determinants influencing the practical utilization of block coding platforms among secondary-level college students in Sri Lanka. Utilizing a quantitative methodology in alignment with the research objectives, the study formulated a conceptual framework grounded in the Technology Acceptance Model (TAM) (Lai & Li, 2005). Informed by existing literature, this framework sought to investigate the connections between the recognized factors and the effective use of block coding platforms.

3.2 Hypothesis Development

H1: EX has a relationship between ATT towards block coding

H2: PEOU has a relationship between ATT towards block coding

H3: PU has a relationship between ATT towards block coding

H4: PE has a relationship between ATT towards block coding

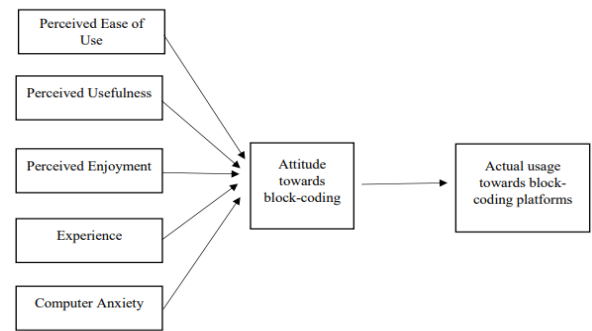


Figure 1: Conceptual framework

H5: CA has a relationship between ATT towards block coding

H6: ATT towards block-coding has a relationship between AU of block coding platforms

H7: EX has a relationship between AU towards block coding platforms mediated by ATT

H8: PEOU has a relationship between AU towards block coding platforms mediated by ATT

H9: PU has a relationship between AU towards block coding platforms mediated by ATT

H10: PE has a relationship between AU towards block coding platforms mediated by ATT

H11: CA has a relationship with AU towards block coding platforms mediated by ATT

4 DATA COLLECTION AND ANALYSIS

4.1 Data Collection

The study focused on the population of secondary-level college students in Sri Lanka who utilize block coding platforms. A total of 171 respondents were included in the data collection process, employing the convenient sampling method for its operational simplicity and cost-effectiveness. An online structured questionnaire consisting of questions about the identified factors and geographical data served as the

instrument for data collection. Following the proposed research model, encompassing five independent variables and one mediating variable in the conceptual framework, a minimum of 137 observations was deemed necessary, with a 5% probability error, to detect an R^2 value of at least 0.1, as per the guidelines by Hair et al. (2012). The analysis was carried out using Smart PLS 4 software.

In a bid to ensure data quality, an initial analysis was conducted using IBM SPSS software. Following a comprehensive preliminary analysis, which involved the removal of non-standardized data, 167 valid data points were considered for subsequent analysis.

4.2 Assessment of Measurement Model

The initial phase of the analysis involved a comprehensive assessment of the measurement model, ensuring alignment with established standards for internal consistency reliability, convergent validity, and discriminant validity. Reflective measurement models were implemented for the conceptual model, employing both Cronbach's Alpha and Composite Reliability methods to gauge internal consistency and reliability. Adhering to the recognized threshold of above 0.7 (Hair et al., 2012), all variables in the conceptual model surpassed this criterion, boasting values exceeding 0.7.

Convergent validity, a pivotal measure of the correlation between

measurement items of the same variable, underwent evaluation using outer loadings and Average Variance Extracted (AVE) values (Hulland, 1999). The expectation here is that the absolute standardized outer loading should surpass 0.7, and to maintain a reflective variable in the measurement model, the AVE value should exceed 0.5 (Henseler et al., 2009). All measurement items in the model demonstrated robust convergent validity, surpassing the 0.7 threshold for outer loadings and exceeding 0.5 for AVE values.

Discriminant validity, assessing the distinctiveness of a construct from others (Henseler et al., 2009), was scrutinized using cross-loadings, the Fornell-Larcker criterion, and the Heterotrait-Monotrait Ratio of Correlations (HTMT). These methodologies affirmed that the studied constructs were adequately distinct from each other. In summary, the outcomes validated the internal consistency, reliability, convergent validity, and discriminant validity of the constructs within the model.

4.3 Assessment of Structural Model

The analysis of the structural model results aims to ascertain the significance of relationships within the model.

Table 1: Assessment of structural model

Relationship	PathCoefficient	T value	P value	Acceptance
EX->ATT	0.071	0.924	0.356	H1 Rejected
PEOU->ATT	0.185	2.479	0.013	H2 Accepted
PU->ATT	0.190	2.848	0.004	H3 Accepted
PE->ATT	0.185	2.479	0.013	H4 Accepted
CA->ATT	0.053	0.775	0.439	H5 Rejected
ATT->AU	0.427	6.774	0.000	H6 Accepted

Table 1 displays path coefficients, p-values, t-values, and the status of hypothesis acceptance resulting from the analysis of the structural model. A significance level of 0.05 and a 95% confidence interval were applied in this assessment.

4.4 *Assessing the Mediation Effect*

Following the initial assessment of the foundational model, an in-depth examination of the mediating influence was undertaken to scrutinize the role of attitude in the connections between the independent variables and the dependent variable. The outcomes of the stipulated relationships in hypotheses H7 to H11 are presented in Table 2, elucidating the insights drawn from the dataset.

5 FINDINGS AND DISCUSSION

The findings and discussion of this study reveal significant insights into the factors influencing the actual usage of block coding platforms among secondary-level college students in Sri Lanka. Out of the eleven hypotheses proposed, two were rejected. Notably, the hypotheses suggesting a relationship between computer anxiety and experience with the actual usage of block coding platforms were not supported by the data. This implies that, contrary to expectations, students' computer anxiety levels and prior experience do not significantly impact their engagement with coding platforms. Additionally, the study found that perceived usefulness (PU) and perceived ease of use (PEOU) exhibit partial mediation in their relationship with actual usage, while the other three factors (EX, PE, and ATT) demonstrate full mediation. These nuanced mediation effects suggest that the interplay between PU and PEOU with actual usage is more complex and may involve additional

factors. The rejection of the hypotheses related to computer anxiety and experience could be attributed to the unique context of the study, where secondary-level students, already familiar with technology, may not experience significant anxiety, and prior experience might not be a decisive factor. The reasons for these rejections underline the importance of considering contextual factors and the evolving nature of students' interactions with technology in shaping their engagement with block coding platforms.

6 CONCLUSION

In conclusion, this study delves into the intricate dynamics of secondary-level college students' engagement with block coding platforms, shedding light on the multifaceted relationships between user perceptions, attitudes, and actual usage. The acceptance of certain hypotheses highlights the paramount influence of perceived ease, usefulness, and enjoyment on students' attitudes and subsequent platform usage. Notably, the mediation analysis underscores the pivotal role of attitude as a significant mediator between user experience, perceptions, and the practical utilization of block coding platforms. These findings contribute nuanced insights to the field of educational technology, offering practical implications for educators and policymakers aiming to foster effective coding education. While recognizing the study's limitations, particularly in terms of demographic focus and sampling methods, the comprehensive analysis sets the stage for future research endeavors to explore this dynamic landscape more expansively and comprehensively.

Table 2: Assessment of mediation effect

Relationship	Path Coefficient	P value	Acceptance
EX->ATT	0.319	0.000	H7 Accepted
ATT->AU	0.453	0.000	
PEOU->ATT	0.403	0.000	H8 Accepted
ATT->AU	0.299	0.000	
PU->ATT	0.312	0.000	H9 Accepted
ATT->AU	0.406	0.000	
PE->ATT	0.361	0.000	H10 Accepted
ATT->AU	0.544	0.000	
CA->ATT	0.416	0.000	H11 Accepted
ATT->AU	0.296	0.000	

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UX Factors that Impact Customers' Engagement with Fashion Retail Websites: Evidence from Sri Lanka

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ABSTRACT

This research delves into the critical but often overlooked aspect of user interface (UI) and user experience (UX) design within the burgeoning fashion retail industry of Sri Lanka. With a significant shift towards online shopping, understanding, and implementing effective UX factors have become pivotal for retailers seeking to engage tech-savvy consumers. Through a comprehensive literature review, key factors influencing customer engagement with fashion retail websites were identified as, encompassing usability, accessibility, desirability, and consumer trust. The study highlights the challenges faced by fashion retailers due to limited awareness of UX factors and offers practical recommendations for improvement. By investing in UI/UX education, conducting user research, prioritizing accessibility, emphasizing desirability in design, and staying updated with industry trends, retailers can enhance their online presence and business growth. This research provides valuable insights for fashion retailers and e-commerce practitioners, ultimately contributing to the development of the industry in the digital era.

KEYWORDS: Customer Engagement, Fashion Retail in Sri Lanka, UX Factors

1 INTRODUCTION

The rapidly expanding fashion retail industry in Sri Lanka is experiencing significant growth, driven by changing consumer preferences, rising disposable income, and the rise of e-commerce. Recognizing the importance of online presence, fashion shops are increasingly focusing on user experience (UX) characteristics to improve customer engagement (Vlasenko et al., 2022).

Expertise in user interface (UI) and UX design is becoming important in the field of e-commerce, where items and services are increasingly traded online. The design of the complete user experience is critical in creating consumer confidence and resolving any concerns ranging from dissatisfaction to privacy concerns (Egger, 2001)

Distinguishing themselves in the competitive online market, fashion

retailers leverage UX factors to create visually appealing, user-friendly interfaces that attract and retain customers, boost conversion rates, and drive sales (Orlova, 2016). However, the impact of UX factors on customer engagement may vary across cultural contexts.

Sri Lanka's booming online fashion market sparks research on how website design (UX) impacts customer engagement. Growing online shopping habits reveal Sri Lankan consumers prioritize convenience, personalization, and attractive interfaces. This study aims to pinpoint key UX factors driving engagement, satisfaction, and business growth within this unique market. By reviewing existing research and understanding consumer preferences, the study will equip fashion retailers and e-commerce players with insights to tailor their strategies for success.

2 LITERATURE REVIEW

The authors conducted a systematic literature review to identify user experience (UX) factors influencing customer engagement on Sri Lankan fashion retail websites. They followed a six-step process including formulating a review question, setting criteria, searching databases, screening articles, extracting data, and summarizing findings. The search focused on English-language peer-reviewed articles published between 2007 and 2023. Ultimately, 40 relevant articles were identified and analyzed to understand key UX factors impacting customer engagement in the Sri Lankan context.

2.1 UX Factors

In web development and design, addressing user behavior is vital for successful implementation. The escalating demand for superior user experiences emphasizes the importance of UX research, aligning website design with human behavior for enhanced satisfaction and performance (Orlova, 2016). User-centered design, as stressed by (Yasmine & Atmojo, 2022), is essential for positive interactions, impacting satisfaction, comfort, and motivation. The influence of UI and UX extends beyond satisfaction, contributing to overall convenience value (Sudjatmoko et al., 2022). This value enriches user experience, playing a crucial role in application development, business processes, and branding. To succeed in website implementation, understanding and incorporating UX factors, from research to human-computer interaction, is key. Prioritizing UX factors becomes pivotal in shaping the future of digital interactions amid the growing demand for excellent user experiences (Debra, 2021).

2.2 Customer Engagement

In the online business landscape, customer engagement is vital for success. Integrating User Experience (UX) into web development is key for attracting and retaining customers. This article explores the intricate relationship between UX and customer engagement, drawing insights from recent research.

Customer engagement is closely linked to user experience, making UX research essential for strategic initiatives. Understanding user behavior through comprehensive research empowers businesses to tailor online platforms and create engaging digital experiences (Debra, 2021).

Human-computer interaction, a core aspect of UX design, directly influences customer engagement. Aligning website design with human behavior fosters a deeper connection between customers and digital interfaces, creating memorable experiences (Orlova, 2016).

The quality of UX directly impacts customer satisfaction, comfort, and motivation to interact with a platform. Positive user experiences, achieved through a user-centered design approach, lead to increased satisfaction and foster a sense of connection beyond transactions (Yasmine & Atmojo, 2022).

A well-designed UX contributes to the value of convenience for users. This convenience becomes a driving force behind customer engagement, with businesses prioritizing thoughtful UI and UX design strategies better positioned to capture and retain their audience (Sudjatmoko et al., 2022).

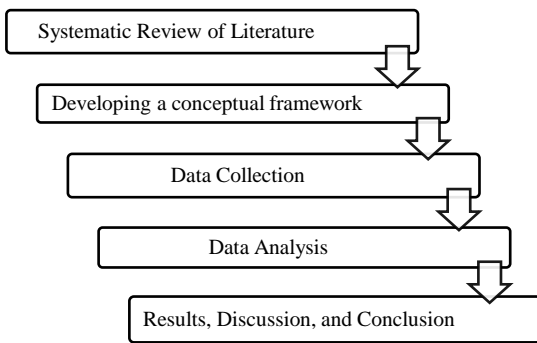


Figure 1: Proposed Methodology

2.3 Fashion Retail Websites in Sri Lanka

The fashion retail sector in Sri Lanka has experienced notable changes in recent times, influenced by both worldwide trends and the distinctive cultural elements of the island. This article examines the essential aspects of Sri Lanka's fashion retail industry, including its evolution, challenges, and the strategies implemented by businesses to succeed in this dynamic market. Notably, the surge in e-commerce has a direct impact on the advancement of fashion retail websites.

3 METHODOLOGY

3.1 Theoretical Framework and Hypothesis Development

Hypotheses of Direct Associations

H1: Usability is a UX factor that drives customers' engagement with fashion retail websites in Sri Lanka.

H2: Accessibility is a UX factor that drives customers' engagement with fashion retail websites in Sri Lanka.

H3: Desirability is a UX factor that drives customers' engagement with fashion retail websites in Sri Lanka.

H4: Consumer trust is a UX factor that drives customers' engagement with

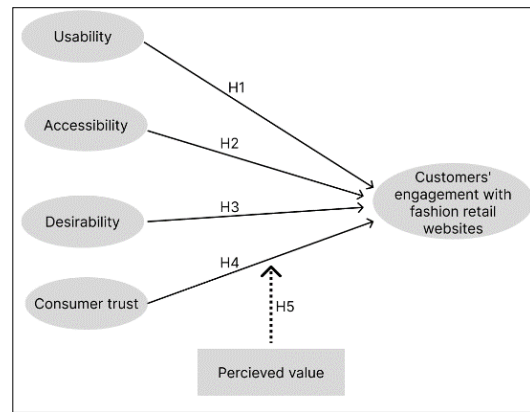


Figure 2: Conceptual Framework

fashion retail websites in Sri Lanka.

Hypotheses of Moderate Associations

H5: The perceived value would strengthen the relationship between consumer trust and customers' engagement with fashion retail websites in Sri Lanka

4 DATA COLLECTION AND ANALYSIS

4.1 Data Collection

This study draws on previous research to identify factors influencing customer engagement on fashion retail websites. The theoretical framework is based on these factors, guiding primary data collection through an online questionnaire survey targeting individuals aged 16 to 45 in Sri Lanka. With 214 responses gathered, non-probability sampling, a mix of convenience and snowball sampling, was chosen for its accessibility and efficiency, given resource constraints.

4.2 Data Analysis

The research will utilize Partial Least Square Structural Equation Modeling (PLS-SEM) to analyze collected data, employing proxies for construct representation through weighted composites. PLS-SEM is chosen for its compatibility with the conceptual model's complexity, offering insights into direct and indirect effects, identifying moderator

effects, and allowing control variable inclusion. This statistical method is preferred for its ability to maintain higher statistical power with smaller sample sizes. SmartPLS4 is specifically designated as the analytical tool for PLS-SEM data analysis in this study, aligning with data operationalization and prior literature.

5 RESULTS AND DISCUSSION

The outcomes of the data analysis indicate the acceptance of four hypotheses (H1, H2, H3, H4) and the rejection of one hypothesis (H5).

The preliminary data analysis for a study on fashion retail websites in Sri Lanka involved screening 219 survey responses for quality. Data checks included identifying outliers, assessing distribution, and ensuring normalcy. Utilizing the PLS-SEM approach, a nonparametric statistical method, the study proceeded to evaluate the measurement model. Internal consistency was confirmed with Cronbach's alpha values above 0.7, and composite reliability scores surpassed thresholds, indicating high reliability. Convergent validity was supported by outer loadings exceeding 0.70 and AVE values at or above 0.50. Discriminant validity was established, with indicators showing greater loadings than corresponding cross-loadings, affirming the distinctiveness of constructs.

5.1 Assessing Structural Model

Table 1 displays the path coefficients, f-squared, and p-values used to examine direct relationships. The findings indicate that all of the hypothesized positive correlations were supported. Thus, without taking into account moderator effects, the findings indicate that four of the chosen independent variable factors have a favorable impact on the UX factors that impact customers' engagement with fashion retail websites in Sri Lanka.

The researcher considered perceived value as a continuous moderator variable and was evaluated accordingly. Table 2 shows the path coefficients and p values needed to evaluate the moderator influence of perceived value on the link between consumer trust and customer engagement with fashion retail websites in Sri Lanka.

As shown in Table 2, the moderation effect of perceived value had no significant effect on the link between consumer trust and customer engagement with fashion retail websites in Sri Lanka. Therefore, the hypothesis H5 was rejected.

5.2 Recommendations and Managerial Implications

Optimizing customer engagement on Sri Lankan fashion retail websites requires culturally attuned design. Tailoring User Experience (UX) to local preferences and incorporating Sri Lankan culture and fashion trends is crucial.

Table 1: Results of Direct Associations

Direct effect of variables	Path Coefficient	f-square	p-value <0.05	Hypothesis tested
AC>EN	0.367	0.129	0.000	H1
CT>EN	0.313	0.096	0.000	H2
DS>EN	0.267	0.077	0.000	H3
US>EN	0.282	0.062	0.001	H4

Table 2: Results for Perceived value

Relationship	Path Coefficient	p-value	Hypothesis tested
		<0.05	
PerceivedValue x CT -> EN	-0.045	0.365	H5

Recommendations include localizing communication and marketing, building a strong brand reputation, analyzing the competitive landscape, and staying informed about economic factors. Investing in technological advancements and providing user education enhances the online shopping experience. Following these guidelines allows fashion retailers to create an engaging and culturally relevant platform for Sri Lankan consumers..

Fashion retailers in Sri Lanka must invest in website usability, visual appeal, and trust-building. Reassessing value strategies, adapting marketing, and collaborating with industry experts are also crucial. By prioritizing long-term customer relationships, Sri Lankan fashion websites can thrive in the competitive market.

6 CONCLUSION

This study looked at how customers engage with fashion retail websites in Sri Lanka to obtain the anticipated results. This found four critical pillars that would help customers connect with fashion retail websites in Sri Lanka, as well as the fact that perceived value moderates the relationship between consumer trust and customer engagement with fashion retail websites. The study presented the links as a conceptual framework using a theoretical perspective based on previous research.

This study demonstrates that all four essential pillars influence client

interaction with fashion retail websites in Sri Lanka. However, this study demonstrates that perceived value has no significant effect on the relationship between consumer trust and customer engagement with fashion retail websites in Sri Lanka. It is obvious, that other elements than those listed in previous scholarly work may influence customers' engagement with fashion retail websites in Sri Lanka.

This study, focusing on fashion retail websites in Sri Lanka, has limitations, identifying only four impact criteria. The generalized model may overlook biases and individual preferences. The PLS-SEM analysis used a questionnaire from urban and suburban residents aged 16 to 45, potentially introducing biases based on location and generation.

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Industrial Management



A Conceptualization to Assess the Impact of Political Ideology on Employee Career Development

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ABSTRACT

Political ideology which constitutes diversified beliefs, values, and principles influence on people's perspectives about the world and the organization of society. It is also a key factor in determining a person's way of thinking and making decisions concerning his/her career development. With the emergence of complexities in the respective business processes of many firms, high attention is paid by researchers on the area of the political ideology of employees and how does it impact on their career development. But many of them have substantiated it from a job creativity perspective only. In order to fill the gap in the literature which focuses on how conservative political ideology impacts on all aspects of employee career development; job creativity, job commitment, and job burnout, the present study attempted to suggest the relevant propositions that could be tested and validated from a future empirical study.

KEYWORDS: Job Burnout, Job Commitment, Job Creativity, Political Ideology

1 INTRODUCTION

Political ideology is not only one of the key factors in determining an employee's way of perceiving, thinking or making behaviour towards the achievement of a firm's goals and objectives but it significantly affects the way he/she interacts with the superiors, subordinates, and peers as well. Therefore, managing employees with diverse political ideologies is a vital task for any business firm. The evolution of political ideology is especially important in a Sri Lankan firm context, a nation that has seen decades of political unrest and ethnic warfare, especially among the younger population (Ramasamy, 2020).

Recent research on creativity at work has centered on the hypothesis that when all employees exhibit a reasonably high level of creativity, it makes the firm more successful and competitive (Madjar et al., 2002). Since politics is a constant

occurrence in practically every organization (Vigoda & Cohen, 2002). Bermiss & McDonald (2018) have identified the significance of the impact of political ideology on employee career perspectives in business firms. Hence, the understanding of the impact of political ideology on employee career development is essential for the business firms as the employee career development is an aspect of human resource development (HRD) (Marsick & Watkins, 1994). In past, many firms have controlled their employees over their career development but now the employees have more freedom to choose their own occupations, which is something that is often not addressed by conventional HRD methods (Holton, Swanson, & Naquin, 2001). To guide individuals in their job decisions, career development theories have focused on vocational choice, assessment

techniques, values, and self-understanding. Many of these early beliefs, however, have doubtful validity in today's diverse workforce, since business processes have evolved to reflect growing economic competitiveness in the global market (Conlon & Thomas, 2004).

2 LITERATURE REVIEW

At present, there is high interest among researchers to make systematic inquiries in the field of political ideology as they want to comprehend why people support left or right ideas and there is a belief that now people hold dynamic political ideas than the static ideas that they have held before (Bauer, Barbera, Ackermann, & Venetz, 2017). Researches have generally defined political ideology as a "unidimensional continuum, running from liberal to conservative or from left to right". Numerous recent investigations commence with a one-dimensional (liberal-conservative or left-right) conceptualization of political ideology. In many cases, this goes beyond being convenient and is actually a component of the conceptual structure. Jost et al. (2008) have argued that differences in motivation among individuals have a major influence on political ideology. The findings of that study have indicated that people who have a strong desire for certainty and stability both in terms of knowledge and existence, are much more likely to be identified as conservatives.

2.1 Political Ideology

Political ideology is fundamentally concerned with issues of power, authority, and governance. It seeks responses to questions, such as, who

ought to lead? what objectives does the government have? and which roles do people and groups play in society? (Harrison & Boyd, 2018). Political ideology, however, is more than just a function of preference. It affects how societies are set up and how we deal with the problems we face today in the actual world. For instance, the policies we support and the steps we take will be influenced by our opinions on healthcare, education, and the environment (Holcombe, 2021). Political ideology, to sum up, is a complicated and varied idea that represents our values, convictions, and experiences (Martin, 2015). Also, it influences how we perceive the function of the state, economy, and individual rights and has practical ramifications for how we set up our communities and deal with the problems we face today (Frieden, 2020).

There are several political ideologies, each with a distinct set of views and norms. Conservatism, liberalism, socialism, and anarchist are some of the most well-known political ideas (Everett & Roma, 2013). While these beliefs appear to be fundamentally opposed, they all share a common goal: to build a more just and equal society. Conservatives place a premium on tradition, stability, and hierarchy. They think that society should be organized on ideas like as individualism and free market capitalism, and that change should be gradual and deliberate (Béteille et al., 1986). Finally, political ideology is a complex and complicated term and it represents our values, beliefs, and experiences. It impacts the employee perspectives on the role of government, economy, and individual rights, and has real-world consequences for their job

outcomes. Moreover, politics is a constant occurrence in practically every firm (Vigoda & Cohen, 2002), whereas conflict affects different aspects and activities within the firms that impact on employee's job outcomes and their own career development (Barki & Hartwick, 2001).

2.2 Job Creativity

The ability to approach a task or an issue in a novel or different way, or the capacity to use one's imagination to develop novel ideas, both constitute indications of job creativity (Birt, 2023). It is significant to generate concepts that are both practical and slightly novel if one is going to be creative. Recent research on creativity at work has centered on the hypothesis that when all employees exhibit a reasonably high level of creativity, it makes the company more successful and competitive (Madjar et al., 2002).

2.3 Definition of Job Commitment

Some employees persist with their firm because they enjoy what they do or their personal objectives may line up with those of that firm (Argyris, 1998). Some could remain out of the concern for what they might lose if they go. Then the others could continue working because they have a duty to the firm or to their boss (Lawrence, 1969).

2.4 Definition of Job Burnout

A persistent response to continuing interpersonal and emotional stress at work is known as job burnout. It is defined by three primary characteristics; feeling worn out, turning cynical or disconnected, and feeling ineffective or unaccomplished (Roethler, 2021). Job burnout is recognized as a prevalent problem in many human services

professions, which has prompted research attempts to be made in several nations to address this issue (Maslach, 2003).

2.5 Political Ideology and Employee Career Development

Employee job creativity is a significant construct that was examined in this research. The concept of employee job creativity can be defined as "the belief that one has in their capacity to produce creative outputs" (Tierney & Farmer, 2002). According to creativity studies, the major factor that is driving the development of workplace creativity also known as job creativity, is autonomous motivation. Creative self-efficacy (CSE) is gaining popularity in the field of creativity study (Karwowski & Barbot, 2016). Creative self-efficacy (CSE) is a subset of Bandura's self-efficacy paradigm that focuses on creative undertakings (Bandura, 1997). According to Bandura's theory, self-efficacy influences individuals' pursuit of goals and the amount of effort they expend in the process. CSE, in particular, includes a person's self-evaluation of their creative ability and potential. This self-evaluation affects their decisions about creative activities, the amount of work they put in, and, ultimately, their capacity to generate inventive results (Lemons, 2010). According to the definition of creativity, it is about trying new things rather than clinging to old ones. Mayer (1999) and Runco (2004) have viewed creativity as a key driver of cultural progress. Conservatives may be concerned about this relationship with change and fresh ideas.

According to Wilson's theory, conservatives may be less creative for three primary reasons; First, when people feel threatened or uncertain, they tend to prioritize their basic demands for safety and security (Simons et al., 2009). This emphasis on basic needs differs from the desire that propels creativity (Bar-Tal, 2001). Second, conservatives frequently desire to adhere to long-held traditions and ideals. Creativity, on the other hand, entails coming up with new and unique ideas. Finally, the authoritarian and anti-hedonistic aspects of conservatism may cause conservatives to underestimate the usefulness of imagination. Feather previously identified these features of conservatism, arguing that they may inhibit the enjoyment and expression of inventive thought (Feather, 1979). In present study, the relationship between political ideology and job creativity will be empirically investigated. Thus it proposes that,

Proposition 01: Conservative political ideology of an employee will be negatively correlated with his/her job creativity.

Job commitment can be defined in a variety of ways. Work engagement, often known as dedication to work or job commitment refers to "how enthusiastically a person performs their assigned tasks while working in a corporate environment" (Mtey, 2005). It captures the sense of obligation a person has to the objectives, mission, and vision of the job that he/she has been assigned (Bhat, 2019). The most frequently referenced interpretation is that of Lodahl and Kejner who define it as the incorporation of values about the quality or value of jobs in regards to the worth of the person (as cited by Lawler & Hall,

1970). However, it appears that this concept is more applicable to work commitment. More generally Job commitment is described as the proclivity to become profoundly involved with one's job and proclivity for continuing with the job. Furthermore, because the concepts of job commitment and job involvement remain so identical, the present study has employed both titles concurrently (Chusmir, 1982).

Although it has been recognized that cross-level alignment can improve the implementation of leaders' policies, such as more liberal members of an organization supporting corporate social responsibility (CSR) initiatives (Gupta et al., 2017), there is still a research gap regarding how this alignment of political ideology positively impacts employee commitment and well-being (Hambrick & Mason, 2019). Gerber et al. (2011) found that political ideology is linked to two characteristics of the Big Five personality traits: openness to experience and conscientiousness. Individuals with more liberal ideas have higher degrees of openness to experience whereas those with more conservative ideologies have higher levels of conscientiousness. Previous studies have demonstrated that openness to experience is associated with creativity, while conscientiousness is a determinant of job performance. Based on these facts, it is possible to conclude that liberals have stronger job creativity, but conservatives excel in job commitment (Rothmann & Coetzer, 2003). Thus, present study proposes that,

Proposition 02: Conservative political ideology of an employee will be positively associated to his/her job commitment.

Another significant construct of this research is the organizational citizenship behavior which was introduced by Organ (1988) and defined it as “voluntary behaviors by individuals that go beyond their assigned roles, are not explicitly rewarded, and contribute to the overall efficiency and effectiveness of the organization”. The informal possibilities of collaboration and contributions that individuals engage in as a result of their job satisfaction and feelings of unfairness are represented by organizational citizenship behaviors and these actions go above and beyond the formal obligations and represent a volunteer effort to improve the collective well-being of the organization (Organ & Reviews, 2018). Thus, present study proposes that,

Proposition 03: The conservative political ideology of an employee will be positively associated to his/her job burnout.

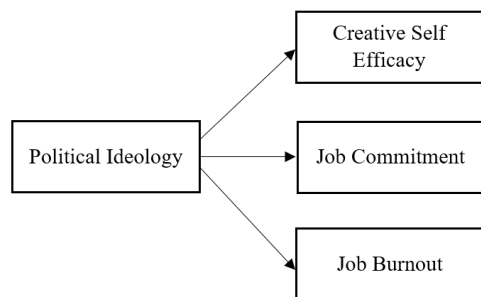


Figure 1: Conceptual framework associated with political ideology

3 CONCLUSION

Many researchers have developed various theoretical frameworks to identify the impact of political ideology on social aspects rather than on business contexts. The causal relationships that are proposed by the present study is a theoretical reflection that discusses how

conservative political ideology impact on the employee career development from the perspectives of job creativity, job commitment, and job burnout within the business context. The reviewed literature was also proved that there is an impact of political ideology on employee career development but many of those studies have focused on job creativity perspective only. Hence, the propositions that were made by present study could be tested and validated from a future empirical study to make wider generalization of those in the business context.

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Analysis of Customer Purchase Intention on Skirting Tiles: A Case Study

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ABSTRACT

Skirting tiles are used for covering up joints between the floor and wall. Though this product concept has emerged in foreign countries, yet it is not popular and has not been introduced to the Sri Lankan market by the tile manufacturers. Though the skirting tiles have been produced for over twenty-five years in Sri Lanka for export purposes, most Sri Lankan customers utilize the cut tiles for the covering skirtings. Therefore, this study aims to assess the potential of introducing skirting tile products to the Sri Lankan market. This study strives to identify the intention of purchasing the skirting tiles and how brand credibility, product design, utilitarian attitudes, perceived concept newness, perceived technology newness and consumer perception of innovativeness influence the purchase intention. The questionnaire has been developed by using a five-point Likert Scale. Respondents were the project customers related to the large construction projects and the researcher has adopted a convenient sampling technique to select the sample. Data is collected for a single point in a particular period; thus the research uses a cross-sectional time frame. Multiple Regression was used to analyze the hypotheses. The results indicate that product design and the consumer perception of innovativeness positively influence the purchase intention of skirting tile products. Future research may address the purchase intention of launching skirting tiles based on the perception of customers. The study indicates that interior product design can attract consumer attention and intention to purchase. Therefore, it is recommended to consider interior product design technologies.

KEYWORDS: Consumer Purchase Intention, Skirting Tiles, Tile Manufacturing

1 INTRODUCTION

The tile manufacturing industry involves the production of tiles for covering floors, walls, and decorative purposes. Tile-bending technology is an enormous aspect in foreign countries. However, in the local market tile bending technology is not much familiar among consumers. Skirting tiles are the product that is used for covering joints between walls and floors. (Fragassa, 2015) Over twenty-five years, this product has been manufactured for export. Sri Lankan tile manufacturers have not introduced the product of skirting tile to the local market. Therefore, there was a research gap. In the field of construction, there are some architectural imperfections. Most

of the problems have been identified due to poor quality of work, lack of supervision, and poor installation methods. There are limited studies to identify the improvements of architectural defects. There are some unique features of porcelain tile products in the market (Isa et al., 2016). A variety of product categories can be identified in the porcelain floor tile. Future research should be done on processable and marketable new product innovation ideas relating to the porcelain tile industry. Product launch is more expensive and more risky (Sánchez et al., 2010). According to previous studies market research should be done in pre launching stage. Further research should be

addressed to the application of product launch strategies. (Hultink & Robben, 1999) This study attempts to identify the potential for launching skirting tile products in the market. The specific objectives are as follows;

- To Identify the factors influencing the purchase intention of the skirting tile product category.
- To analyze the impact of factors on the purchase intention of the skirting tile product category

2 LITERATURE REVIEW

2.1 Consumer Purchase Intention

Individuals often reflexively think about what type of use it will be taken rather than asking what is it. There is a relationship between consumer utilitarian and hedonic attitudes to increase consumer buying intention patterns. Throughout the phase of making decisions, customers make a final choice on whether or not to spend money on the product. (Lowe & Alpert, 2015) Theories of consumer behaviors refer that; there are two main reasons for purchasing a product. (1) Hedonic attitudes which are the emotional satisfaction of sensory attributes. (2) Utilitarian attitudes which are the functional attributes of the usage of a product (Voss et al., 2003).

2.2 Consumer Perception of Innovativeness

Consumer perception of innovativeness refers to the willingness to purchase the previous product which has unique features to other competitive products. (Lowe & Alpert, 2015) The previously acquired information is used by consumers when they are finding unique features. There are significant variations among peoples' product

experiences. Therefore, the product innovativeness concept has more challenges for making products with different attributes. Implementation of new technology than prior technologies can be identified as innovation. According to past research innovativeness can be expressed as what extent newly introduced products fulfill key elements of customer needs better than the existing products (Lowe & Alpert, 2015). A product that is less functioning than the expected level can be categorized as a psychological risk (Bashir et al., 2021).

2.3 Utilitarian Attitudes

Utilitarian attitudes represent a perspective that aligns with daily activities and seeks to promote actions. Maintaining large square meters of buildings is much more complex. For the vast area maintenance, some professionals are engaging in the task of repair management and cleaning management. Hospital facility managers indicate that interior finishes have a significant role in keeping a hospital's environment with zero infection. Therefore, wall finish material selection and floor edge covering materials selection should be done very carefully. High cleanability wall covering is suitable for the design of hospitals and other similar healthcare. (Lavy & Dixit, 2012) Constructional defects of wall and floor finishes refer to uneven floor level, detached floor tiles, floor tile cracks, improper fixing of wall tile, and detached skirting. To eliminate that type of constructional issues appropriate materials should be applied (Isa et al., 2016).

2.4 *Perceived Concept Newness*

Perceived concept newness represents the consumer judgement of the product's newness. Awareness of the product's usability tends to create positive purchase intention in consumers' mindsets. (Lowe & Alpert, 2015) Skirting tile introduction is an alternative solution for eliminating edges and usage difficulties of traditional skirting cut tiles. Bend tile innovation is a considerable point of the tile manufacturing industry. It can function as proper fixing of wall and floor skirtings. Bent tiles could be introduced as a new alternative to traditional skirtings (Fragassa, 2015).

2.5 *Perceived Technology Newness*

Perceived technology newness represents the consumer judgement of the product's innovative technology. According to the bent tile technology single ceramic or porcelain material can be bent at 90° degrees. Tile bending technology covers a large part of the tile industry. These types of technical solutions are suited for public place designs (Fragassa, 2015).

2.6 *Product Design*

Product design refers to the creating and developing process of a new product. That is an important aspect of manufacturing. Features such as cleanliness and hygiene of the product usage should be considered under the product design stage. Considering the wall edges and corners; bent tile application is best for the maintenance. Dust and debris frequently gather on wall edges. (Fragassa, 2015) Ideas of the facility managers and facility designers should be integrated to achieve the

organizational goals. Facility Managers have a better awareness of usability. From a designer's viewpoint, they should have considered the idea of facility managers. Previous studies refer to some issues that happened to the organization in the case of not considering facility maintenance in the initial stage of the product design. (Lavy & Dixit, 2012)

2.7 *Brand Credibility*

Brand Credibility refers to the trustworthiness of a consumer for brand identification. Consumers may feel less risk in buying products from well-recognised brands. Differences in appearance such as size, colour and surface of the advertising can be categorized as product performance risks (Isa et al., 2016).

3 METHODOLOGY

Saunders's Research onion concept was utilized to structure the design of the research. (Saunders & Tosey, 2012) Under the Onion model interpretation; the outermost layer of this study refers to positivism research philosophy. When peeling to the other layers; a deductive research approach and quantitative methodological choice have been used to complete the study. Five-point Likert scale has been used to collect qualitative responses quantitatively. Furthermore, a case study-based research strategy and cross-sectional time horizon method have been used. The convenience sampling method has been used for the sample selection. The size of the population indicates forty-five project customers. The questionnaire was addressed to the professionals who related to the construction field project customers such as large-size construction firms. The

questionnaire has been sent to the whole population.

H₁: Brand credibility positively affects the purchase intention.

H₂: Product design positively affects the purchase intention.

H₃: Perceived technology newness positively affects the purchase intention.

H₄: Utilitarian attitudes positively affect the purchase intention.

H₅: Consumer perception of innovativeness positively affects the purchase intention.

H₆: Perceived concept newness positively affects the purchase intention.

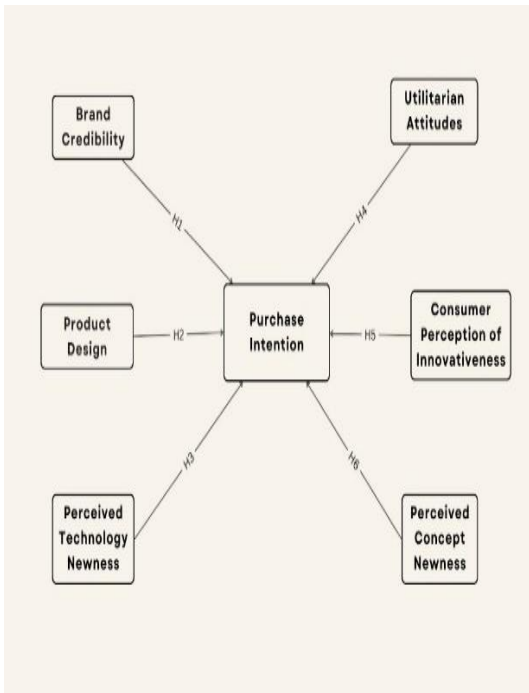


Figure 1: Research Model

4 DATA ANALYSIS

The reliability of the given data set and the validation of the data set were checked using appropriate statistical tests with the use of SPSS software. (Pallant, 2020) By using descriptive statistics, the 3.33 mean value of customers have the intention to purchase Skirting tile products. Multiple linear regression was used to analyze the collected data. Before

implementing multiple linear regression, assumptions have been checked such as normality, linearity, homoscedasticity, multicollinearity and independence of residuals. The multiple linear regression results are mentioned below;

Table 1: Multiple Linear Regressions

R-value	R square	Adjusted R square	Standard error
0.754	0.568	0.494	0.67872

Table 2: Coefficient Table

Variable	Beta value	T statistics	P value	Results
Perceived concept newness	-0.212	-1.742	0.09	Not Supported
Perceived technology newness	-0.119	-0.780	0.44	Not Supported
Utilitarian attitudes	0.194	1.496	0.14	Not Supported
Brand Credibility	-0.304	-1.544	0.13	Not Supported
Product design	0.672	3.295	0.00	Supported
Consumer Perception of innovativeness	0.471	3.447	0.00	Supported
Perceived Concept Newness				

5 DISCUSSION

Multiple linear regression analysis indicates that 56.8% variability of the purchase intention can be explained by the predictor measurements. (Consumer perception of innovativeness, Utilitarian attitudes, Perceived concept newness, Perceived technology newness, Brand

credibility and Product design). Findings of the beta values indicate that the product design and consumer perception of innovativeness have a statistically significant positive relationship with the purchase intention. These results are aligned with the previous research which refers to the product design strongly affecting the purchase intention because it made buyers aware of the benefits of using both hedonic benefits and utilitarian benefits. (Wonggotwarin & Kim, 2017) Previous research suggests that the broader perspective of the experience of innovativeness at the brand level is another contribution to the current consumer-perceived innovativeness and enhances the intention to purchase (Shams et al., 2015). Study results show that the Perception of innovativeness positively affects the purchase intention. Therefore, these results align with the previous research findings.

Previous study refers to how Brand credibility influences the buying intention of a product (Shteyneker et al., 2019). However, this research study found that brand credibility does not impact the purchase intention. Therefore, there is a contradiction with the previous studies. Reasons can be sometimes consumers have intention to buy some new product due to brand credibility but in actual scenario they do not do in reality. Furthermore, Previous research suggests that higher purchase intention can be caused by higher utilitarian attitudes (Lowe & Alpert, 2015). In this study, findings indicate that there is no statistically significant relationship between the utilitarian attitudes and purchase intention. Therefore, there is a contradiction with the previous research

on the area of utilitarian attitudes. It is essential to acknowledge that this study is done on a case study basis and project customers who are the business customers only engage with the construction and setting interior designs. They do not have much experience in the utilitarian aspects of floor skirtings. Furthermore, non-parallel results with the previous research studies can be affected due to findings that align with the firm-specific criteria which restricts the generalization of findings over Sri Lanka. Therefore, future research should be addressed to study the purchase intention of the skirting tile product from an overall Sri Lankan market perspective.

6 CONCLUSION

Tile bending technology is an emerging technology in the tile manufacturing industry. Adding new functional features to the porcelain tile can attract more consumer attention to the product. Considering the pre-launch stage of the product may be a critical stage. Innovative launches have been widely researched that align with the brand credibility, product design and the utilitarian attitudes of the consumer. This study has identified the market requirement for skirting tiles. Responders of this research are the customers who are related to large construction projects. The hypotheses have been tested by using multiple linear regression analysis. The results of this study refer to product design and consumer perception of innovativeness having a positive relationship with purchase intention. This research is based on a case study therefore results can not be generalized over Sri Lanka.

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Analysis of Drivers Affecting the Implementation of Sustainable Logistics Practices in The Fast-Moving Consumer Goods (FMCG) Industry in Sri Lanka

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ABSTRACT

This research focuses on the relationship between sustainable logistics practices and drivers affecting the implementation of sustainable logistics practices. A literature review has been employed to identify the sustainable practices related to logistics functions and drivers affecting the implementation of sustainable practices. To identify sustainable practices and drivers that apply to the fast-moving consumer goods industry in the Sri Lankan context, semi-structured interviews with industry professionals were conducted and Partial Least Squares Structural Equation Modeling was employed for the data analysis. It has been revealed that the above-mentioned drivers have a positive impact on the implementation of logistics practices. Ultimately the finding of the research recommends that the government rules and regulations should be strict for the successful implementation of sustainable logistics practices in warehousing and packaging.

KEYWORDS: Drivers, Green Logistics, Green Supply Chain, Sustainability, Sustainable Logistics Practices

1 INTRODUCTION

The Fast-Moving Consumer Goods (FMCG) industry in Sri Lanka is a major sector encompassing the manufacturing and distribution of consumer products with a short shelf life. While the profit margins on individual FMCG products may be small, their high-volume sales enable the cumulative profit to be substantial (Vibhuti et al., 2014). The FMCG sector contributes over 30% to the Gross Domestic Product (GDP) and employs nearly 20% of the workforce (FMCG Sector Archives, n.d.). Logistics are referred to the comprehensive process of managing the acquisition, storage, and transportation of resources or goods to their destination (Kenton, 2023). According to Ghoumrassi and Tigu (2017), the primary objectives of logistics are enhancing overall organizational performance and customer

satisfaction through the improved delivery of products or services to customers. As the demand for logistics has increased, global logistics activities cause 9-10% of CO₂ gas emissions (Prabodhika et al., 2020).

2 LITERATURE REVIEW

2.1 Sustainable Logistics Practices

Practicing technology-related information sharing plays a major role in achieving paper usage reduction (Baah et al., 2021; Indrasiri & Rathnayake, 2015; Lakmali & Jayaratne, 2018). Recycling of wastes and graywater is also highlighted as an important sustainable practice (Baah et al., 2021; Evangelista, 2014; Indrasiri & Rathnayake, 2015; Sureeyatanapas et al., 2018; Perotti et al., 2012). The use of fiber concrete in construction is identified as an innovative and sustainable material choice for

infrastructure within warehouses, contributing to environmental conservation (Indrasiri & Rathnayake, 2015). Further, according to Perotti et al. (2012), it has been discovered that implementation of rainwater capture infrastructure, re-usage of pallets and containers, and encouragement of tree planting for CO₂ compensation are sustainable logistics practices. Warehouse space optimization has been identified as a sustainable practice by (Vienažindienė et al., 2021; Zhang et al., 2014). Further, another study has emphasized that the acquisition of vehicles with cleaner energy sources and the optimization of delivery routes align with the broader goal of reducing the carbon footprint of transportation activities (Baz & Laguir, 2017). According to Zhang et al. (2014), mapping the energy and fuel consumption of vehicles is an important sustainable practice in transportation. It has been discovered that optimizing delivery routes for emission reduction, nighttime transportation operations to avoid traffic, and strategic location selection for distribution centers as sustainable transportation (De Assis et al., 2023). Other studies have emphasized the importance of transportation optimization for sustainability, highlighting practices such as tour optimization, the use of lower-energy transport modes, and the implementation of eco-packaging solutions (Sureeyatanapas et al., 2018). Considering the sustainable practices in packaging has highlighted the importance of minimizing packaging materials usage (Evangelista, 2014; Indrasiri & Rathnayake, 2015). The establishment and compliance with

recycling policies are highlighted as a fundamental sustainable practice by (Vienažindienė et al., 2021; Zhang et al., 2014). Another sustainable approach involves repurposing used paper for packaging, as advocated by (Indrasiri & Rathnayake, 2015).

2.2 Drivers Affecting the Implementation of Sustainable Logistics Practices

According to Lakmali and Jayaratne (2018), a combination of factors, including organizational policies, employee pressure, and top management commitment, are driving the implementation of sustainable practices. According to Matopoulos and Bourlakis (2010), market competition conditions and supply chain pressures impact on implementation of sustainable logistics practices. The desire to reduce operational expenses has been identified as a driver for the implementation of sustainable logistics practices (Dhull & Narwal, 2016). Consumer pressure emerges as a predominant social driver, as identified by Dhull & Narwal, 2016; Bey et al., 2013). The guidance and regulations provided by logistics industry associations and central governmental and regional environmental regulations motivate sustainable logistics practices (Zhang et al., 2014).

3 METHODOLOGY

This research is based on both qualitative and quantitative approaches. A systematic literature review was conducted to identify sustainable logistics practices and their drivers. The applicability of the reviewed information has been evaluated by conducting semi-structured interviews with 4 industry

professionals who are in the top management of the leading FMCG companies. The Population for the research is the individuals who are executives and above in the FMCG logistics sector. According to Cohen (1992), the minimum required sample size was 130 and this research has a sample of 137 individuals working in the logistics function of the FMCG industry. Further, a survey questionnaire was distributed via LinkedIn, and the relationship between sustainable logistics practices and their drivers was assessed using the Partial Least Squares Structural Equation Modeling (PLS-SEM) as the data distribution does not follow a normal distribution.

4 RESULTS AND DISCUSSION

This Research assessed the relationship between drivers and sustainable practices in Transportation, Warehousing, and Packaging separately in three different models.

The Results imply that the Organization and Management (OMD), Rules and Regulations (RRD), Industry and Market (IMD), Economy (ED), and Society (SD) positively impact the implementation of sustainable logistics Practices in Transportation (SPT). Further, the OMD, IMD, ED, and SD positively impact the implementation of sustainable logistics Practices in Warehousing (SPW) and the implementation of sustainable practices in packaging (SPP), while Rules and Regulations Drivers do not make an impact on the SPW and SPP. Table 1 shows the summary of the data analysis for three models in Transportation, Warehousing, and Packaging.

According to the analysis, OMD, which is an internal driver, has been identified as the major driver, and the immense engagement and support of top management and the employees can drive the organization towards the SPT.

Table 1: Summary of the Data Analysis

	Path Coefficient	t-value	p-value	97.50 %
OMD -> SPT	0.399	4.559	0	0.573
IMD -> SPT	0.271	0.582	0.003	0.452
RRD -> SPT	0.245	1.657	0.009	0.441
ED -> SPT	0.165	2.131	0.033	0.309
SD -> SPT	0.178	2.138	0.033	0.337
OMD -> SPW	0.192	2.442	0.015	0.358
IMD -> SPW	0.387	4.754	0	0.543
RRD -> SPW	0.073	0.591	0.554	0.327
ED -> SPW	0.263	2.642	0.008	0.447
SD -> SPW	0.278	2.853	0.004	0.457
OMD -> SPP	0.208	2.431	0.015	0.382
IMD -> SPP	0.438	6.42	0	0.335
RRD -> SPP	0.105	1.446	0.148	0.262
ED -> SPP	0.291	3.891	0	0.427
SD -> SPP	0.292	4.209	0	0.429

Top management can take the lead in establishing organizational policies and the general public, including consumers, pays attention to

organizational contributions to sustainability when making purchasing decisions, creating an additional layer of motivation for companies to prioritize green initiatives in transportation. Employing sustainable logistics practices is considered a strategic move for organizations that enhances their competitive advantage in the market.

However, strict rules and regulations coming from the government are necessary for these initiatives to be effective and government actions can have a significant effect on organizational decisions to adopt SPW and SPP. Examples of this include establishing energy consumption standards and regulations as well as offering financial incentives for the adoption of renewable energy sources. It highlights that every driver except RRD is found to have a positive impact on the SPP. An external driver named IMD emerges as a significant force and employing SPP is considered a strategic move that will give FMCG manufacturing organizations an advantage over their competitors in addition to being in line with social and environmental concerns.

The research has revealed that the Firm Size amplifies the positive association between the RRD > SPT and between IMD > SPW. In the context of transportation, organizations where the number of employees is less than 100 have more influence from rules and regulations than organizations with more than 100 employees. As organizations where the number of employees is less than 100 are growing rapidly, IMD influences the SPW. As medium-scale organizations are growing rapidly, industry and market factors influence the

implementation of sustainable practices. Therefore, medium-scale organizations can gain a competitive advantage by implementing sustainable practices in warehousing. Table 2 shows the summary of the moderation effect of Firm Size.

Table 2: Summary of the Moderation Effect

	Scale 1		Scale 2		MGA
	t-value	p-value	t-value	p-value	2-tailed p-value
OMD - > SPT	8.121	0	9.286	0	0.12
IMD - > SPT	5.568	0	2.614	0.009	0.942
RRD - > SPT	6.887	0	0.836	0.403	
ED -> SPT	6.924	0	2.652	0.008	0.174
SD -> SPT	5.511	0	6.712	0	0.096
OMD - > SPW	4.199	0	1.99	0.047	0.584
IMD - > SPW	8.054	0	1.78	0.075	
RRD - > SPW	1.584	0.113	0.901	0.368	0.622
ED -> SPW	6.546	0	4.159	0	0.963
SD -> SPW	2.663	0.008	2.554	0.011	0.858
OMD - > SPP	3.166	0.002	6.084	0	0.302
IMD - > SPP	7.49	0	4.396	0	0.576
RRD - > SPP	3.486	0	0.822	0.411	
ED -> SPP	7.101	0	5.31	0	0.947
SD -> SPP	5.185	0	7.697	0	0.488

5 CONCLUSION

This research provides a comprehensive understanding of the drivers affecting the implementation of sustainable practices. Further, the study recommended there should be strict rules and regulations for the successful implementation of sustainable practices. Moreover, product types can be measured as a moderating variable by future researchers to examine how differences in the kind of goods handled affect the adoption of sustainable logistics practices. Nevertheless, this study focused on sustainable practices in transportation, warehousing, and packaging. Future research can examine the relationship between drivers and sustainable practices in procurement, reverse logistics, and manufacturing in a different context or a similar context.

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Analysis of Working Postures of Workers in the Apparel Industry Using the Ovako Working Posture Analysis Score: A Case Study

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ABSTRACT

The challenging demands of the apparel sector require employees to perform repetitive tasks for longer periods. The adoption of unhealthy, awkward postures by the employees for prolonged periods causes discomfort, fatigue, and even musculoskeletal disorders. This study was conducted to analyze the working postures of the employees in the apparel sector, identify the risks and effects of different postures on employee wellbeing, and provide recommendations to avoid these effects. A prominent textile factory in Sri Lanka, was selected for the study. The study adopted stratified sampling method to select employees from five departments of the company; raw material store, sample room, cutting department, production floor and finishing department. Three to five photographs of each employee were taken in their working environment on a random basis and photographs that failed to reflect the working postures were omitted from the analysis and arrived at a sample of 202 employees. An observational method of risk assessment was used to calculate an ergonomic score: Ovako Working Posture Analysis System score. A number of employees across risk levels was tabulated for each department as the input for the percentage component bar graphs. The study found that the majority of the employees had a low to middle-range level of ergonomic risk.

KEYWORDS: Ergonomic Interventions, Observational Risk Assessment, Ovako Working Posture Analysis System Score

1 INTRODUCTION

The global economy is contributed significantly by the apparel industry. This industry produces diverse garment products to cater various consumer demands. To ensure timely delivery to the market, many employees contribute their labor, often engaging in repetitive tasks. The demanding nature of these tasks requires employees to frequently compromise their well-being by adopting convenient but potentially unhealthy postures. The apparel industry includes different functions including cutting, sewing, and finishing. More attention needs to be paid on the ergonomic condition of these functions owing to the high number of employees working in these areas. The unhealthy postures

adopted by these employees lead to discomfort, fatigue, and eventually the risk of musculoskeletal disorders (MSDs).

This case study delved into the intricate world of the apparel industry in Sri Lanka, the most significant and dynamic contributor to Sri Lanka's economy (EDB Sri Lanka, n.d.). It aimed to shed light on the ergonomics of working postures, addressing the crucial question of how to enhance the well-being of workers while optimizing production. This study seeks to address the problem of inadequate understanding and mitigation of ergonomic issues within the apparel industry, with a focus on working postures and their impact on worker well-being.

2 LITERATURE REVIEW

2.1 Ergonomics

Ergonomics is defined as an applied science which concerns designing and arranging equipment so that people and things interact most efficiently, and safely” (Karwowski et al., 2021). The competition among firms and increased consumption levels of the global population forced companies to streamline their production procedures. This resulted in increased workloads, repetitive tasks, and awkward postures thereby increasing the risk of work-related Musculoskeletal Disorders (MSDs) (Sakthi Nagaraj et al., 2019). Zare et al.(2015) state that in addition to worker health and safety improvement, ergonomics directly affects product quality by reducing the risk of error and defect rate, improving worker focus and satisfaction.

2.2 Occupational health and safety issues in apparel industry

A number of occupational health and safety standards have been created for the textile sector by the International Labour Organization (ILO). ILO Recommendation for Textile, Clothing, Leather and Footwear industry (ILO , 2022) provides specific guidance on the management of occupational health and safety in the textile industry, whereas ILO Convention No. 155 (ILO Convention C155 - Occupational Safety and Health Convention, 1981.) mandates that countries develop and implement national policies, programs, and systems to prevent occupational accidents and diseases and to promote occupational health and safety. While the clothing sector is generally perceived as a safe working environment where there is a

less chance of heavy damage accidents, it is a sector where injuries do not arise from immediate accidents, but rather as a result of adverse effects of working conditions, observed as MSDs (Isler et al., 2018). A case study conducted by Erdinc & Vayvay (2008) revealed that awkward postures adopted by workers and difficulty in handling and monitoring the machines lead to musculoskeletal discomfort in workers such as back pain and neck pain. In addition to these factors, Delleman & Dul (2002) made a significant discovery that there was a significant relationship between the workers' perceptions of the ergonomic design of their workstations and their working postures. According to the study's subsequent findings, people who believed their workstations to be less ergonomic were more likely to choose uncomfortable working positions, which raised their chance of developing MSDs.

2.3 Ergonomic Interventions in the Textile and Apparel Industry

Ergonomics can help to improve productivity, quality, and worker health and safety in the apparel industry (Abeysekera & Illankoon, 2016). Erdinc & Vayvay (2008) have suggested ergonomic training programs, workstation adjustments and machine tilting as effective ergonomic interventions to reduce the risk of MSDs. However the effectiveness of these interventions are usually constrained by poor planning, implementation and evaluation (Koningsveld et al., 2005). The authors further suggest a model in implementing ergonomics in work place based on three principles; a participatory approach, a multidisciplinary approach and a continuous improvement approach. Isler et al. (2018) stated that ergonomic

education given to employees should not be constricted about how to use the body and tools ergonomically, but also should further extend on how to rest the muscles correctly after their work shifts in order to make the ergonomic interventions effective.

2.4 Observation methods of Ergonomic Practices

In assessing the ergonomic risks associated with the working habits of employees, analysis of postures plays a major role. As stated by Kee (2022) the observational techniques are inexpensive, easy to use, flexible, and do not interfere with workers' tasks or the jobs being performed while evaluating the working postures. Kee (2022) in his attempt to compare Ovako Working Posture Analysis Score (OWAS), Rapid Upper Limb Assessment (RULA) and Rapid Entire Body Assessment (REBA) scoring methods has found that while RULA is the most frequently used method to assess postural risks, it is also the scoring method whose risk levels were more significantly associated with MSDs than with that by the OWAS and REBA scoring method.

3 METHODOLOGY

The study used OWAS ergonomic scoring method to assess the postural

risks of the employees in the sample. The level of risk associated with the specific postures were decided using the operative classes defined by (Karhu et al., 1977) for OWAS score.

3.1 Participants (Population and Sample)

Company A, the subject of the case study consisted of nine departments. Working postures of employees from five departments; raw material storage, sample room, cutting department, sewing floor and the finishing department were collected.

The population of the study was the total number of employees from the selected five departments of Company A, which accounted for 795 employees. The total sample size calculated at a confidence level of 95% was 260 observations, as per the Morgan table. A stratified sampling method was used to select the sample and strata were the departments in the factory.

3.2 Data Collection

Photographs of the employees in each selected department in their natural working environment were taken using a Galaxy M11 smartphone. The employees for photographs were selected on a random basis to fill the required strata. Three to five photographs were taken from each employee and the photographs

Table 1. Risk scores of OWAS method
(Source: Author Compile)

Department	Risk Level				Total
	1	2	3	4	
Cutting	24	11	0	0	35
Production	51	62	0	0	113
Raw Material Store	7	2	0	0	9
Finishing	24	12	0	0	36
Sample Room	2	7	0	0	9
Total	108	94	0	0	202

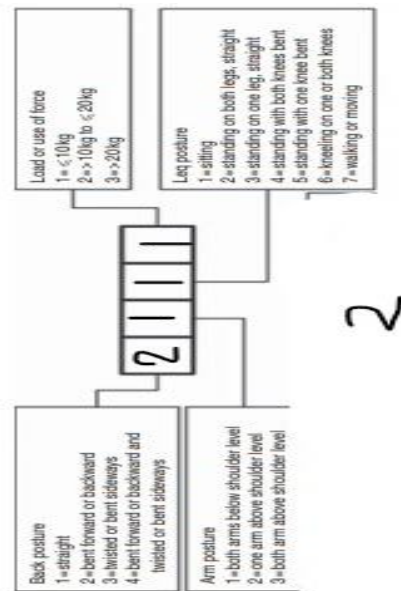


Figure 1: OWAS Score worksheet
(Source: Author Compile)

that failed to reflect the working postures were omitted from the analysis. The remaining photographs of 202 employees were coded and categorized based on their departments.

3.3 Data Processing

The ergonomic score was calculated manually to derive an ergonomic risk score for the individuals in the sample. The score was calculated using a simple worksheet (Figure 1) and arrived at a final risk score. The risk level that corresponded for the calculated risk score for each employee was decided using the OWAS risk assessment table (Karhu et al., 1977).

Number of employees across risk levels, determined by the OWAS score, was tabulated for each department in an Excel spreadsheet (Table 1).

4 RESULTS AND DISCUSSION

A comparison of postural risks of employees from each department in reference to the OWAS score is in figure 2. The percentage component bar graph showed how the percentage of employees

belonging to each risk level contributed to the total as a whole across all five departments.

Employees from these five departments were classified into the least two risk levels defined by the OWAS score system, suggesting that the overall MSD risks faced by the employees could be considered low. The majority of the employees from the Cutting department, Raw material storage and Finishing department belonged to risk level 1, which the OWAS score defined as a normal posture and required no ergonomic interventions. The results from the production floor and the sample room showed a deviation, where the majority of the employees were categorized into the risk level 2, which indicated low postural stress exerted on individuals and need of ergonomic arrangements in near future.

ANALYSIS OF WORKING POSTURES OF WORKERS IN THE APPAREL INDUSTRY USING THE OVAKO WORKING POSTURE ANALYSIS SCORE: A CASE STUDY



Figure 2: Share of risk levels on tasks and postural risk indexes from OWAS score. (Source: Author Compile)

5 CONCLUSION

The scores reflected the high stress exerted on arm and back muscles caused by flexed back postures, extended arm and shoulder postures of the sewing machine operators for prolonged periods. The findings of the study suggested that although the overall ergonomic risks faced by the employees from the five selected departments were low, some level off ergonomic interventions were needed, specially in the production floor and the sample room. The majority of employees from these two departments were sewing machine operators. It could be deduced that the arched back and neck potures along with extended arm and leg postures adopted by these sewing machine operators caused ergonomic risks. Ergonomically designed workstations that could be easily adjusted based on the employee height, regular training and awareness sessions on using correct work postures were sugested to mitigate the ergonomic risks prevailing in the selected company.

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Assessing the Current State of Solid Waste Management at a Sails Cable Manufacturing Company in Sri Lanka

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ABSTRACT

The manufacturing of sail cables involves high precision and detail, leading to increased waste generation and environmental challenges. The purpose of this study was to determine the forms of solid waste generated by a composite rigging component manufacturing company in Sri Lanka and to identify the most significant solid waste types, utilizing factory site observations and secondary data. A study identifies titanium as the most significant solid waste type, followed by cotton and carbon rod waste. Further, the study used a cause-and-effect diagram and a five why analysis for the most significant solid waste type identified. The findings suggest that recycling is a more effective approach to handling solid waste in the manufacturing sector than landfills or burning. Collaborating with environmentally sustainable companies like SIS can reduce landfill waste and promote sustainable waste management strategies. Recycling titanium offers benefits like reduced energy consumption and emissions.

KEYWORDS: Manufacturing Firm, Solid Waste, Solid Waste Dispose, Titanium

1 INTRODUCTION

The manufacturing of sail cables involves high precision and attention to detail, requiring labor-intensive manual operations and frequent design adjustments. The industry has seasonal demand, leading to increased waste generation and environmental challenges. The company specializes in creating goods tailored to specific customer orders, prompting the need for sustainable waste management practices. Materials used in sail cable manufacturing are chosen to withstand sea conditions, including high-strength alloys, stainless steel, and corrosion-resistant materials. Recycling cables is primarily motivated by the value of conducting metal, while plastic is sometimes overlooked. The production process involves several stages, including job IDing, metal components, carbon rod

pulling, and final inspection. Other operations include carbon rod manufacturing, taco manufacturing, and cone molding.

The company has three main production lines: multi-strand carbon rigging, synthetic yarn rigging, and metallic parts. Each line requires separate production planning, with two main stages: non-buildable and buildable. The non-buildable stage involves communication with customers and standard lead-time procedures. The buildable design plan is executed after incorporating the non-buildable plan. Even with the availability of planning stages, the company encounters frequent design changes from their customers. Some of these design change requests are received in the middle of the production process. If the changes do not match with the ongoing process, the whole working

process must be removed and needs to start from the beginning. These frequent design changes from customers lead to increase waste and negatively impact manufacturing productivity.

The objective of this research is to identify types of solid wastes generated and causes of the most significant waste types. Thereby provide recommendations to the company on solid waste management activities.

2 LITERATURE REVIEW

2.1 Waste

Manufacturing business are referred to any businesses creates things that fulfill a need or desire by combining completed goods with raw materials (Carol & Florah, 2019). The fast industrialization and urbanization that have accompanied the exponential expansion in the human population have resulted in massive waste creation. Due to the increase of customer demands, manufacturing companies must supply their orders without thinking about proper waste management ways to the solid waste collected in factories. Further, the generation of solid waste is closely linked to soil, water, and air pollution. Lack of space to collect the waste is other major problem. The fundamental components of waste sector (such as trash generation and insufficient mechanism for garbage collection, transport, treatment, and disposal) are linked to the major issues of solid waste management. The main idea of a sustainable solid waste management program is to replace traditional garbage dumps, which are expensive and harmful to the environment, with effective waste management system that keep valuable resources inside the economy.

Waste is defined differently by many academics and industry experts. Waste was defined by Formoso, Isatto, Soibelman, & Cesare (2002) as any losses resulting from actions that cause direct or indirect costs but do not improve the product from the customers' perspective. Waste can be termed as unwanted, excess, unproductive, unused, junk, refuse. Koskela (1992) further explains that waste as the occurrence of material losses as well as the completion of unnecessary work, both of which result in increased expenditures but do not improve the product.

2.2 Types of Waste

The forms of waste could be solid, liquid, and gas. Further, there are seven categories of waste in lean manufacturing as overproducing, waiting, transporting, over processing, excess inventory, excess motion, and defects (Jackson, 2012). These seven can be classified into three main interrelated categories in no order, they are waste in raw materials, human and time.

When more products are created than can be sold, excess waste from overproduction results, leaving finished goods inventories sitting around. Causes can be happened are volume incentives (sales, pay, purchasing), high-capacity equipment, line imbalance or poor shifting and cost accounting practices that encourage buildup of inventory. (Domingo, 2015).

When additional work is completed on a product or customer order, it constitutes waste. Sometimes the goal is to please the customer, yet the labor is done anyhow because it is not compensated. Time, money, and human

resources are all being wasted. This occurs when more work is done on a process than is necessary. This also includes using components that are more complex or expensive than absolutely required (Warner, Christie, Jackson, & Vengosh, 2013).

Waiting time waste occurs when resources, such as people and equipment, must wait unnecessarily because other resources, such as information, are delayed in arriving or becoming available. Causes can be happened are, line imbalances, inflexible work force, material shortage or delay and manpower shortage or delay (Domingo, 2015).

Transportation waste happens due to unnecessary material movement and unnecessary tools or equipment movement. Waste produced by shifting things from one place to another mainly with equipment movement. Waste produced by shifting things from one place to another mainly with people and inventory stuff. Transport waste is created whenever anything is moved or transported needlessly from one place to another, including individuals, items, supplies, tools, documents, or materials. (Domingo, 2015).

This Muda refers to the raw materials, work-in-progress, or finished goods that are dispersed across the warehouse and shop floor. The ability to guarantee the continuity of the manufacturing process, even if the production is discontinuous or defined by many product kinds, it made possible by the presence of minimal inventory. However, the time spent keeping goods and parts in storage does not contribute any value and instead incurs costs (for lightning, handling, immobilization, and

air conditioning of the space) and damage risk (Domingo, 2015).

Motion waste occurs when bodily motions are made during a task are not necessary and examples include sifting among objects, bending over, reaching, walking, and lifting. This type of muda is committed by employees as they rummage through a messy or unorganized workspace in search of tools or documents. Motion waste frequently causes workflow disruptions and delays the start of work (Domingo, 2015).

Defects means processing due to the production of defects or processing due to rework or repair of defects or materials used due to defect and rework. Due to unclear customer specifications, incapable processes, lack of process control, and unskilled personnel, defects can occur. Continuous quality improvement and preventive measures are the most effective means to cut defect waste (Domingo, 2015).

3 METHODOLOGY

Primary and secondary data were collected in this study. They were both qualitative and quantitative. Secondary data were collected from the Environmental Health and Safety (EHS) department covering the period from March to August 2023. Primary data were collected through observations at the waste collection spots and interviews with key personnel involved in waste management, including EHS engineers in the company, and production staff which provided insights into operation practices, challenges, and potential solutions. This research was intended to find the most significant waste types in terms of cost. Once the significant waste

types were identified, cause and effect diagrams were drawn based on the data collected through observations and interviews. Appropriate solid waste management practices were identified based on the interview responses and considering available options in the industry.

4 RESULTS

According to the observation, plastic, polythene, cardboard, cotton, carbon rod, and Titanium were identified as the solid wastes generated in the company. To determine the most significant solid waste types, it is necessary to consider the monetary value of these solid wastes. For that purpose, tabulate the cost of dispose of each solid waste in the company during this period. Table 1 shows the dispose cost of each solid waste type.

Titanium is the most significant solid waste type, followed by cotton waste and carbon rod waste. Cotton waste is formed due to protective clothing and lack of recycling techniques. Titanium waste and Carbon Rod waste was the major concern as those have higher disposal cost and

Table 1: Dispose cost for solid waste per month in LKR

Solid waste type	Monthly disposal cost in LKR per kg
Cardboard	15,262,500
Carbon rod	102,043,220
Polythene	6,250,000
Titanium	439,560,000
Plastic	106,610,085
Cotton waste	140,056,000

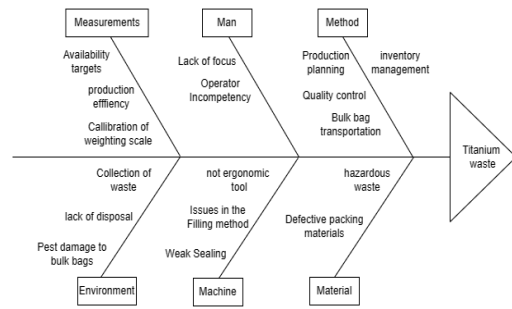


Figure 1: Cause and Effect Diagram for Titanium Waste

directly involve with cable production process.

Fig 1 and fig 2 shows the cause-and-effect diagram and five-why analysis diagram for identified most significant solid waste (Titanium waste). Cause-and-effect diagram for the Titanium waste was drawn to find the causes of the of the identified significant solid waste type generated in the company.

Titanium waste can be processed into value-added products through industrial processing. Sustainable solid waste management prioritizes reducing waste dumps and utilizing usable resources. Seasonal product manufacturing enterprises must practice proper waste management to minimize environmental impacts, comply with legal obligations, and improve production processes.

Questions	Answers
1)Why is titanium used in manufacturing?	Due to high production demand.
2)Why do titanium wastes happen under high production demand?	After cutting titanium bars according to relevant shapes, there will be a huge waste.
3)Why is left-over titanium not recyclable or re-usable?	Due to the unavailability of burning furnaces.
4)Why is titanium waste cannot be disposed of?	Titanium is a hazardous metal waste.
5)Why is it difficult to dispose of hazardous titanium waste?	Due to the high cost of disposal.

Figure 2: Five Why Analysis for Titanium Waste

The study suggests that titanium waste can be value-added by collaborating with environmentally sustainable companies like SIS, thereby reducing landfill waste and promoting a more sustainable waste management strategy. Manufacturing industries face challenges in initial solid waste management steps like quantity and characterization, necessitating urgent efforts to integrate all components of waste management.

Recycling titanium offers numerous benefits, including reduced energy consumption, fewer emissions, and reduced waste. It reduces waste accumulation and landfill space. Purified titanium is used in plate production, while recycling promotes environmental protection and resource efficiency. Metal recycling is increasingly important due to public demand for resource conservation and environmental protection.

5 CONCLUSION

This research study identifies solid waste types within a company, focusing on titanium metal waste. The study aims to reduce environmental impact, comply with regulations, and optimize resource usage. Titanium metal waste disposal is crucial due to infrastructure limitations and economic benefits. The company reclaimed and reused titanium waste for prosthetic items. Secondary data was collected on recycling rates, disposal methods, and costs.

The study suggests value addition for handling manufacturing industry solid waste, reducing costs and promoting sustainability. Titanium metal waste

disposal is crucial due to infrastructure limitations and economic benefits.

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Corporate Social Responsibility Influence on Environmental Performance in The Sri Lankan Rubber Manufacturing Industry

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ABSTRACT

The concept of Corporate Social Responsibility (CSR) has become an integral aspect of present business operations and is driven by the growing awareness of environmental concerns and the need for sustainable practices. Moreover, understanding environmental performance and CSR initiatives in the manufacturing industry is important as it is associated with the intensive use of resources. Also, the rubber manufacturing industry has a diverse impact on the environment. Therefore, the objective of this research was to study the impact of Corporate Social Responsibility on Environmental Performance, identify categories of CSR, and how they were prioritized by the organizations. The methodological choice was quantitative. Thus, data were collected in a 7-point Likert scale. The unit of analysis was an employee at the executive level or above as selected. The sample size was 364 and was completed from the responses of employees in the top listed companies of the Sri Lankan rubber manufacturing industry. Moreover, the snowball technique was used to distribute the questionnaire among the employees. Descriptive statistics, correlation matrix, and regression analysis were used in the data analysis. Accordingly, results showed a significant influence of CSR on environmental performance. Moreover, CSR projects could be categorized into four types; CSR to environment, CSR to consumer, CSR to employee, and CSR to community. Amongst, CSR to consumer was the major category of CSR that companies prioritized in the rubber manufacturing industry of Sri Lanka.

KEYWORDS: Corporate Social Responsibility (CSR), Environmental Performance, Rubber Manufacturing Industry

1 INTRODUCTION

The concept of Corporate Social Responsibility (CSR) has become an integral aspect of present business operations and is driven by the growing awareness of environmental concerns and the need for sustainable practices (Aguilera et al., 2007). Usually, most of the manufacturing industries are associated with intensive use of resources and the high rate of material usage which has a critical impact on the environment (Smith, 2012). Sri Lankan manufacturing industry consists of food manufacturing, beverages, textile manufacturing, rubber manufacturing, chemical manufacturing, and other manufacturing (Department of Census and Statistics, 2022). The Sri

Lankan rubber industry is one of the major players in the global market hence; it has made a significant contribution to the country's economy (Ministry of Industries, 2023). Furthermore, Sri Lanka generated about 900 million dollars in 2022 from rubber exports. According to forecasts of industry experts, this value will be increased by 3 billion by 2025 (The Daily FT, 2023). The rubber industry uses high composition of natural resources and operates in an ecologically sensitive environment. Thus, understanding the impact of CSR on its environmental performance is important for researchers, academicians, industrial practitioners, and environmental policy makers. Accordingly, this study aimed to

investigate the impact of CSR activities on the environmental performance of the rubber manufacturing industry.

2 LITERATURE REVIEW

2.1 Corporate Social Responsibility

CSR and environmental performance have been gaining an increasing attention in today's business world (Chandler, 2017). According to the United Nations Industrial Development Organization (UNIDO), CSR is a management concept that companies integrate social and environmental concerns in their business operations and interactions with their stakeholders. Accordingly, the researchers have categorized these CSR activities into four types: CSR to environment, CSR to employees, CSR to community, and CSR to consumer (Farooq et al., 2014). Moreover, environmental CSR activities are very attractive among the most of the companies in today's business world (Cochran, 2007). Every organization needs the support from the community to perform their business operations and survive in the market (Farooq et al., 2014). Employees are the internal stakeholders in an organization hence; a crucial factor for effectiveness of business operations and achieving organizational goals and objectives (Suganthi, 2019). Consumers are among the most important external stakeholders of an organization because the success of organizations depends on the satisfaction of their consumers (Turker, 2008).

2.2 Environmental Performance

Environment is mostly concerned in today's world causing the rapidly changing climate and other natural

disasters. Enhancing environmental performance is the best option for organizations to gain competitive advantage (Teece et al, 2003).

2.3 Rubber Industry of Sri Lanka

According to the Fair Rubber Association, CSR and environmental sustainability are crucial factors in the rubber industry. This organization represents the importance of contributing to an improvement of the working and living standards of the employees in rubber and promoting environmentally friendly rubber production (Kunz, 2021). According to the Sri Lankan context, almost all of the organizations in the rubber industry consider the importance of CSR practices and environmental performance of the organization. Most importantly, top ranked companies in the rubber industry of Sri Lanka have focused on CSR and environmental friendly projects to achieve the benefits of Fair Rubber Association membership and license.

3 METHODOLOGY

A questionnaire was developed using surveys validated by previous researchers (Rehman et al., 2022; Shahzad et al., 2020) and was distributed among the prospective respondents through emails to collect data.

Accordingly, the below mentioned hypotheses were developed and tested in this study.

H₁ - CSR to environment has an influence on Environmental Performance

H₂ - CSR to employees has an influence on Environmental Performance

H₃ - CSR to community has an influence on Environmental Performance

H₄ - CSR to consumers has an influence on Environmental Performance

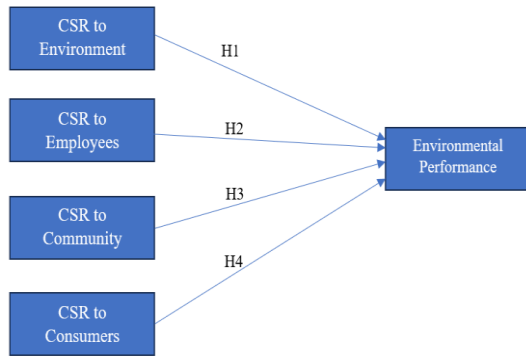


Figure 1 : Research Model

The Annual Survey of Industries stated 125 establishments of Rubber products manufacturing (Department of Census and Statistics, 2022). 34,822 persons engaged in these establishments in the Rubber Industry of Sri Lanka. Number of working proprietors and other employees (excluding operatives) was 6,664. The unit of analysis was an employee at the executive level or above. Therefore, the population size was 6,664. This study used simple random sampling technique. Accordingly, the sample size was selected to be 364 (Krejcie & Morgan, 1970) under 95% confidence level and the margin of error was 5%. The sample size was completed from the responses of employees in the top companies of the rubber manufacturing industry (Ministry of Industries, 2023).

4 DATA ANALYSIS

The Cronbach's Alpha test was used to assess the internal consistency and reliability of the variables of a research (Pallant, 2020). Cronbach's Alpha value of all variables is 0.948

and the significance was 0.000. As Cronbach's Alpha was greater than 0.9 with significant value of $P < 0.005$, the internal consistency was excellent and this research tool was reliable (Pallant, 2020). Therefore, this research tool would give credible results.

Furthermore, Cronbach's Alpha values for CSR and environmental performance are 0.903 and 0.864 with the significance 0.000. Therefore, all the constructs were reliable for the research and showed internal consistency. Correlation analysis was used to describe the strength and direction of the linear relationship between two variables (Pallant, 2020).

The correlation between the Environmental Performance and CSR to the Community was significant at 0.01 with a Pearson correlation coefficient value of 0.578. Therefore, it showed a strong positive relationship between the Environmental Performance and CSR to the Community. The correlation between the Environmental Performance and CSR to the Environment was significant at 0.01 with a Pearson correlation coefficient of 0.572. Therefore, it showed a strong positive relationship between the Environmental Performance and CSR to the Environment. The correlation between the Environmental Performance and CSR to Consumers was significant at 0.01 with a Pearson correlation coefficient of 0.579. Thus, it showed a strong positive relationship between the Environmental Performance and CSR to Consumer. The correlation between the Environmental Performance and CSR to Employee was significant at 0.01 with a Pearson correlation coefficient of 0.664. Therefore, it showed a strong positive relationship between Environmental

Performance and CSR to Employees. Then, Regression analysis was conducted. Accordingly, B values indicated how one unit of the independent variable increased when; there was an increase or decrease in the dependent variable. Moreover, the + or – sign showed that if there was an increase or decrease. For standard Beta values, significant value P must be $P < 0.05$.

Table 1: Effect of CSR on Environmental Performance

Model	B	Significance
(Constant)	0.825	0.001
CSR to Community	0.114	0.017
CSR to Environment	0.047	0.378
CSR to Consumer	0.165	0.000
CSR to Employee	0.205	0.000

There were positive effects between CSR to Community, CSR to Consumer and CSR to Employee on Environmental Performance when the significance < 0.05 . CSR to the environment showed less effect on Environmental Performance and $P > 0.05$. Therefore, it was concluded that the variable was not making a significant unique contribution to the prediction of the dependent variable.

Table 2: Effect of CSR on Environmental Performance

Model	B	Sig.
(Constant)	0.987	0.000
CSR	0.841	0.000

Thus, in summary, CSR showed a positive effect on Environmental Performance.

5 RESULTS AND DISCUSSION

This research aimed to examine the relationship between CSR and Environmental Performance in rubber manufacturing industry of Sri Lanka. According to previous researchers in Pakistan, CSR showed an influence on Environmental Performance (Channa et al., 2021). The results obtained from this study also concluded that CSR had an influence on Environmental Performance in the rubber manufacturing industry of Sri Lanka. Conversely, a study was conducted for the construction and manufacturing industry in Malaysia and identified that CSR had no direct influence on Environmental Performance (Rehman et al., 2022). The reason for the difference between those results might be the difference in the countries where those studies were conducted.

6 CONCLUSION

The results of the analysis were justified that CSR to employees, CSR to community, and CSR to consumer showed a positive significant impact on environmental performance. In the context of the rubber industry, CSR and environmental performance were crucial factors. Most importantly, CSR activities focusing on the employees had the most significant effect on environmental performance of the organization. Therefore, the study concluded that employees were a critical factor in improving the environmental performance of an organization.

The present study only focused on the rubber manufacturing industry. Thus, future studies should be focused on the overall manufacturing industry to see the difference in the results. Furthermore, this study was conducted only for the top 10 rubber manufacturing companies in Sri Lanka. Therefore, further studies should be conducted for other companies to see the difference of the outcomes.

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Empirical Study on Agile Adoption of Fast-Moving Consumer Goods Industry

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ABSTRACT

This study investigates the adoption of Agile Project Management (APM) methodologies in the Fast-Moving Consumer Goods (FMCG) industry. The Fast-Moving Consumer Goods sector, which is confronting problems such as digital transformation and changing consumer preferences, stands to benefit from APM practices. The significance of this study reclines in its potential to provide a fundamental perspective for these companies, enabling them to enhance their project management practices and adapt to a rapidly evolving market. During the study authors have reviewed the relevant literature and identified the six most appropriate factors which drive the adoption of APM methodologies by project teams in Fast-Moving Consumer Goods firms; maintaining backlogs, running sprints, encouraging a cross-functional teams, conducting stand-up meetings, establishing information radiators, and retrospectives. This study adopts a quantitative approach, employing Partial Least Squares (PLS) path modeling analysis techniques to assess hypotheses derived from the collected data. The unit of analysis encompasses a project team within Fast-Moving Consumer Goods firm, facilitating a targeted investigation into APM methodology adoption. Overall, the research findings and insights can inspire and shape the direction of future research endeavors in the agile project management field, promoting a deeper understanding and advancement of this area of study.

KEYWORDS: Agile Practices, Agile Project Management, Consumer Goods Industry, Fast-Moving Consumer Goods

1 INTRODUCTION

Although there is no established definition, the term "Fast-Moving Consumer Goods" describes goods that are relatively inexpensive, frequently bought and fast consumed items on which buyers exert only minimal purchasing effort (Leahy, 2011). It is one of the highest revenue generation industries, encountering massive challenges including the rise of e-commerce, digital transformation, and the change in consumer preferences towards more personalization and individualization tendencies (Nguyen, 2019). The APM methodologies could be a potential remedy for Fast-Moving Consumer Goods firms in order to

flexibly cater for consumer needs and sustain in the market in the long run (Kartiko et al., 2022), (Miller, 2019), (Udokporoa, et al., 2020).

The adoption of APM methodologies among Fast-Moving Consumer Goods firms remains rarely explored in previous research endeavors. Despite a growing awareness of the potential benefits associated with adopting APM methodologies, project teams within Fast-Moving Consumer Goods firms lack crucial insights into the specific factors that facilitate successful adoption.

Table 1: Agile practices

Agile Practice	Description	Reference
Maintaining backlogs	Backlogs serve as dynamic and prioritized lists of requirements which capture the essence of what the end users expect to receive.	(Nguyen, 2019; Viscadi, 2013)
Running sprints	A sprint defined as a quick microproject that lasts only a few days or weeks and consists of a specified set of backlog activities.	(Baird & Riggins, 2012; Sharma et al., 2012)
Cross functional teams	By bringing together experts from different functional areas and it foster a collaborative environment where diverse perspectives are considered from the start	(Cooper & Sommer, 2016; Zayat & Senvar, 2020)
Information radiators	Information radiators are visual displays used in APM to offer stakeholders with present updates on the project's status, progress, and performance indicators	(Bosch et al., 2013; Whitworth & Biddle, 2007)
Stand-up meetings	In the short meeting, each team member shares their accomplishments since the last meeting, their planned objectives for the upcoming period.	(Nguyen, 2019; So & Scholl, 2009)
Retrospectives	Retrospectives are dedicated meeting at the end of each iteration or project milestone to reflect on their work.	(Cooper & Sommer, 2016; Nguyen, 2019)

2 LITERATURE REVIEW

In order to gain an inclusive understanding of the possible factors contributing to the successful adoption of APM methodologies in Sri Lankan Fast-Moving Consumer Goods firms, the literature review was conducted.

Agile project management has gained immense popularity in the software industry due to its ability to adapt into rapidly changing requirements and deliver incremental value to customers. It emphasizes close customer involvement throughout the development process, enabling continuous feedback and ensuring that the final product meets the evolving needs of the end-users (Agbejule & Lehtineva, 2022), (Pinton & Torres, 2020), (Zakrzewska & Jarosz, 2022). If these practices could be

implemented in Fast-Moving Consumer Goods firms, there is a higher chance of increasing the adoption of agile methodologies (Chathuranga et al., 2023).

During the article review process, the authors identified six major agile practices that have been adopted by the software industry. Theoretical perspective of these practices, along with the sources for each practice, discussed in Table 1. Based on above literature findings, the following conceptual framework has been constructed as shown in Figure 1.

3 METHODOLOGY

This study adopts a quantitative approach as the collected data will be analyzed using Partial Least Squares (PLS) path modeling analysis techniques

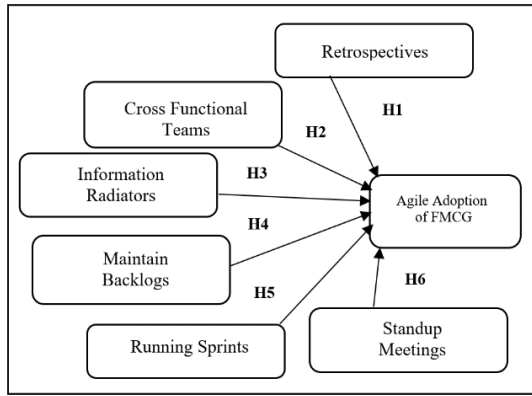


Figure 1: Conceptual Framework

to test hypotheses. The population of the study is the total project teams of Fast-Moving Consumer Goods firms in Sri Lanka. Based on annual report statistics (2020-2023) of leading Fast-Moving Consumer Goods firms, most of them have a 1500+ employee population. Therefore, it was challenging to collect responses from the entire population, so the authors decided to determine a minimum sample size according to recommendations on Cohen table (sample size 137, significance level 5%). As data collection is conducted only once, this study is conducted as a (one-shot) cross-sectional study.

The primary data collection relied on a structured questionnaire administered to the selected sample, utilizing a survey questionnaire approach for quantitative data collection. It was distributed using

Table 2: Demographic analysis

Measure	Item	Percent age%
Age	21-30	68.70%
	31-40	10.40%
	41-50	11.90%
	51-60	9%
Gender	Male	55.20%
	Female	44.80%
Work Experience	Less than 2 years	58.20%
	2-5 years	17.90%
	6-10 years	4.50%
	More than 10 years	19.40%

online platforms such as email and social media platforms (LinkedIn, WhatsApp) to respondents.

3.1 Analysis of Demographics

Demographic characteristics such as age, gender, and work experience were considered to gain a comprehensive understanding of the study's participants. Table 2 shows the demographic representation of the sample chosen (N = 174).

3.2 Analysis using PLS SEM Software

The proposed conceptual model in Figure 1, was used to empirically analyze the data using the partial least squares structural equation modeling (PLS-SEM) technique, and SmartPLS version 4

Table 3: Hypotheses

Hypotheses	
H1	Conducting Retrospectives (IV) enables the adoption of APM by project teams in Fast-Moving Consumer Goods firms (DV).
H2	Encouraging cross functional teams (IV) enables the adoption of APM by project teams in Fast-Moving Consumer Goods firms (DV).
H3	Establishing Information Radiators (IV) enables the adoption of APM by project teams in Fast-Moving Consumer Goods firms (DV).
H4	Maintaining Backlogs (IV) enables the adoption of APM by project teams in Fast-Moving Consumer Goods firms (DV).
H5	Running Sprints (IV) enables the adoption of APM by project teams in Fast-Moving Consumer Goods firms (DV).
H6	Implementing stand-up meetings (IV) enables the adoption of APM by project teams Fast-Moving Consumer Goods firms (DV).

Table 4: Measurement model results

Construct	Cronbach's alpha	Comp. reliability	AVE value	HTMT
RunSprint	0.81	0.886	0.72	0.849
CrossFuncTeams	0.471	0.675	0.48	0.692
StanUpMeet	0.607	0.786	0.558	0.747
MainBackLog	0.764	0.861	0.676	0.821
InfRad	0.802	0.852	0.587	0.771
ConRetro	0.945	0.96	0.857	0.926
AgileAdopt	0.742	0.843	0.656	0.802

Table 5: Outcomes of structural model analysis

Path	Path coeff.	95% CI	T-value	P value	Hypo thesis	Supported?
ConRetro -> AgileAdopt	0.087	[-0.072, 0.215]	1.195	0.232	H1	No
CrossFuncTeams -> AgileAdopt	0.196	[0.071, 0.327]	2.818	0.005	H2	Yes
InfRad -> AgileAdopt	-0.042	[-0.17, 0.136]	0.525	0.6	H3	No
MainBackLog -> AgileAdopt	0.288	[0.157, 0.413]	4.415	0	H4	Yes
RunSprint -> AgileAdopt	0.198	[0.055, 0.336]	2.718	0.007	H5	Yes
StanUpMeet -> AgileAdopt	0.095	[-0.026, 0.23]	1.456	0.146	H6	No

software. The structural model was examined by testing the hypothesized relationships. Moreover, the bootstrapping method was used on 5000 subsamples to assess the significance and path coefficients, as suggested by (Hair et al., 2012).

When considering the collective model there are three variables which do not meet the satisfactory P values (<0.005). Therefore, authors have conducted individual analysis for respective relationships in H1, H3, H6 in order to test those relationships without any dependencies from other variables. During those independent analyses each path received satisfactory p values which were significant to accept H1, H3 and H6. Resulted values: ConRetro -> AgileAdopt p-value 0, InfRad -> AgileAdopt p-value 0.001 and StanUpMeet -> AgileAdopt p-value 0.

4 RESULTS AND DISCUSSION

During the assessment of measurement model authors conducted to establish that the indicator measurements are satisfactory in terms of internal consistency reliability, convergent validity, and discriminant validity. By looking at the measurement model (Table 4) resulted Cronbach's alpha values for each construct is above 0.5, composite reliability values and AVE values also above 0.5, where authors could be satisfied with each construct tested. The HTMT ratio values of each construct are the highest for each of them which implies the identified constructs can be authors could be satisfied with each construct tested.

The assessment results of the structural model captured the structural validity of hypotheses constructed, which was evaluated using the test components included in Table 5. During the data analysis state there were three indicators used in measuring variable reliability.

The direct relationship between running sprint variables and agile adoption is significant enough with 0.198 coefficient value and 0.007 p value ($p < 0.05$). This implies that running sprints enables the agile adoption in Fast-Moving Consumer Goods industry.

Authors were able to prove that the maintaining backlogs enables agile adoption with enough statistical proof because the direct relationship between maintaining backlogs variable is significant enough with 0.288 coefficient value and 0.00 p value ($p < 0.05$). According to the data analysis conducted it implied there is a significant relationship between cross functional teams and agile adoption. Statistics show 0.196 co-efficient value and 0.005 p value ($p < 0.05$) where it accepts the hypothesis made based on literature.

When measuring the structural model collectively, the rest of three variables were not significant due the impact of other variables. But during the individual structural model analysis each variable got accepted with sufficient significance.

Overall, authors' data supports all the hypotheses in the base model (H1 to H6). R-Square value is 0.242 which basically means that the proportion of the variance in agile adoption of Fast-Moving Consumer Goods industry that can be explained by above six factors that simply highlights 25% of variance or exploratory power can be explained by those six agile practices on the agile adoption of Fast-Moving Consumer Goods industry. As mentioned above in the collective structural model running sprints, maintaining backlogs and cross functional meetings are the important variables which got accepted with the

impact of the rest of variables. Therefore, running sprints, maintaining backlogs and cross functional meetings are very important practices when considering agile adoption of the Fast-Moving Consumer Goods industry.

5 CONCLUSION

In conclusion, the study recommends targeted workshops and virtual training to address low awareness of APM in Fast-Moving Consumer Goods context and emphasizes Agile as a transformative mindset for successful implementation. The integration of digital Agile tools such as Jira, Microsoft Project is advised for streamlined project management and improved communication. Despite acknowledging limitations like limited geographic focus and data constraints, the research offers actionable insights, identifying six key Agile practices crucial for agile adoption. Also, the study may not directly consider the variations in organizational structures, sizes, or cultures of different Fast-Moving Consumer Goods firms in Sri Lanka.

Additionally, considering the dynamic nature of the industry, ongoing research and adaptation of agile methodologies will be essential for Fast-Moving Consumer Goods companies to stay competitive and agile in the evolving marketplace. Finally these recommendations serve as a practical guide for Fast-Moving Consumer Goods organizations, enhancing innovation and responsiveness in agile project management.

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Factors Affecting Effective Usage of ERP Systems and Moderation Implications of Business Environment: A Study on Sri Lankan Banking Sector

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ABSTRACT

The implementing process causes challenges due to industry-specific business processes in banks and ERP post-implementation failures cause for the waste of resources consumed for initial implementation success. The critical factor contributing to post-implementation failure lies in the suboptimal utilization of the Enterprise Resource Planning (ERP) system, which can have significant repercussions. Due to a lack of prior work on the post-implementation stage of ERP and no study was conducted on the moderation effect of industry competition and technological advancement, this study aimed to find the factors affecting effective ERP usage and how industry competition and technological advancement moderate the association. A survey-based questionnaire was distributed and collected data from the end users who have experienced using ERP systems to perform their jobs in the banking sector. IBM SPSS software was used for primary data analysis and hypotheses were tested using the Partial Least Squares Structural Equation Modeling (PLS-SEM) approach since this is suitable for evaluating most complex models. As the finding, all the independent variables named top management support (TPM), user training in the post-implementation stage (UTP), continuous support from vendors (CSV), and the complexity of the ERP system (CPM) were the factors affecting effective ERP usage (EFU). Considering the moderating effect of industry competition and technological advancement, it implied a significant positive moderating impact between top management support and effective ERP usage.

KEYWORDS: ERP Post Implementation, ERP Usage, Moderating Effect, Success Factors

1 INTRODUCTION

ERP systems in banking streamline information exchange, improving coordination and response to risks (Rajan & Baral, 2015). Challenges in implementation arise from outdated systems hindering data migration and user adaptability (Metaxiotis & Liagkouras, 2017). Adapting ERP systems to evolving business needs, especially post-implementation, is crucial (Alkhaffaf et al., 2018). This research aims to find factors influencing ERP utilization in Sri Lankan banking, considering how industry competition and technological advancements

influence the relation between those identified factors and effective ERP usage. Investigating the key factors for the effective use of an ERP System is therefore critical to achieving adequate value from the ERP. As a result, the researcher hopes to provide an overview of ERP systems usage in the banking sector and giving the recommendation to enhance ERP usage in banking sector.

2 LITERATURE REVIEW

2.1 Enterprise Resource Planning System

The ERP system is a software system designed to manage and aggregate data to

support multiple operational units or duties (AlMuhayfith & Shaiti, 2020). They also provide real time, accurate information across multiple areas of the organization, allowing managers to respond quickly to market changes and identify growth opportunities (Beleț & Purcărea, 2017).

2.2 ERP Implementation in the Banking Sector

ERP systems help to continuously grow and promote competitiveness. It has the ability to assist the seamless operation of global banks, assuring compliance through standardized systems encompassing all banking functions (Alkhaffaf et al., 2018). ERP implementation decisions in banks are influenced by different factors such as benefits, cost, infrastructure, leadership orientation, strategic planning.

3 METHODOLOGY

Figure 1 shows the independent, dependent, and moderating variables included in the study. Based on the

developed conceptual framework, hypotheses were developed.

3.1 Hypothesis for Direct Association

H1: Greater TMS in the post-implementation stage has a positive impact on EFU. (Dezdar & Ainin, 2011). H2: Providing extensive UTP has a positive impact on EFU (Salih et al., 2022). H3: CSV in the post-implementation stage has a positive impact on EFU(Tongsuksai et al., 2021) . H4: Less CPM has a positive impact on EFU (Kotadia, 2020). H5: High industry competition amplifies the positive association between (a) TMS, (b) UTP, (c) CSV, (d) less CPM , and EFU. H6: Dynamic technology advancement amplifies the positive association between (a) TMS (b) UTP, (c) CSV, (d) less CPM, and EFU. Since noting a gap in existing literature, planned to employ PLS-SEM for a qualitative analysis without being constrained by established theories (Almahamid, 2019). The population included all ERP users in the

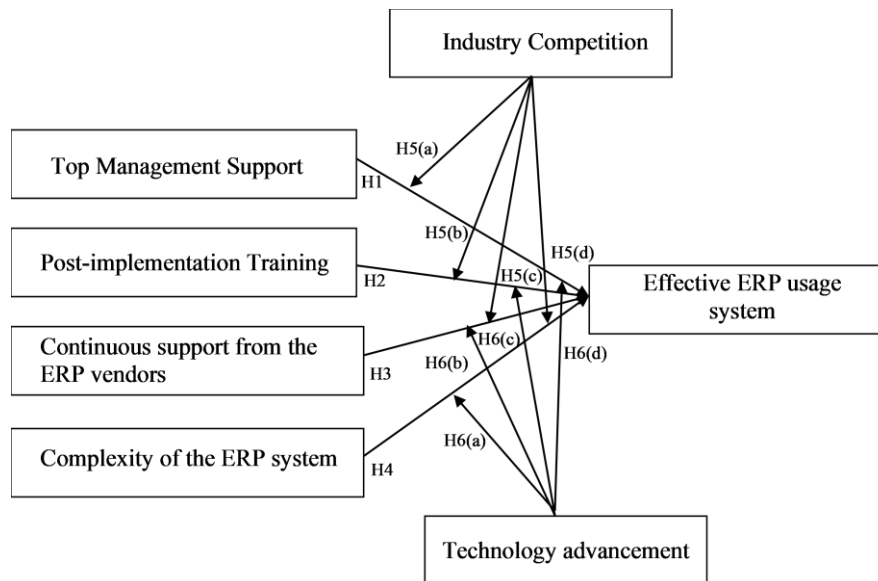


Figure 1: Conceptual Framework for the Study

banking sector organizations. As the sampling technique, a combination of snowball sampling and convenience sampling was used since many researchers used them often (Sedgwick, 2013). The study used a minimum sample size by (Cohen,1992) of 130 samples to achieve a statistical power of 80% for detecting an R2 value of 0.1 with a 5% probability error. Preliminary data analysis was conducted using SPSS software to identify outliers and normality. Despite the nonparametric PLS-SEM method's nonparametric nature, it was suitable for assessing the study.

4 RESULTS AND DISCUSSION

4.1 Assessing the Measurement Model

In this study, the chosen measurement specification aligns with both reflective and formative approaches, as the measurement model was inspected for both formative and reflective variables. Industry competition and technological advancement were measured categorically. The study confirmed the internal consistency and reliability of constructs since Cronbach's alpha values were falling between 0.5 and 0.9. Factor loadings exceeding 0.6 demonstrated high convergent validity, aligning with the literature. Additionally, nearly all indicators exhibited greater loadings than their cross-loadings, which supported for discriminant validity (Hair et al., 2011).

The evaluation of convergent validity, collinearity, and the significance and relevance of the formative indicators was conducted and here in this study, formative constructs showed path coefficients for convergent validity

above 0.7, suggesting robust convergent validity (Hair et al., 2016). Additionally, all indicators exhibited VIF values below 5, indicating no significant collinearity issues, enhancing model reliability. Indicator weight significance, determined by t-values exceeding thresholds, indicated the relevance of all indicators in the study (Hair et al.,2022).

4.2 Assessing Structural Model

As shown in Table 1, path coefficients, confidence intervals, t-values, and p-values were utilized to evaluate the direct impact, revealing that all hypotheses demonstrated a significant positive relationship. The results indicated significant relationships (P values < 0.05 and 0.01) between independent variables (TMS, UTP, CSV, CPM) and the dependent variable (effective ERP usage), with positive path coefficients (0.143, 0.668, 0.383, 0.310) indicating a positive correlation between these variables.

Table 1: Direct Effect of Variable

Rel atio n	TMP- >EFU	UTP- >EFU	CSV- >EFU	CMP- >EFU
Pat h Coe ffi ci ent	0.143	0.668	0.383	0.310
T Stat istic	2.352	16.951	4.818	4.368
P Val ue	0.019	0.000	0.000	0.000
95 % CI	0.275, 0.267	0.604, 0.758	0.224, 0.533	0.187, 0.466

4.3 Assessing Moderation Effect

The study categorized responses based on high/low industry competition (IC) and technology advancement (TA) levels. Path coefficients and p-values were then analyzed (Refer Table 2 & Table 3). Multi-group analysis revealed industry competition impacted the positive association between TPM and EFU, while technology advancement affected the same association. However, industry competition and technology advancement didn't impact the positive association between UTP, CSV, CMP, and EFU, and neither did technology advancement. TMS was crucial for fostering a positive organizational culture in competitive environments with high technological advancements. UTP was highlighted as essential for equipping employees with the skills needed for efficient ERP utilization. CSV was essential for ongoing assistance, updates, and troubleshooting. Balancing CMP with user-friendly interfaces and minimal customization was essential. (Chou et al., 2014; Egdair et al., 2015; Hasan et al., 2019).

Table 2: Summary of Moderating Effect of Industry Competition

	High IC		LOW IC		MGA
	t-val	p-val	t-val	p-val	2tailed p-value
TMS -> EFU	15.744	0.000	1.304	0.192	-
UTP -> EFU	16.283	0.000	11.022	0.000	0.981
CSV -> EFU	22.283	0.000	6.810	0.000	0.784
CMP -> EFU	13.606	0.000	2.545	0.110	0.849

5 CONCLUSION

The research emphasized the importance of top management support in effective ERP usage, emphasizing the need for clear communication, employee participation, and a reward system. It recommended comprehensive training programs for banking professionals and collaboration with ERP vendors for timely issue resolution. Further, Striking a balance between customization and standardized processes was key. The study acknowledged limitations related to its specific context in the Sri Lankan banking sector, cautioning against generalizing findings to other regions. The author suggests future research should explore more moderators impacting ERP system usage in the banking sector to gain deeper insights.

Table 3: Summary of Moderating Effect of Technology Advancement

	High TA		LOW TA		MGA
	t-val	p-val	t-val	p-val	2tailed p-value
TMS -> EFU	2.39	0.017	0.735	0.452	-
UTP -> EFU	14.069	0.000	15.533	0.000	0.755
CSV -> EFU	3.016	0.000	2.754	0.000	0.688
CMP -> EFU	2.940	0.003	4.771	0.000	0.880

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Identification of Strategies to Mitigate Harmful Environmental Impacts from Fiberglass Boat Building Companies in Sri Lanka: A Case Study

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ABSTRACT

The disposal of fiber-reinforced polymer waste by the numerous boat-building companies varying from homebound small-scale to large entities does not seemingly have a standardized method. The present study was carried out to identify major causes for creating such waste in the production process and provide appropriate solutions to mitigate and take appropriate control over the disposal of those wastes to the environment. The study has used the real-time observation method and a questionnaire that was distributed among the managerial and non-managerial level employees of a purposively selected boat-building company to collect data for understanding the relevant causes. After analyzing the data, the study has proposed some suitable and feasible solutions to mitigate and take appropriate control over the disposal of fiber-reinforced polymer wastes to the environment. Some of those proposed solutions have already been implemented by the selected company and the other solutions are to be implemented after studying the feasibility of those.

KEYWORDS: Boat-building, Fiberglass, Waste

1 INTRODUCTION

Fiberglass boat building is a prominent and evolving industry in Sri Lanka that contributes about 5% of the gross national exports. This industry is decorated by around 70 boat-building companies in Sri Lanka where most of them operate as home yard companies without proper standardization of framework of operations in their objectives. As the word suggests – fiberglass this industry involves a plastic-like component that has durable and long-lasting properties. This makes as the ideal cause for vessel production that is used in sea and waterways traveling due to its light weight and makes it more appropriate for that purpose. However, naturally, the fiberglass takes about 50 years to decompose and at present the irresponsible operations by the respective boat manufacturers make this concern much more serious (Job, 2014). Moreover, it was

identified through the industry survey that there is a significant release of fiberglass waste into the environment from fiberglass boat-building companies. This waste most commonly ends up being released to the environment without any justification in the process and often no rationale is kept. Built around all these matters, however, there is subtle environmental impact it caused due to inevitable concern about the non-decomposing nature of the fiberglass.

Accordingly present study was built around identifying these matters within the framework of fiberglass boat-building companies in Sri Lanka by direct observation of relevant concerns and implementation of possible and feasible solutions to take control and reduce the harmful environmental impact that is created by those companies through their production processes.

2 LITERATURE REVIEW

First and foremost, unlike any other industry, the waste that is generated in the fiberglass boat-building industry is non-degradable. The main constituent in this industry is glass-reinforced polymer which is also commonly known as Glass Reinforced Polymer (GRP). According to (Sheepanannaga, 2022), Fiber reinforced polymer (FRP) composites are extensively used in the marine, automobile, military, and aircraft industries due to their high strength-to-weight ratio and corrosion resistance properties. FRP's prime application in the marine industry includes personal boats, sheathing of wood hulls, submarine sonar domes, pipelines, etc. Generally, the speed of a boat is reduced due to issues like an increase in the net weight of the boat and this happens due to the absorption of water weight into fiber composites (Dejhalla, 2018). The moisture absorption in the polymer composite materials varies according to the polymer chemistry, leading to reversible or irreversible physical, mechanical, and thermo-mechanical changes (Sheepanannaga, 2022). All these productions end up being fiberglass waste somewhere in the timeline. According to (Sheepanannaga, 2022), glass-reinforced polymer (GFRP) and Basalt fiber reinforced polymer (BFRP) composite materials are subjected to microscopic attack and rust due to prolonged exposure to seawater or harsh environments. The prolonged exposure to seawater produces stress corrosion cracking. The damage due to water absorption grows with time, affecting the material's strength, thereby failing. Some of the effects of moisture absorption of FRP include reduced

mechanical and physical properties, weakening of the fiber-matrix interface, etc. Furthermore, GRP tends to break and bend as time passes, which is a natural phenomenon of GRP. Apart from these, fishermen also tend to keep up with new trends and designs which push them to buy new boats. Due to all these concerns and matters, new and modest GRP boats are inevitably being manufactured alongside the timeline and it is creating a continuous flow of demand for fiberglass boats in the Sri Lankan market.

3 RESEARCH METHODOLOGY

The present study is categorized as an action research and it has intentionally followed an exploratory form. Furthermore, it followed an applied form in its latter case. Both primary and secondary data were collected from a purposively selected fiberglass boat-building company. Mainly two questionnaires were shared among managerial and non-managerial employees (n = 34) separately to be held accountable to confirm the identification done through direct observation by the researchers. After that suitable solutions were implemented as required by the point and nature of the identification.

4 RESULTS AND DISCUSSION

Through the responses that were received from both types of questionnaires, the following reflections were found;

- 100% of managers and 61.2% of non-managers believed that FRP is not treated well at the premises.
- 100% of managers said that the company does not have a scheduled setup to take care of the waste while

71% of non-managers also said the same.

- 100% of managers said that they have not personally faced any health impacts from exposure but 35.4% of non-managers have faced one incident.
- 60% of managers and 100% of non-managers have known that someone has faced health impacts due to exposure to FRP.
- 100% of managers and 100% of non-managers are willing to support and contribute to a system that would control issues.

4.1 Identification of Root Causes of the Problem

a. Impact of Fiberglass Cut-offs

When the mat is laid within the molding procedure and resin is poured over to wet the layup, the mat starts to expand a little creating a surface outside the mold, this is where cut-off pieces are generated. For strength purposes, it is also essential to lay up the mat as adequately as it is. Further, when different mold parts are about to be connected, then those end pieces need to be cut out with a sharp knife and end up in their course to be leftovers. None of these could be used or recycled as their properties are passed during the hardening process. These wastes are generally burnt in mild fires in homemade furnaces. The fumes created in these situations are very toxic and usually take a black color which is bringing all people around it to a huge concern.

b. Impact of Fiberglass Dust

To achieve the expected smoothness of the boat surface, it is ground using sandpaper grinders before colors are applied. Then the hardened surface is

almost close to the glass level but it produces dusty FRP formation while doing that grinding process. The fumes hold a roast smell and the particles start spreading to a wider spectrum from the place of its grinding. This particular process creates impacts on the environment and people who engage in the grinding process because the fume is dusty and it cannot be tolerated by the people for a long period and it creates breathing problems for them. Moreover, it could go and settle in the environment which disrupts the natural environment as well.

4.2 List of Alternative Solutions

As mentioned above, the observable FRP wastes are primarily generated in fiberglass cutoffs and dust formation. Hence, the alternative solutions for mitigating or controlling those wastes are suggested as follows;

a. Fiberglass Cutoffs

The cutoff pieces are currently burned inside the company premises in small quantities and the harmful impact of this was discussed previously. Therefore, the possible solution for this is to send those fiberglass cutoffs either to high-temperature kilns or to be used as land-filling as an intermediate strategy to mitigate the issue. At very high-temperature levels, such as, 900⁰C, the harmful impact of fiberglass cutoffs tends to be nullified. Also, when those are used for land-filling purposes, over a designated period, the FRP pieces shall be decomposed with the soil. However, that might indeed take a very long period.

b. Fiberglass Dust - on Technicians

The technicians of the boat building process vigorously have to work with bare faces. Hence, as a solution to this problem, the researchers were able to

introduce a body cover and high-capacity face mask to reduce their exposure of fiberglass dust. However, employing a fully automatic mechanized method for the grinding process without human involvement would be the best solution for eliminating this negative impact on the people.

c. Fiberglass Dust - on the Environment

The dust that is generated from the grinding process could be controlled by its impact on the external environment by means of using a water curtain in the grinding bay. Although this solution was implemented by the researchers in several occasions, it failed within the context of the industry and it cannot be sustained for a long period.

4.3 Comparative Analysis and Feasibility Study of Alternative Solutions

a. Fiberglass Cut-offs

I. Cause – The essential laying of Chopped Stranded Mat - CSM that leaves extra pieces of hardened fiberglass pieces. That will have to be cut off and then smoothed.

II. Possible Solutions – Since the creation of extra pieces is inevitable, the solutions will be described accordingly to take responsibility for the cutoff parts. The solutions could either be to deliver them to nearby landfilling spaces or to burn them at high-temperature levels in the kilns.

III. Feasibility – The three aspects of feasibility could be analyzed as follows;

(i) Technical Feasibility – The technical side of the aforementioned two solutions would be identical as packaging the leftovers and delivering those would require a similar effort from the in-house employees.

(ii) Operational Feasibility – The operational aspect of burning the fiberglass cutoffs through kilns is slightly overworked as it is required to send those to the kilns which are located away from the company (around 100 km away from the place of operation).

(iii) Economic Feasibility – The option of burning the fiberglass cutoffs through kilns is not economically feasible as it requires following a lengthy process to be sent over to very far away locations which costs much to the company. Hence, the landfilling option could be easily adopted as it is much more convenient and less costly.

b. FRP Dust on Technicians

I. Cause – Due to Grinding of uneven fiberglass strands and edges.

II. Possible Solutions – There are two aspects of solutions using full body covering up for technicians and using an automated grinding process where no human involvement is used.

III. Feasibility – The three aspects of feasibility could be analyzed as follows;

(i) Technical Feasibility – The automation process might involve an impeccable level of expertise and complexity. Hence, the full body covering up for technicians could be done quite conveniently.

(ii) Operational Feasibility – There could be notable challenges in automating a system to operate as it is not something that employees are familiar with. If so, more training would have to be done for them. Hence the next option of full body covering-up, the technicians might take a little time to get used to it by covering their bodies and faces rather than being bare of.

(iii) Economic Feasibility - The investment in a fully automated grinding process could be very high and almost

impossible. Introducing body covers and high-capacity masks for technicians could easily be done with a low-cost investment.

c. FRP Dust on the Environment

I. Cause – This is due to the grinding of uneven FRP strands and edges.

II. Possible Solutions – There is only one identifiable solution to control the exposure of dust to the environment which is using the water curtains around the grinding bay and controlling dust limited to that area.

III. Feasibility - The three aspects of feasibility could be analyzed as follows;

(i) Technical Feasibility – There would not be any technical challenges except for the setup of the apparatus which needs a considerable time duration.

(ii) Operational Feasibility – The operations of the normal flow will not be affected by any course in this venture.

(iii) Economic Feasibility – The amount of investments could be considerably large and setup cost could be high. Also, it is notable that it would take a longer period to set up the apparatus.

4.4 Selection of the Best Feasible Solution and Rationale

a. Concern about the fiberglass cutoffs

After considering the feasibility of the identified possible options, it is evident that delivering the waste to a faraway location might involve a significant amount of cost to be incurred. The wastage that could be sent out for land-filling purposes could be convenient and the result could be identical. Therefore, the best solution would be to use the cutoffs for land-filling purposes as only about 5 - 7 Kilograms are produced per boat and the maximum amount of production at the premises would limit

the wastage to around 25 Kilograms per month.

b. Concern about FRP Dust on Technicians

Going alongside the feasibility in the previous section, it is clearly understood that the automation procedure cannot be implemented conveniently, and technical, operational as well as economic feasibility is limited therein. Therefore, the most feasible option is to use body covers and marks for the technicians.

c. Concern about FRP Dust on the Environment

The impact of dust on the external environment could only be controlled by covering the grinding premises. As per the studies, using water curtains on the grinding bay would be the ideal solution although economically infeasible and might take a longer time to set up.

5 CONCLUSION

When it was achieving the objective of the present study, the investigation was based only on one company. Hence, the inability to access other companies to assess the impact of FRP wastes on the natural environment was the main limitation of this study. Moreover, the gap in the relevant literature was very high both in Sri Lankan and global contexts. The primary data collection had to be limited only to the in-house employees and the literacy of some of the participants was very poor and limited. Therefore the question items had to be designed in a much simpler form. The versatility of questions was reduced drastically thereby. The identified problems of the fiberglass boat building process of the selected company were addressed and feasible solutions. Some of those solutions were attempted and

employed within the company premises. However, some proposed solutions would take a longer time to set up and involve a considerable amount of investment. After implementing those proposed solutions, the results could be measured quantitatively by the future researchers of this study context.

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Impact of Community Attitude on Sustainability of Tourism Industry: A Case Study in Sri Lanka

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ABSTRACT

Tourism-induced changes in a country can influence the local community attitudes towards the industry, thus, impacting on its sustainability in the country. The tourism industry in Sri Lanka is undergoing a new phase after the COVID pandemic and also Sri Lanka is one of the countries in the world which is experiencing rapid growth in tourist arrivals. Reviewed literature showed that tourism-induced changes impact on living conditions, local culture, religious norms, health, and environmental pollution as some of the key variables are influencing the attitude of the local host communities towards the tourism industry. Thus, it is affecting the sustainability of the tourism industry in the country. This case study investigates the impact of community attitude on the sustainability of tourism industry in Sri Lanka. 53 no. of individuals in and around Negombo which is a popular beach destination in Sri Lanka was selected randomly as interviewees to collect data. The industry survey results showed that among the most dominant tourism-induced changes identified, the local host community's perception on the living standard had a significant positive impact on the sustainability of tourism. Furthermore, although the majority of local communities were worried about the potential health risks and cultural threats, they had a positive attitude towards the tourism-induced changes for their living conditions. However, some of the interviewees expressed their concerns about the tourism sustainability, but they were confident that with the proper intervention of the authorities, the industry could flourish in the country.

KEYWORDS: Attitudes, Host Community, Tourism

1 INTRODUCTION

Tourism development should be sustainable and balanced, taking into account of the needs and interests of visitors, the industry, the environment, and local communities (Gursoy et al., 2011). The tourism sector encompasses a diverse range of activities and stakeholders, such as, accommodation providers, food and beverage outlets, transport operators, vehicle rental companies, sports and recreation facilities, travel agencies, conference organizers, and even the local community who may have direct or indirect contact with tourists and the sector. All these stakeholders, who have

different roles and responsibilities in delivering tourism services and products to tourists, face various challenges and opportunities arising from tourism development, such as, increased income, employment, infrastructure, cultural exchange, environmental degradation, social disruption, congestion, inflation, and competition (Biyiri, 2018). These tourism-induced changes influence their attitudes towards the industry.

Although there are many case studies in the international context for exploring the relationship between the attitudes and sustainability of the tourism industry, in Sri Lankan context such are limited. Accordingly, as it is depicted in Figure 1, present study aimed at

investigating the impact of community attitude on tourism-induced changes, thereby to see how it affects the sustainability of the tourism industry in Sri Lankan context.

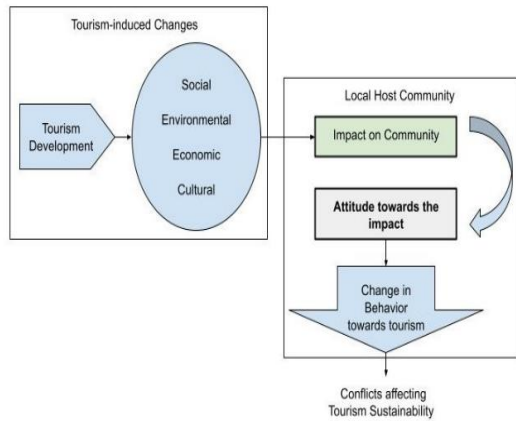


Figure 1: Conceptual Framework

2 LITERATURE REVIEW

2.1 *Tourism-induced changes and impact of those on the attitude of local host communities*

The impact of tourism-induced changes on the attitude of local communities is becoming an increasing concern to the policy makers of the country. The economic, environmental, infrastructural, and socio-cultural impacts of tourism are taken into consideration to help different stakeholders make informed decisions about tourism development and management, however, its effect on tourists needs to be evaluated on a separate scale.

Some of the positive impacts of economic change are job creation, income, and improving living standards (Pizam, 2010). However, economic dependency where the local economy depends only on tourism-related activities could create a situation where

local communities of the host country are exposed to economic fluctuations and external shocks that affect tourism demand (Duncan & Fyall, 2013). Therefore, the dependency on tourism can be a risk factor for sustainable development of that country as well. Moreover, the environmental impacts of tourism are also significant as those contribute to greenhouse emissions, especially from transportation, depletion of water resources, pollution, deforestation, soil erosion, and loss of biodiversity (Gursoy et al., 2011). But many other scholars have argued that tourism should be more sustainable and eco-friendlier and advised tourism authorities to take action on the matter (Gursoy & McCleary, 2004). Accordingly, the researchers of the present study believe that tourism should be developed in a sustainable and responsible way that balances both the needs of visitors and hosts while preserving the cultural heritage for future generations.

2.2 *Local host community's attitude toward tourists and tourism development*

Many recent studies of local host communities' attitudes on tourism offer a comprehensive overview of the theories and approaches that are used in this field. They have focused on the attitudes and perceptions of the local community towards tourism development and its impacts (Gossling et al., 2020; Wassler et al., 2019). However, many scholars have not adequately explored the root causes and influences behind the development of these attitudes. Furthermore, they have not considered how these attitudes and perceptions are reflected in their service delivery and interaction with tourists.

Ramkissoon et al. (2013) have revealed a correlation between the attitudes of local host communities toward tourism development and their perceptions of tourism induced changes. Positive perceptions led to positive attitudes, while negative perceptions led to negative attitudes. However, local residents do accept certain negative tourism development-induced changes as a tradeoff for the economic benefits received (Lei et al., 2023). They have stated how local host communities might become skeptical if they do not perceive positive social changes emerging from tourism development.

Moreover, the attitudes of local communities toward tourism can vary and change over time. Factors such as, natural disasters, economic crises, or negative tourist incidents can affect how local communities perceive tourism (Zhang et al., 2014; Gursoy et al., 2011; Lei et al., 2023). These studies explain that both tourists and local communities have complex and dynamic responses to tourism-related issues, depending on their prior knowledge, experience, and expectations. The researchers of present study also have understood the need and importance of regularly assessing the attitudes of local host communities toward tourism in order to ensure the sustainability of the industry.

2.3 Impact of attitude of local host communities on the satisfaction of tourists

Tourists' satisfaction is directly related to attitudes of local host communities toward the tourism industry (Tasci et al., 2007) and when people focus on their own attitudes, they have a

tendency to act on them (Dolnicar & Leisch, 2008). This could be clearly shown through the relationship between host community attitudes and their behavior as a result of it. Tasci et al. (2017) also have stated that the attitude of the host community is influenced by their perceptions of tourism's impact on the local community. Kim & Han (2010) further confirmed this finding by suggesting that if the tourism industry was to improve the attitudes of host communities, they need to first address their concerns about the tourism-induced changes in the community. Thus, leading to higher tourist satisfaction levels and ensuring sustainability of the industry.

3 RESEARCH METHODOLOGY

3.1 Research Design

The study aimed at investigating the attitude of local communities of the host country, Sri Lanka towards the tourism industry as a result of tourism-induced changes and its impact on the industry sustainability.

3.2 Research Model

Through the reviewed literature, it was found that the studies have explored similar problems and those were used extensively to establish the link between the attitudes of local host communities, tourism-induced changes, and sustainability along the framework outlined in Figure 1. This was used by present study to conceptualize the constructs for developing the industry survey.

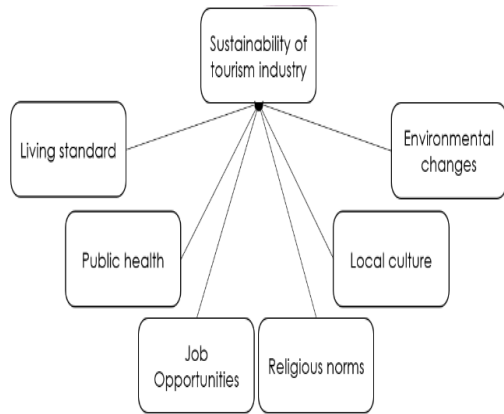


Figure 7: Research Model

3.3 Sample

The responses of 53 no. of individuals were selected purposively from the local community in Negombo area to collect data for the analysis. Negombo was selected as it is one of the attractive tourist destinations in the country due to the availability of golden beaches and close proximity to the international airport of the country.

4 RESULTS AND DISCUSSION

4.1 Demographic Characteristics of the Respondents

The majority of the survey respondents presented a persona of a young, educated, and unmarried, Buddhist guy about 30 years of age born into a 05-member family and now earning a salary of around Rs. 150,000 by working in the tourism industry.

4.2 Statistical Results

The results in Table 1 showed that the standard deviation of all variables was low which indicates that the data points have clustered around the mean. This implies a high level of consistency and reliability in the data which was desirable for this research purpose. After performing the stepwise regression analysis, the results that were shown as in the Table 1 revealed that only living standard was found as statistically significant at 0.05 level.

Table 7: Results of Regression Analysis

Community Perceptions	Coefficient	Std. Deviation	T-value	Sig.
(Constant)	0.850	0.240	3.55	0.001
Living Standard	0.257	0.104	2.48	0.017
Religious Norms	0.183	0.109	1.68	0.100
Job Opportunities	0.85	0.130	0.66	0.514
Public health	0.089	0.131	0.68	0.500
Environment change	0.001	0.130	0.00	0.997
Local culture	-0.096	0.125	1.42	0.161

4.3 Descriptive Analysis

As the final phase of the survey, respondents were asked two optional questions. For the question of “State any problem that you have seen in the tourism industry in Sri Lanka, or any such you think might happen in the future”, 32 respondents, of which many highlighted issues with the government, tourist facilities, health concerns, and etc. Figure 3 show the keyword tag in the issues highlighted by the respondents.

Question two asked for any suggestions on how to improve tourism sustainability while satisfying both the local community and tourists. 25 respondents provided very valuable suggestions, among which some of the key suggestions were to promote rural areas and innovation within such, provide better transport facilities with the intervention of the private and



Figure 8: Answers for Optional Question 1



Figure 9: Answers for Optional Question 2

government institutes, migrate towards higher paying tourists, provide low-cost access to historical and religious sites, more public awareness, etc.

5 CONCLUSION

Based on the results that were shown in Table 1, the local community’s perception on the living standard had a significant positive impact on the sustainability of tourism. Hence it could be concluded that the tourism induced changes from the perspective of living standards of the local communities of Sri Lanka has a significant impact on the sustainability of the tourism industry of the country. According to the findings of the study, most people do have a positive attitude towards the development of the tourism industry in Sri Lanka. Even though they have concerns about the public health of the community, they are ready to shake it off in return for the benefits of tourism, such as, gaining improved living standards for them.

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Level of Reverse Logistics Implementation Practices in Electrical Equipment Manufacturing Industry: A Study in Sri Lankan Context

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ABSTRACT

Reverse Logistics refers to the backward flow of forward logistics, in which the purchased product is sent back to the manufacturer. Product returns can happen for various reasons such as defects, wrong products or being returned for repair. Reverse Logistics is not much interested among industries, because manufacturing firms should bear an additional cost for the implementation. The electrical equipment manufacturing sector has frequent reverse logistics activities compared to other sectors. This study explores the level of reverse logistics implementation practices in the electrical equipment manufacturing industry in the Sri Lankan context. The research study aims to identify the level of reverse logistics implementation and investigate major factors that may influence reverse logistics implementation. Hypothesis have been tested in three major categories Recognition and perception, Internal Factors, and External Factors. Data collection has been done using a questionnaire in which respondents have to rate factors in a five-point Likert scale. The questionnaire was distributed among 98 electrical equipment manufacturing companies and 84 responses were received. The findings of this study indicate that there is a positive correlation between the Recognition of Reverse Logistics and the Level of Reverse Logistics Implementation. The researchers recommend that awareness of the reverse logistics concept is more effective when implementing sustainable reverse logistics practices. Formulating government policies on reverse logistics activities would improve the implementation of the reverse logistics activities.

KEYWORDS: Electrical Equipment Manufacturing Industry, Product Returns, Reverse Logistics

1 INTRODUCTION

Reverse logistics (RL) refers to the backward process of normal logistics. Product returns, source reduction, recycling, material substitution, refurbishment, repair, and remanufacturing are different activities in reverse logistics (Lai, Wu, & Wong, 2013). Reverse logistics development is relatively low compared to other industry practices. Better management of reverse logistics can be motivation to achieve the expected profit margin. Logistics can become a crucial matter in the manufacturing industry due to rising customer concerns, increasing customer awareness of competitive products, demands from business partners, and pressure on product disposal and recycling (Ho, Choy, Lam, & Wong, 2012). According to the industry viewpoint, reverse logistics is

comparatively more difficult than other practices (Mangla, Govindan, & Luthra, 2016). Several studies have been done on the difficulties related to reverse logistics implementation in different countries including China, Indonesia, Hong Kong, Malaysia, and India (Samarasinhe & Haijun, 2019). The objective of this study is to identify the major factors that may influence reverse logistics implementation in the electrical equipment manufacturing industry and the relationship among these factors on the level of reverse logistics implementation.

2 LITERATURE REVIEW

Reverse logistics can be recognized as planning, controlling, and organizing the backward flow of material (Subramanian & Subramanyam, 2012). Reverse logistics activities of electrical

and electronics products can be categorized as refurbishment, recycling, and repairing. There should be distinct duties for employees and maintaining well-manageable customer complaint handling to enhance the overall performance of the reverse logistics system. Reverse logistics is less researched than forward logistics (Pandian & Abdul-Kader, 2017). During the period after a product has been officially launched to the public, there should be better communication with customers and functional departments including the product returns handling section, and the product repairing section. It can increase the product's success. Managers have suggested some activities related to reverse logistics practices; customer field support, on-site investigations of customer problems, dedication to resolving every customer concern, and direct operating contact (Millson & Wilemon, 2006).

Businesses are responsible for the recovery or proper disposal of trash created by the items they manufacture. People's awareness of reverse logistics practices is highly affecting environmental protection and having sustainable reverse logistics practices reduces waste production (Rubio & Jiménez-Parra, 2014). Increased customer expectations, varying demand, and market rivalry are major challenges in the electrical and electronics products manufacturing sector (Pandian & Abdul-Kader, 2017). There are some challenges when implementing reverse logistics practices in manufacturing firms. Some of the challenges are no favourable system for managing the returned products, lack of awareness of the employees, lack of management support and lack of related company policies. Reverse logistics practices are complicated because there are some activities related to warehouse management. Companies are willing to take risks by doing continual audits of returned products. Technical Feasibility and transport management, recycling

programs and other related issues can happen during the reverse logistics practices (Sharma, Panda, Mahapatra, & Sahu, 2011).

The application of reverse logistics practices is not yet familiar within the industry. From an industry viewpoint, there should be additional fundraising capacities for the implementation like returned goods handling cost, employment wages, refurbishment charges, government taxes etc. (Mangla, Govindan, & Luthra, 2016). Business partners in the supply chain refer to suppliers, manufacturers, wholesalers, dealers, retailers and service providers. These factors are highly affected to the reverse logistics implementation (Ho, Choy, Lam, & Wong, 2012). Lower Government support is caused by the lower awareness and motivation of reverse logistics practices in manufacturing industries. Better legislation practices and tax policies should be introduced for sustainable reverse logistics practices (Ho, Choy, Lam, & Wong, 2012). Government promotion and regulation programs can improve the awareness of reverse logistics. Although the government supports making policies for the manufacturing sector some environmental burdens can't be able to control (Kulatunga, Jayatilaka, & Jayawickrama, 2013).

3 METHODOLOGY

The critical realism approach of the research philosophy has been used to conduct this study. To investigate the level of RL implementation, various axiological assumptions have been included; assuming minimum personal biases affected for responding, reliable actual values have been used through the questionnaire, and practical relevance has been used to responding. The deductive approach has been used to navigate theoretical assumptions to final observations. This study aims to test the hypothesis which is based on the research model in Fig 1. There are 98

electrical equipment manufacturers (Ministry of Finance, 2020) in Sri Lanka, and the questionnaire has been distributed among all the companies and 84 responses have been received. Five-point Likert scale was used to collect the qualitative responses quantitatively. In this study, quantitative data analysis methods have been used to analyze the data.

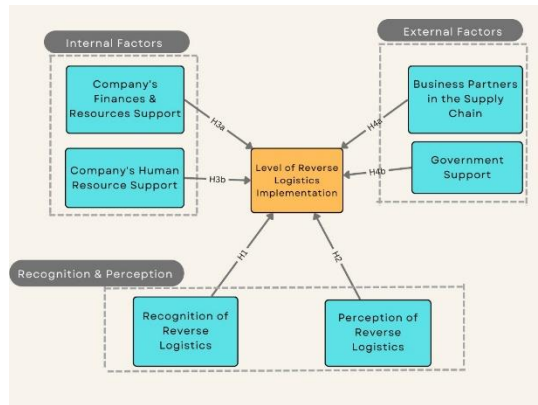


Figure 1: Research Model

H₁: The degree of recognition influences the level of implementation of reverse logistics.

H₂: The degree of perception influences the level of implementation of reverse logistics.

H₃: Internal factors affect the level of reverse logistics implementation.

H₄: External factors affect the level of reverse logistics implementation.

Previous studies suggest that recognition of the reverse logistics concept is more important when measuring RL implementation. Therefore in this study recognition of the RL concept has been taken as an independent variable. Perception of the reverse logistics concept is highly affecting the study background. Because most companies stumble to launch reverse logistics concepts due to additional cost. Some internal and external factors may affect to company's current process. In the Sri Lankan Context Government policies can have a major impact on companies externally.

4 DATA COLLECTION

The Questionnaire was expected to be responded by professionals who are working in the operational section in reverse logistics implementation. To increase the rate of response there were various follow-up techniques including sending request letters to the companies, making calls and e-mailing. The questionnaire consists of seven sections. The first two sections consist of the recognition and perception of the company. Others refer to handling and operational activities by using infrastructure and human resources. The last section refers to government action regarding reverse logistics practices.

5 DATA ANALYSIS

Eight predictor variables have been tested by using the ANOVA test. Results indicate that the P value (0.000) < 0.05 for six predictor measurements. The other two were excluded. The significance of the multiple linear regression analysis has been checked by using F statistics.

Table 1: ANOVA results

Model	Sum of square	Degree of freedom	F statistics	Significance
Regression	34.277	6	6.287	0.000
Residual	69.962	77	0.909	
Total	104.238	83		

The resulting R² value (0.329) indicates the weak positive correlation between the dependent variable and independent variables. This means the model explains 32.9% of the variance in the Level of RL implementation.

Table 2: R square value of the fitted model

R value	R square (R ²)	Adjusted R square	Standard error	Durbin Watson
0.573	0.329	0.277	0.9532	2.315

Table 3: Coefficient table

Hypothesis	Beta value	T statistic	P value	Results
Recognition of RL	0.539	4.683	0.000	Supported
Perception of RL	-0.104	-0.853	0.39	Not supported
Human resource support	0.054	0.245	0.807	Not supported
Business partners in the supply chain	-0.017	-0.141	0.888	Not supported
Government support	-0.136	-1.363	0.177	Not supported
Internal factors	0.092	0.364	0.717	Not supported

6 DISCUSSION

According to the results of the regression analysis; P value results indicate that only one independent variable aligned with the fitted model. Recognition of RL has a statistically significant relationship with the level of RL implementation. Furthermore, results have concluded that Perception of RL, Human resource support, Business partners in the supply chain, Government support, and Internal Factors have no statistically significant relationship with the level of RL implementation. Reverse Logistics practices are emerging techniques among developing countries which related to product returns handling. Considering the electrical equipment manufacturing sector, there are some frequent product returns. According to the ANOVA tables results, six predictor measurements such as Recognition of RL, Perception of RL, HR Support, Finance and resource support, Business partners in the supply chain and Internal factors have statistically significant relationships with the Level of RL implementation. Other two predictor variables (Government support and external factors) are excluded. There is no statistically significance relationship with the dependent variable according to the ANOVA results. However, previous studies suggested that government support is essential to reverse logistics implementation (Ocampo, Himang,

Kumar, & Brezocnik, 2019). The Sri Lankan government does not play an important role in the implementation of reverse logistics. Scholars suggested that instead of evaluating government support there should be an investigation of the government policies regarding the reverse logistics implementation (Ho, Choy, Lam, & Wong, 2012). Regression analysis indicates a positive correlation between the level of reverse logistics implementation and recognition of RL. The model explains that 32.9% of the variability in the dependent variable (Level of RL implementation) can be explained by the independent variables. (Recognition of RL, Perception of RL, HR Support, Finance and resource support, Business partners in the supply chain and Internal factors). The quantitative analysis of the beta values (correlation coefficients) revealed that Recognition of RL has a positive correlation with the Level of Reverse Logistics Implementation. Therefore this is aligned with the previous research which concluded the recognition of reverse logistics affects the level of RL Implementation (Ho, Choy, Lam, & Wong, 2012). Other variables are not strongly correlated with the dependent variable. Therefore, there is a contradiction with the previous references. There are some reasons to get with contradiction such as most companies have implemented logistics activities by using third-party logistics providers therefore company is not much involved in reverse logistics activities except product repairing (Ho, Choy, Lam, & Wong, 2012). Therefore, in this study results are valid with that statement. Furthermore, non-parallel results with the previous research studies can be affected due to findings aligning with the one industry perspective. This study has been done only for the electrical equipment manufacturing sector which restricts the generalization of findings over the manufacturing industry. There is a major limitation of that study. Therefore, future research should be addressed to study the Level of

Reverse Logistics Implementation in the Sri Lankan manufacturing Industry.

7 CONCLUSION

Reverse logistics is an emerging technique among nations. It is one of the optimal solutions for waste reduction in the manufacturing sector. Through the proper handling of reverse logistics activities, companies can minimize the relevant product returns cost and defect items' cost in significant amounts. This research has studied the level of reverse logistics implementation practices in the electrical equipment manufacturing industry in Sri Lanka. Findings of this study refers that there is positive correlation between the recognition of reverse logistics and the level of reverse logistics implementation. The rest of the variables have no strong relationship with the dependent variable. A major limitation of this study is that the research findings only addressed the electrical equipment manufacturing sector. Therefore, generalizing the results is not possible to apply overall product manufacturing sector. Future studies should be addressed to explore the moderating effects of reverse logistics practices.

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The Determinants of Non–Revenue Water in Central Province, Sri Lanka

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ABSTRACT

Providing safe drinking water to urban communities in developing countries is a significant challenge. Non-Revenue Water (NRW) refers to water produced but lost before it reaches users, resulting in no revenue generation. NRW is a common issue worldwide, with various causes such as illegal connections, faulty meters, disconnections, and zero bills. This study helps to the National Water Supply and Drainage Board (NWSDB) in Sri Lanka identify the causes of NRW, manage repair and maintenance, and ensure a reliable water supply system. This study aims to analyze the factors affecting NRW such as leakage, Illegal Connections, Defective Meters, Disconnections, and Zero Bills, and their relationship with NRW. According to the study, NRW percentage and leakages, defective meters, disconnections, and zero bills have a positive correlation. However, illegal connections have a negative correlation.

KEYWORDS: Disconnections, Connections, Leakages, NRW, NWSDB, Water Supply Scheme

1 INTRODUCTION

Providing safe drinking water to urban communities in developing countries is a challenging task. Non-revenue water (NRW) is water lost before it reaches users, leading to no revenue generation for the utility. NRW is a significant challenge worldwide, caused by several reasons, including leakages, burst pipes, unauthorized consumption, metering inaccuracies, poor asset management, and data inaccuracy.

In Sri Lanka, the NWSDB provides water supply to Kandy City. However, a significant amount of water is lost in the supply system, leading to a high NRW level. NRW is a major issue in Sri Lanka, especially in the central province where most water resources are located. RSC Central's water supply scheme, with over 80 resources, is supervised by engineers and technical officers. Despite this, NRW issues in surrounding areas affect water distribution to consumers.

This study aims to analyze the factors affecting NRW such as leakage, Illegal Connections, Defective Meters, Disconnections, and Zero Bills, and their relationship with NRW and conduct descriptive analysis of NRW and Stepwise Multiple Regression on independent variables like leakage, Illegal Connections, Defective Meters, Disconnections, and Zero Bills, with the dependent variable being Non-Revenue Water.

2 LITERATURE REVIEW

NRW is a major problem in Sri Lanka, especially in the central province where most water resources are located. This has significantly reduced the utility's revenue from selling treated water. (Perera and Rathnayake, 2018). NWSDB faces major losses due to NRW generation, impacting its finances. It bears over 3.5 billion rupees loss annually, including revenue and production. (Malithi., 2016).

NRW is affected by staff productivity, water consumption, average price, energy costs, and service provider size/structure. (Abdullah Murrar, Abdelrahman Tamim, Subhi Samhan, 2017). Higher costs and consumption rates can motivate utilities to reduce water loss. The higher population can also help by increasing demand for services and production costs. (Alejandro Salazar Adams, América N. LutzLey, 2012). A decrease in consumption without a reduction in leakage would increase the percentage of NRW, making it difficult to use percentages to measure water losses. (Mckenzie, Siqalaba, and Wegelin, 2012).

3 RESEARCH METHODOLOGY

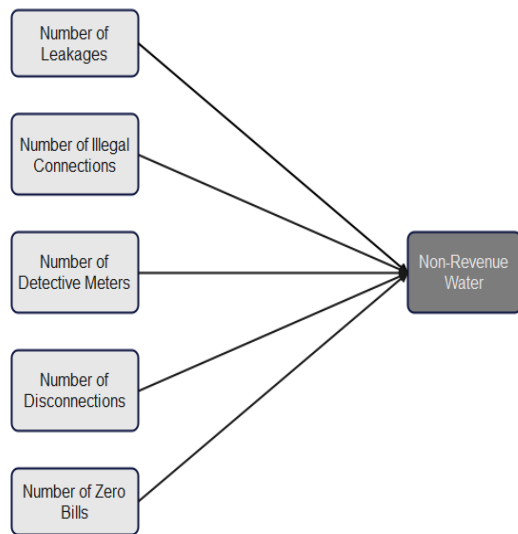


Figure 1: Methodology for Identifying the Factor Relevance of NRW

NRW is a growing issue in developing countries like Sri Lanka, including Central Province where it has reached a staggering average of 35%. This causes significant losses for the NWSDB and creates problems for those

who rely on legitimate water consumption.

The research followed a quantitative approach and used secondary data from the NRW Section. R-Software was used for data analysis, including regression analysis, correlation analysis, and descriptive statistics.

4 RESULTS AND ALTERNATIVE SOLUTIONS

4.1 Results

The Descriptive Data Analysis shows that 26.84% is the highest NRW%, while the number of illegal connections is lowest with a median value of 0. This indicates the company's success in minimizing unauthorized water connections, which could lead to revenue losses and operational challenges.

The correlation matrix shows a weak negative correlation between the NRW% and the Number of Illegal Connections, a weak positive correlation between the NRW% and the Number of Defective Meters, and a strong positive correlation between the NRW% and the Number of Leakages, Disconnections, and Zero Bills.

Based on the p-values from Multiple Linear Regression, some variables such as Intercept, Number of leakages, Number of Disconnections, and Number of Zero Bills have statistical significance at a 5% level of significance. However, the Number of Illegal Connections and the Number of Defective Meters are not significant. Therefore, step-wise regression is necessary to determine the best-fitted model.

The best model includes NRW Percentage, Disconnections, Zero Bills, Leakages, and Defective Meters with an AIC value of 499.02.

Table 1: Descriptive Data Analysis

Variable Name	Min.	Med.	Mean	Max
NRW %	4.60	27.15	26.84	39.7
No: L	706.0	1404	1451.0	4413
No: IC	0.00	0.0	0.7143	8.0
No: DM	3.00	1350	2237.0	7312
No: D	0.00	341.5	745.93	2777
No: ZB	687.0	6807	7335.0	13050

Table 2: Estimated Co-efficient of the model

	Estimate	Std Error	t value	Pr(> t)
(Intercept)	17.13944	1.49269	11.482	< 2e-16
No: L	0.00244	0.00083	2.929	0.00389
No: IC	-0.18020	0.26202	-0.688	0.49260
No: DM	0.00028	0.00022	1.317	0.18961
No: D	0.00279	0.00054	5.226	5.27e-0
No: ZB	0.00049	0.00023	2.138	0.03398

4.2 Alternative Solutions

Understanding and addressing the causes of NRW such as leakages, defective meters, disconnections, and illegal connections is crucial for efficient water management. Implementing measures like regular maintenance, infrastructure upgrades, efficient management practices, and advanced technologies for leak detection and monitoring can help create sustainable water distribution systems. This is especially important in developing countries where providing safe drinking water is a challenging task due to rapid urbanization.

5 CONCLUSION

NRW percentage and leakages, defective meters, disconnections, and zero bills have a positive correlation. However, illegal connections have a negative correlation. Leakage, caused by aged pipes and faulty piping work, is the main cause of NRW. Defective meters lead to errors in water meter readings and disconnections can cause air to filter into water connection lines, impeding water flow. As the number of disconnections rises, consumers may resort to acquiring legal or illegal connections, leading to zero bills.

6 LIMITATIONS AND FUTURE RESEARCH OPPORTUNITIES

This study has limited only to 05 variables and also to central province. Sample data limited to only fo5 years. This study can expand to whole country and increased the number of variables. Sample data should be considered more than 5 years.

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Mathematics & Mathematical Modelling



Case Study of Social Network Analysis Based on Graph Theory

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ABSTRACT

In the present world, nobody can ignore social media and social networks. Most people are using social networks to do their day today life activities. In this work, mainly focus on analyzing Facebook social network based on a real-world data set using graph theory concepts. A graph is a mathematical structure with nodes and edges. The method that we have used can apply to analyze similar types of social networks such as LinkedIn, Twitter, Instagram etc. From the graph theory concepts we can get important information about our own users and other parties of the network. The very first part of this work we have discussed about the data collection and preparing data to analysis. In the next part it is discussed analyzing data using 'Gephi' software which is used to construct the graph model and finally we have identified the important uses and their behaviors using graph theory concepts. By the analysis we can identified some important details such as who is the most influential member, who has the highest number of connections with each other, who is the most famous one in the network etc. This research mainly concerns analyzing and visualizing networks and by following these steps to build conclusions for any network using their own data and information.

KEYWORDS: Facebook Network, Graph Theory, Social Network Analysis

1 INTRODUCTION

Social media is a platform for broadcasting information whereas social networks are a platform for communicating with one another. The media sharing network is a website that enables users to store and share their multimedia files (photos, videos, music) with others. The most popular network system among people is media sharing networks which are Facebook, twitter, Instagram, LinkedIn, YouTube etc. In mathematics, networks are often referred to as graphs, and the area of mathematics concerning the study of graphs is called graph theory. A social network is hypothesized as a graph, that is, a set of vertices (or nodes) representing a person and a set of lines (or edges) representing one or more social relations among them.

Graph theory techniques and properties help to analyze and visualize the behavior of networks (Lanel, 2020).

Analyzing properties of social networks is an important area of study. A better understanding of characteristics, hidden properties, and features of a network can be used to predict the behavior of the network. Facebook is one of the most common social media platforms among people. Since all the people throughout the world are using social media platforms, it would become a complex process to dig information from those networks.

2 LITERATURE REVIEW

Analyzing graph theory properties of online social networks mainly about Facebook, LinkedIn and YouTube are a hot topic in literature. They have

identified suitable graph models for these social networks and built different graphs to represent these models. (Lanel, 2020) Extracting emergency events data from twitter and tweeter network and analyse them using neural network analysing topological characteristics of huge online social networking services such as Cyworld, MySpace, and orkut (Ahn, 2007) can be found in resent literature.

3 METHODOLOGY

First, we collected data from number of 10 students as a sample. Here our

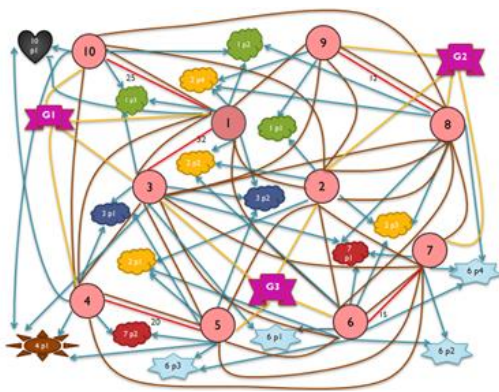


Figure 1: Activities in Facebook

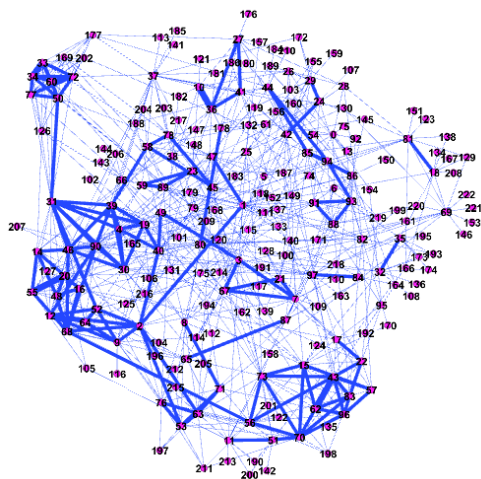


Figure 2: Facebook Friendship Graph

focus is to reduce the complexity among large data sets and see how the interaction is between each friend, their groups, creating posts and reacting to the posts, messaging etc. After collecting data, we sketched that network to get a clear idea about the relationships between each other.

According to Fig.1 this has taken three types of nodes and four types of relationships as edges. As nodes we took users, posts, and groups. As relationships we took friendship, reaction on posts, group membership and messages. The main idea of this is to show the activities on Facebook using a graph model.

To construct our Facebook network, we collected real world data set by doing survey from group of 221 university students. According to our data set we construct a network with 221 nodes and 698 edges to represent our Facebook model.

To construct the Facebook model, we used Gephi, which is an open-source software for analyzing and visualizing networks.

To analyze our Facebook network model, we basically used content which is shown in Fig. 3 under the following categories such as metric, network structure, temporal, random walks, and visualization. (Alamsyah, 2021)

4 RESULTS

Network metrics identify the most important or central character of the network. Under metric analysis we discussed homophily, density, centrality, and transitivity those are measured principal nodes in a network tends to have links to other nodes, how close the network is to complete, the most

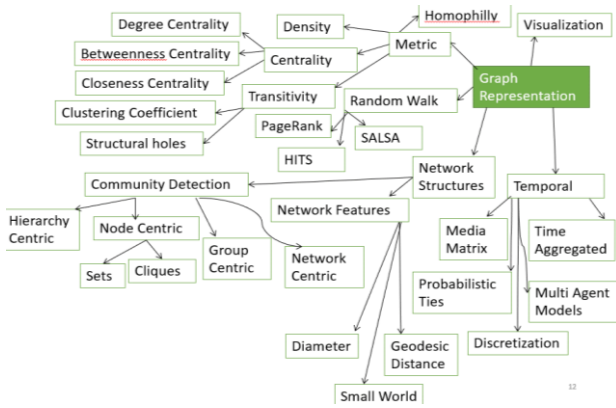


Figure 3: Social network analysis taxonomy based on graph representation (Alamsyah, 2021)

influential character of the network and tendency of the nodes to cluster together respectively.

Centrality measures the most influential and important node in the network. Centrality is divided into three parts such as degree centrality, betweenness centrality and closeness centrality. Betweenness Centrality shows the number of times a node lies on the shortest path between other nodes. If the betweenness centrality is high the meaning of that is some people represent a group of people in the network. Betweenness centrality can be calculated using the following equation where σ_{st} shows all the shortest distances from node s to t and $\sigma_{st}(v)$ shows the count of the paths that passing through node v :

$$C_B(v) = \frac{\sigma_{st}(v)}{\sigma_{st}}. \quad (1)$$

Closeness Centrality shows how close a node is to all other nodes in the entire network. If the closeness centrality is high the practical meaning of that is the connection between people in the network has a very close relation. Closeness centrality C_x can be calculated by using the following equation where

$d(v, w)$ is the measured distance between the nodes v and w . G is the set of all vertices in the graph.

$$C_x = \sum_{w \in G} \frac{1}{d(v, w)} \quad (2)$$

Transitivity is a measure of the tendency of the nodes to cluster together. If the transitivity is high, the network contains communities or groups of nodes that are densely connected internally. Clustering coefficient indicates how nodes are embedded in their neighborhood. A structural hole refers to an “empty space” between contacts in a person’s network. It means that these contacts do not interact closely.

The average path length is the average distance between any two nodes in the network. The average path length can be calculated using the following equation where $I(i, j)$ denote the length of the shortest path (or geodesic) between nodes i and j (or the distance between i and j) (Ahn, 2007)

$$\text{Average path length} = \frac{\sum_{i \geq j} I(i, j)}{n(n-1)/2} \quad (3)$$

The page rank, Hyperlink – Induced Topic Search (HITS) and Stochastic Approach for Link Structure Analysis (SALSA) discussed under random walk. The PageRank algorithm measures the importance of each node within the graph, based on the number incoming relationships and the importance of the corresponding source nodes. The PageRank algorithm assigns a numerical value to each web page based on the quantity and quality of links pointing to it

According to the theoretical definitions of HITS (Hyperlink-Induced

Topic Search) that computes two separate values for each node. The first value, called Authority, measures how valuable information is stored at the node and the second value called Hub, measures the quality of the node's links. (Chakraborty, 2018) In Modularity divide entire graph into different clusters based on neighbors of the connections. In Fig. 4 shown the modularity of the data.

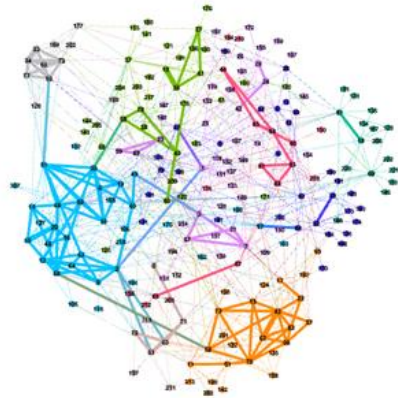


Figure 4: Modularity

5 DISCUSSION

The graph density of our model is 0.029. It is a very low value compared with the complete graph. This value practically means that the users in the network do not know each other very well.

User ID 3 has the maximum betweenness centrality 2661.3641 which is shown in Fig. 6. Therefore, User ID 3 represents many more people in the network. User ID 75 has the minimum closeness centrality 0.2353 which is shown in Fig. 8. That means in the entire network user ID 75 is less close to other nodes compared with the whole network. User ID 3 has the maximum closeness centrality which is 0.4297. That means user ID 3 is very close to all the other nodes in the entire network. Therefore, we can say, user ID 3 has the highest

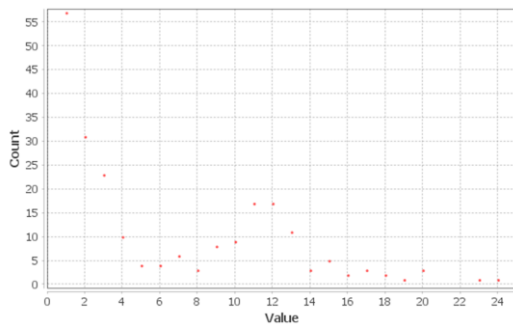


Figure 5: Degree Distribution

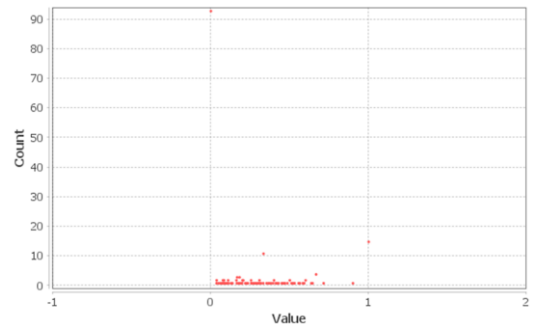


Figure 7: Clustering Coefficient Distribution

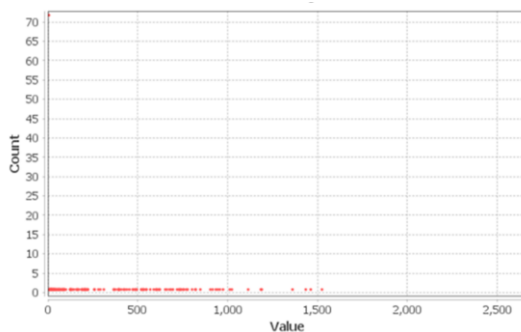


Figure 6: Betweenness Centrality Distribution

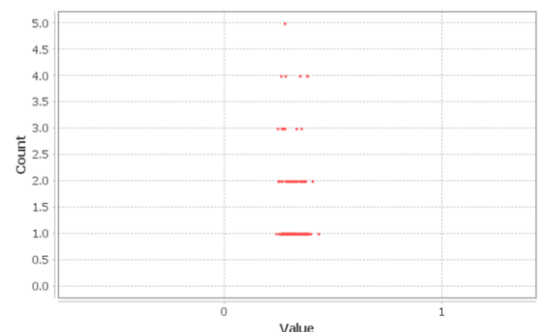


Figure 8: Closeness Centrality Distribution

potential for independent communication. According to this data set the average clustering coefficient value is 0.301 which is a very low value shown in Fig. 7. Normally the average clustering coefficient value is between 0 and 1. If the neighborhood is fully connected, the clustering coefficient is 1. Here everyone does not know each other very well.

According to our data set User ID 90 has the high authority and hub. That means User ID 90 has the most valuable and important friendships and connections in the Facebook account. According to the degree distribution there is only one member who has the maximum number of friends. Using the data set we can find who has the maximum number of connections here. That is number of 24 friendships has the person who has user ID 3. The average degree distribution is 6.317 shown in Fig. 5.

According to the distribution all the friends have an eccentricity of 4, 5 or 6. Most of them have an eccentricity of 5 i.e. the furthest user of most of the users in this network is 5 links away from them. The radius of a graph is determined by the minimum eccentricity, while the diameter is determined by the maximum eccentricity among its vertices. Here the radius is 4 and diameter is 6.

6 CONCLUSION

In this work, we have exhibited a case study involved in the social network which applies the concepts of graph theory. The contribution of this paper can help many researchers from various

viewpoints to grasp the important facts and identify the behavior of the users in social network. In addition, we provided practical examples and explanations of the potential of graph theory to analyze the social networks. In the future, we hope to extend the results in describing the uses of the graph theory in other social networks such as twitter, linkedIn and WhatsApp. Further we hope to investigate the related networks involve in the fields of Biology, Chemistry and Medicine.

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Mathematical Model for Dengue Transmission Dynamics

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ABSTRACT

Dengue is a rapidly emerging pandemic disease in many parts of the world, especially in tropical and non-tropical areas. The dengue outbreak has a multisectoral impact on the medical, societal, economical, and political sectors. Dengue incidence has increased in Sri Lanka over the past 20 years, with deaths and illnesses. Almost all the districts in Sri Lanka have reported cases and posed a threat to the health of the people. Dengue fever is caused by dengue virus, first recorded in the 1960s in Sri Lanka. In this study, we propose a mathematical model to describe the transmission of dengue with a standard incidence rate for both human and vector populations. The impact of treatment capacity in the case of an epidemic scenario has been studied by using a constant treatment function. The equilibrium points and the basic reproduction number are computed. The conditions leading to the disease-free and endemic equilibrium are determined. We observed that the reproduction number affects the asymptotic stability for both disease-free and endemic equilibrium points. The Lyapunov function theory is used to discuss the global stability. Based on actual data of infective population gathered from the Institute of Epidemiology Unit Ministry of Health in Sri Lanka, the parameters for infection and disease-related death rates are estimated. Numerical simulations of various compartments are used to investigate the impact of the key parameters affecting the disease's transmission.

KEYWORDS: Global Stability, Lyapunov Function, Reproduction Number, Standard Incidence Rate, Treatment Function

1 INTRODUCTION

A broad spectrum of diseases is brought on by dengue ranging from subclinical infection to severe flu. Effective mosquito management is the cornerstone of dengue prevention in the absence of an antiviral medication or vaccine (Wickramaarachchi et al., 2018). There are no specific antiviral drugs to treat dengue infection. The creation of the vaccine is crucial for eradicating the disease (Bhatt et al., 2013) parallel to vector management to control the spread of dengue. To explain this kind of phenomenon, epidemiologists have used mathematical modeling as a tool. Mathematical modeling gives precision and strategy for problem solutions and provides a systematic understanding of

the system modeled. So in this study, a new mathematical model related to SIR and SI Mathematical Models with standard incidence rate and a constant treatment function is proposed to describe the dynamics of transmission of dengue.

2 METHODOLOGY

2.1 Model Formulation

In forming our model, it is assumed that all newborn humans, as well as mosquito populations are infection free and susceptible. Furthermore, it has been considered that all the susceptible and infected humans and vectors are homogeneously mixing with each another. It has been supposed that the treatment infectives become recovered when they are treated in treatment sites.

$$\left. \begin{aligned} \frac{dS_H}{dt} &= \lambda_H - \frac{\beta_1}{N_M} S_H I_M - \mu_H S_H + Y_H \left(\frac{\lambda_H}{\mu_H} - S_H - I_H \right) \\ \frac{dI_H}{dt} &= \frac{\beta_1}{N_M} S_H I_M - r_H I_H - \mu_H I_H - u - d I_H \\ \frac{dS_M}{dt} &= \lambda_M - \frac{\beta_2}{N_H} S_M I_H - \mu_M S_M \\ \frac{dI_M}{dt} &= \frac{\beta_2}{N_H} S_M I_H - \mu_M I_M \end{aligned} \right\} (1)$$

where N_H and N_M represent the total human and total vector (mosquito) populations at time t . S_H, I_H, S_M, I_M denote; susceptible, infected human populations and susceptible, infected vector populations respectively. The number of newly infected people bitten by an infectious mosquito is $\frac{\beta_1}{N_M} S_H I_M$ where β_1 is the infection rate of susceptible humans resulting due to the biting of mosquitoes. λ_H and λ_M are the birth rate of the human population and the vector population, μ_H is the natural mortality rate of the human population, μ_M is the natural death rate of the vector population. $\frac{\beta_2}{N_H} S_M I_H$ denotes the incidence of newly infected vectors, where β_2 is the rate of susceptible mosquitoes become infected as a result of biting effect of infectious humans. d , r_H and Y_H represent the disease-related death rate, the natural recovery rate for the infected human, and the transmission rate from the recovered class to the susceptible class, respectively. The treatment function is defined by,

$$T(I_H) = \begin{cases} u, & \text{if } I_H > 0 \\ 0, & \text{if } I_H = 0 \end{cases}$$

The positively invariant region for the reduced model is given by,

$$D_1 = \left\{ (S_H, I_H, S_M, I_M) \in \mathcal{R}_+^4 : N_H \leq \frac{\lambda_H}{\mu_H}, N_M \leq \frac{\lambda_M}{\mu_M} \right\}$$

3 ANALYSIS

3.1 Existence and Uniqueness of the Mathematical Model

The system (1) is biologically sound.

Proposition: Solutions of (1) remain non-negative and are bounded for $t > 0$.

(1) 3.2 Next Generation Matrix Method

By using the next generation matrix method, the basic reproductive number (R_0) is calculated as,

$$R_0 = \sqrt{\frac{\beta_1 \beta_2 \lambda_H \lambda_M}{N_H N_M \mu_H \mu_M^2 (r_H + \mu_H + d)}}$$

The disease free equilibrium (DFE) of (1) is given by,

$$E_d^0 = (S_H^0, I_H^0, S_M^0, I_M^0) = \left(\frac{\lambda_H}{\mu_H}, 0, \frac{\lambda_M}{\mu_M}, 0 \right).$$

The endemic equilibrium points (EEP) of (1), $E^* = (S_H^*, I_H^*, S_M^*, I_M^*)$ can be found by solving the following system of equations.

$$\left. \begin{aligned} \frac{dS_H^*}{dt} &= \lambda_H - \frac{\beta_1}{N_M} S_H^* I_M^* - \mu_H S_H^* + Y_H \left(\frac{\lambda_H}{\mu_H} - S_H^* - I_H^* \right) \\ \frac{dI_H^*}{dt} &= \frac{\beta_1}{N_M} S_H^* I_M^* - r_H I_H^* - \mu_H I_H^* - u - d I_H^* \\ \frac{dS_M^*}{dt} &= \lambda_M - \frac{\beta_2}{N_H} S_M^* I_H^* - \mu_M S_M^* \\ \frac{dI_M^*}{dt} &= \frac{\beta_2}{N_H} S_M^* I_H^* - \mu_M I_M^* \end{aligned} \right\} (2)$$

After solving these equations, according to the Descartes' rule of sign, it is proved that, for $R_0 \leq 1$ there is no positive endemic equilibrium of (1) and the endemic equilibrium exists for $R_0 > 1$.

3.3 Local Stability Analysis

Theorem 1: The disease free equilibrium E_d^0 is locally asymptotically stable when $R_0 < 1$, and is unstable when $R_0 > 1$.

Proof: The Jacobian matrix at DFE is considered as follows.

$$J(E_d^0) = \begin{bmatrix} -(\mu_H + Y_H) & -Y_H & 0 & -\frac{\beta_1}{N_M} S_H^0 \\ 0 & -(r_H + \mu_H + d) & 0 & \frac{\beta_1}{N_M} S_H^0 \\ 0 & -\frac{\beta_2}{N_H} S_M^0 & -\mu_M & 0 \\ 0 & \frac{\beta_2}{N_H} S_M^0 & 0 & -\mu_M \end{bmatrix} \quad (3)$$

By taking the characteristic polynomial of (3) it is given that two roots are negative. Other two roots are given by the following quadratic equation.

$$\lambda^2 + a_1\lambda + a_2 = 0 \quad (4)$$

where,

$$\begin{aligned} a_1 &= r_H + \mu_H + \mu_M + d \\ a_2 &= \mu_M(r_H + \mu_H + d)(1 - R_0^2) \end{aligned}$$

According to the Routh-Hurwitz criteria we observe that all the roots of the (4) are negative if $R_0 < 1$ and at least one root is positive for $R_0 > 1$.

Theorem 2: The endemic equilibrium E^* is locally asymptotically stable if and only if the inequality $R_0^2 > \frac{\lambda_H \lambda_M}{\mu_H r_H S_M^* I_H^*}$ holds.

Proof: The Jacobian matrix at EEP is considered as follows.

$$J(E^*) = \begin{bmatrix} -\frac{\beta_1}{N_M} I_M^* - \mu_H - \gamma_H & -\gamma_H & 0 & -\frac{\beta_1}{N_M} S_H^* \\ \frac{\beta_1}{N_M} I_M^* & -(r_H + \mu_H + d) & 0 & \frac{\beta_1}{N_M} S_H^* \\ 0 & -\frac{\beta_2}{N_H} S_M^* & -\frac{\beta_2}{N_H} I_H^* - \mu_M & 0 \\ 0 & \frac{\beta_2}{N_H} S_M^* & \frac{\beta_2}{N_H} I_H^* & -\mu_M \end{bmatrix} \quad (5)$$

By taking the characteristic polynomial of (5), and according to the Routh-Hurwitz criteria, the desired result is obtained. (Allen, 2010)

3.4 Global Asymptotic Stable

The global stability for DFE and EEP of (1) have been analyzed based on the Lyapunov function. In here also it is obtained two theorems.

Theorem 3: The disease-free equilibrium E_d^0 of the model (1) is globally asymptotically stable in the positively invariant region D_1 if $R_0 \leq 1$.

Proof: Consider the following positive definite Lyapunov function.

$$L = w_1 I_H + w_2 I_M \quad (6)$$

Where $w_1 = \frac{\mu_M}{\beta_1}$, and $w_2 = \frac{\lambda_H}{\mu_H N_M}$. After relevant calculations we obtain,

$$L' \leq \frac{\mu_M(r_H + \mu_H + d)}{\beta_1} (R_0^2 - 1) I_H$$

Consequently, the largest compact invariant set $L = \{(S_H, I_H, S_M, I_M) \in D_1 : L' = 0\}$ is the singleton E_d^0 and by Lasalle's invariance principle, E_d^0 is asymptotically stable in the positively invariant region D_1 if $R_0 \leq 1$.

Theorem 4: The endemic equilibrium point E^* of the model (1) is globally asymptotically stable on D_1 if $R_0 > 1$ and if,

- I. $(S_H - S_H^*)$ and $(I_H - I_H^*)$ have the same sign.
- II. $(S_M - S_M^*)$ and $(I_M - I_M^*)$ have the same sign.

Proof: Consider the following positive definite Lyapunov function.

$$\begin{aligned} V &= \frac{1}{2} (S_H - S_H^*)^2 + w_1 \frac{1}{2} (I_H - I_H^*)^2 \\ &\quad + \frac{1}{2} (S_M - S_M^*)^2 \\ &\quad + w_2 \frac{1}{2} (I_M - I_M^*)^2 \end{aligned} \quad (7)$$

where, $w_1 = \frac{(S_H - S_H^*)}{(I_H - I_H^*)_1}$, $w_2 = \frac{(S_M - S_M^*)}{(I_M - I_M^*)_1}$.

(5) After some calculations it is given that,

$$\begin{aligned} V' &= -(\mu_H + \gamma_H)(S_H - S_H^*)^2 \\ &\quad - \mu_M (S_M - S_M^*)^2 \\ &\quad - \mu_M (S_M - S_M^*)(I_M - I_M^*) \\ &\quad - (r_H + \mu_H + \mu_M \\ &\quad + d)(S_H - S_H^*)(I_H - I_H^*) \end{aligned}$$

By Lasalle's Invariance principle desired result is verified.

3.5 Numerical Simulations

In order to validate the analytical results numerically, the data of infected human and the number of death cases due to dengue, have been collected from Institute of Epidemiology Unit, Sri Lanka.

The following equation is used to determine the β_1 value (Ögüt, 2001).

Table 1: Month wise Dengue Cases in Sri Lanka from 2019 to 2023 (Institute of Epidemiology Unit, Sri Lanka)

Month	2019	2020	2021	2022	2023
January	5,580	11,608	1,496	3,046	5,050
February	3,736	5,368	1,794	2,410	2,222
March	3,832	1,683	849	2,794	4,337
April	2,970	511	1,702	2,309	4,861
May	4,260	1,548	970	3,442	2,407
June	6,019	2,252	1,489	2,820	
July	8,897	2,288	1,950	2,471	
August	9,546	1,559	1,104	3,136	
September	7,307	1,209	580	418	
October	11,573	1,028	702	702	
November	21,769	779	1,916	2,082	
December	19,560	1,318	3,195	3,966	
Total Suspected	105,049	31,162	36,120	76,467	33,742
Total Infected	104,899	31,126	17,721	29,524	18,855
No of death	150	36	26	72	22

$$\beta = \frac{\Delta I_n}{S + I_{n-1}} \quad (8)$$

where, I_n is the number of infected human population at time period n .

Table 2: Parameter Values

Parameter	Value
β_1	0.3374 (Calculated)
β_2	0.6748(Assumed)
λ_H	Variable
λ_M	Variable
r_H	0.1429
γ_H	0.00274
μ_H	3.9×10^{-5}
μ_M	0.0714
u	Variable
d	0.000002802 (Calculated)

4 RESULTS AND DISCUSSION

By using the parameter values from Table (2), (Chakraborty et al., 2020) the simulations for both susceptible and infected human and mosquito populations have been performed in both scenarios when $R_0 < 1$ and $R_0 > 1$. To see the effect of the treatment function, Fig. 2 has been generated for different values of u . It can be seen that the increased value of u decreases the index of the infected population of Fig. 2.

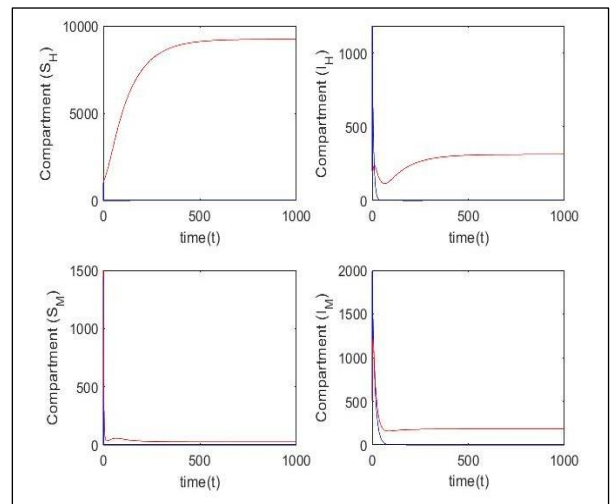


Figure 1: Time Series of the Compartments for $R_0 < 1$ and $R_0 > 1$.

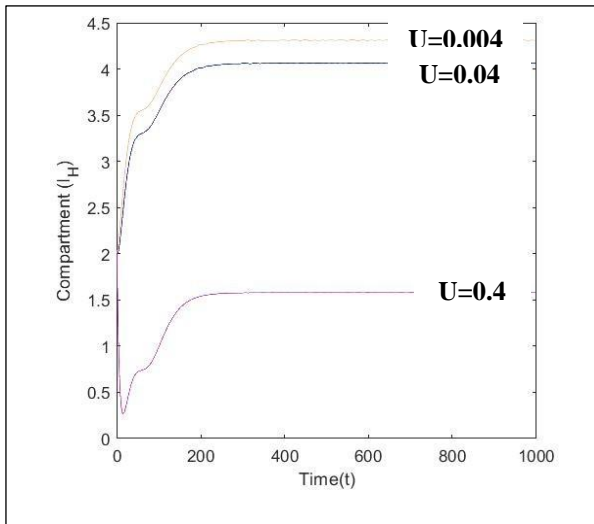


Figure 2: Effect of the Treatment Function over the Infected Human Population.

5 CONCLUSION

A simple and relevant mathematical model has been formulated and analyzed to describe the transmission of dengue with a standard incidence rate for both human and vector populations. The impact of treatment capacity in the case of an epidemic scenario has been studied by using a constant treatment function. The basic quantities such as disease-free equilibrium, endemic equilibrium, and basic reproduction number have been calculated. It is found that the endemic equilibrium point exists when the reproduction number is greater than one. The local stability of the equilibrium points has been established using the Jacobian matrix. Lyapunov functions have been used to discuss global asymptotic stability. It is emphasized that reproduction number affects the asymptotic stability for both endemic and disease-free equilibrium points. When $R_0 \leq 1$, the disease-free equilibrium point exhibits global asymptotic stability. But as $R_0 > 1$, the endemic equilibrium point becomes globally asymptotically stable. Based on the data gathered from

the Institute of Epidemiology Unit Ministry of Health in Sri Lanka, the parameters for infection and disease-related death rates have been estimated. Time series of the compartments have been generated. Additionally, it has been noted that, the treatment function has a significant impact on the infected person. This shows that in order to eliminate the disease and destroy the endemic equilibrium, adequate treatment facilities must be provided and if not, the spread of infection will be out of control.

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On the Computation of Wavefront Aberrations Through Contact Lenses

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ABSTRACT

The human eye exhibits its imperfections due to various factors that may cause vision defects. These defects have been measured using the aberrometers and represented as ocular aberrations (OA). However, highly aberrated eyes (keratoconus) produce their measurements outside of the dynamic range of the aberrometer. Therefore, such patients wear trial lenses during the measurements. As a single measurement make ambiguous conclusions, multiple readings are collected from the patient in each sitting. These trial lenses are smaller than the cornea. Therefore, they tend to move on the cornea during the measurements. The displacement of the trial lens directly causes the measurements to be misleading and then causes vision corrections. Unlike prior work, in this work, we propose an approach using the ray tracing method, that is, the geometry of the lens has been taken into account to identify the wavefront distortion caused by contact lenses since the wavefront distortion through a lens must be addressed in order to have accurate vision corrections. We have considered the actual data of four keratoconus patients for the numerical simulations conducted using MATLAB and compared the results with results from an existing direct approach (approximation). According to the quantitative results, the study concluded that there are significant differences in results between the proposed approach and the existing approach; that is, the geometry of the lens cannot be ignored despite the fact that the lens is thinner.

KEYWORDS: Keratoconus Eyes, Ray Tracing, RGP Lenses, Wavefront

1 INTRODUCTION

The imperfections of the human eye lead to vision defects, which cause for poor image quality (IQ) on the retina. The ocular aberrations (wavefronts) have been used to quantify the vision defects. These wavefronts have significance in wavefront-guided corrections such as refractive surgeries and the design of customized contact lenses. The ocular aberrations are split in two, namely, lower-order aberrations and higher-order aberrations(HA). Myopia (nearsightedness), Hyperopia (farsightedness), and Astigmatism are lower-order aberrations(LA). These defects can be corrected using suitable spherical lenses. However, HA such as spherical aberrations and coma cannot be corrected using the spectacles. Hence, adaptive

optics, contact lenses, refractive surgery, and customized contact lenses have been used in clinical practice to compensate for HA. Adaptive optics are not practically usable for correcting vision defects. In addition, the reflective surgeries are not reversible and very complicated. Therefore, contact lenses could be used as a feasible technique for vision corrections.

Rigid Gas Permeable (RGP) lenses have the potential to correct LA and HA and are healthier than soft contact lenses. However, accuracy of corrections will depend on measurements of the OA. There are different methods to measure the OA. Shack-Hartmann Aberrometer is the most common and powerful method to measure the wavefronts (Dai, 2008). Designing of RGP lenses for Keratoconus eyes required them to wear trial lenses

while the patients are sitting for the measurements. As these lenses are smaller than the eye, they tend to move on the cornea. The rotation and movement of the trial lens cause misleading outcomes on measurements, preventing perfect vision corrections. When the measurements of the wavefronts are taken while wearing a trial contact lens, after each blink, that lens has the possibility of rotation and displacement due to its smaller size. As a result, wavefront distortion through a lens should be conducted effectively for wavefront-guided corrections. This study is dedicated to obtain the wavefront distortion due to the RGP lenses since it critically assists to explore the variability of wavefront readings due to lens motion on the eye and in wavefront-guided corrections.

2 LITRATURE REVIEW

Over the decades, many researchers have conducted studies to explore the wavefront aberration through contact lenses. Guirao et al. (2001) focused on the effect of the lens motion on IQ based on the wave aberration data of ten eyes and developed an analytical expression to quantify the wave aberrations related to decentration. They also experimented with an ideal correction method (ICM) for each eye, that is, when the lens is centered, it would fully correct the eye's wavefront aberration. Then they assumed that it is their lens. They ignored the shape and the geometry of the lens.

In 2003 Brabander et al. have investigated the effectiveness of non-axisymmetric soft contact lenses in correcting HA, included by keratoconus, a condition characterized by abnormal corneal shape. The study additionally

investigated how rotation and displacement of these lenses affect their ability to give optimal correction, reducing the quality of vision correction obtained. They examined the corneas of nine keratoconus patients. The study emphasized the importance of specific lens placement. The conclusion drawn was that translation error, or the displacement of the lens on the eye's surface, should not exceed 0.5mm. Brabander et al. considered the lens and the eye as a single optical system.

The study conducted by López-Gil et al. (2009) searched into the limitations associated with vision correction using contact lenses. Among the four experiments conducted in their research, one specifically focused on examining the influence of lens rotation on the effectiveness of vision correction. Second, they studied the rotations of a contact lens on the eye using an optical method. They investigated the limitations of wavefront corrections based on a group of normal and highly aberrated eyes when the corrections suffer from a permanent rotation and translation in the third experiment. The fourth one estimates the error made when applying the correction corresponding to the wavefront measured at the entrance pupil plane on the corneal plane, using a straightforward approximation. They investigated that lens rotation had a negative impact on the ability of the contact lens to correct the eye accurately and optimally. Also, lens rotation can be caused by variables like blinking, eye movement, and fitting. They also considered the contact lens and the eye as a single optical system.

Consequently, we study the wavefront distortion through a lens since

it leads to enhance accuracy of both wavefront measurements and corrections.

3 METHODOLOGY

This study is based on the ray tracing approach, which is performed through the lens from the tear layer to exit plane. The following sections explain the wave propagation and algorithm of wave propagation. The Figure 1 shows the cross section of an eye with an trial lens.

3.1 Wave Propagation

A normal vector of S at a point (x, y) is given by the cross product of s_x and s_y which are partial derivatives of $S(x, y)$ with respect to x and y . Also the surface unit normal defined $\hat{n}_w = \frac{s_x \cdot s_y}{\|s_x \cdot s_y\|}$. The unit normal vector of S at point (x, y) is:

$$\hat{n}_w = \frac{1}{\sqrt{w_x^2 + w_y^2 + 1}} [-w_x \quad -w_y \quad 1]^T \quad (1)$$

Also, similarly both unit normal vectors to posterior and anterior surfaces $\hat{n}_i(x, y)$ and $\hat{n}_o(x, y)$ can be written as:

$$\hat{n}_i = \frac{1}{\sqrt{s_{ix}^2 + s_{iy}^2 + 1}} [-s_{ix} \quad -s_{iy} \quad 1]^T \quad (2)$$

$$\hat{n}_o = \frac{1}{\sqrt{s_{ox}^2 + s_{oy}^2 + 1}} [-s_{ox} \quad -s_{oy} \quad 1]^T, \quad (3)$$

where o and i stands for outer and inner surface of the lens respectively. The ray $T(\alpha, x, y)$ hits the surface S_i and the angle that the incidence ray makes with the normal of $S_i(x, y)$ at (x_i, y_i, z_i) is referred to as the angle of incidence which is given by θ_{i1} and the angle of refraction is θ_{i2} .

3.2 Algorithm for Wavefront Propagation

The angle of incidence θ_{i1} can be obtained through the dot product,

$$\theta_{i1} = \cos^{-1}(\hat{n}_i \cdot \hat{n}_w) = \cos^{-1}(a_{iw}), \quad (4)$$

where $\hat{n}_w \cdot \hat{n}_i = a_{iw}$. Using the refractive law, the angle of refraction θ_{i2} ,

$$\theta_{i2} = \sin^{-1}\left(\frac{\mu_w}{\mu_l} \cdot \sqrt{1 - (a_{iw})^2}\right), \quad (5)$$

where μ_w is the refractive index of lens, and μ_l is the refractive index of the medium. The direction of the ray inside the lens can be written using orthogonal basis for the plane spanned by \hat{n}_i and \hat{n}_w ,

$$\hat{n}_l = \frac{\mu_w}{\mu_l} (\hat{n}_i a + \hat{n}_w), \quad (6)$$

where a is $\left(\sqrt{\frac{\mu_l^2}{\mu_w^2} - (1 - a_{iw})^2} - a_{iw}\right)$. The ray inside the lens hits the surface S_o and the angle that the refracted ray makes with the normal of $S_o(x, y)$ at (x_o, y_o, z_o) is referred to as the angle of incidence which is given by θ_{o1} . The direction of the ray outside the lens can be written as,

$$\hat{n}_a = \frac{\mu_l}{\mu_a} (\hat{n}_o b + \hat{n}_l), \quad (7)$$

$$\text{where } b \text{ is } \left(\sqrt{\frac{\mu_a^2}{\mu_l^2} - (1 - a_{oi})^2} - a_{oi}\right).$$

Equation (6) and (7) yield:

$$\hat{n}_a = \left(\frac{\mu_w}{\mu_a} \hat{n}_w + a \frac{\mu_w}{\mu_a} \hat{n}_l + b \frac{\mu_l}{\mu_a} \hat{n}_o\right) \quad (8)$$

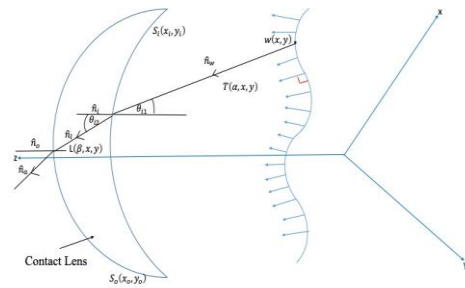


Figure 1: The cross section of an eye with an trial lens consists of with posterior surface of the trial lens $S_i(x, y)$, the anterior surface $S_o(x, y)$, and $W(x, y)$ is the selected wave. Also, propagation of a specific ray through the lens from tear layer to pupil plane is illustrated.

3.3 Computation of Intersection Points (x_i, y_i, z_i) and (x_o, y_o, z_o)

The equation of the normal line from wavefront to the $S_i(x, y)$ denoted by $T(\alpha, x, y)$ and the intersection point satisfies the following nonlinear equation, $S_i(x + \alpha_0 \frac{w_x}{p}, y + \alpha_0 \frac{w_y}{p}) - w(x, y) - \alpha_0 \frac{1}{p} = 0$, (9)

where p is $\sqrt{w_x^2 + w_y^2 + 1}$. Similarly, obtained the next nonlinear equation (10), considering the same process on outer surface.

$$S_i(x_i + \beta_0 \frac{s_{ix}}{s}, y_i + \beta_0 \frac{s_{iy}}{s}) - S_i(x_i, y_i) - \beta_0 \frac{1}{s} = 0, \quad (10)$$

where s is $\sqrt{s_{ix}^2 + s_{iy}^2 + 1}$. Nonlinear equation of α_0 and β_0 can be computed using the numerical approach.

3.4 Computation of Optical Path Length

Once the intersection points are calculated, we compute the optical path length in lens:

$$d_{lens} = \|((x, y, w(x, y)) + \alpha \hat{n}_w(x, y)) - (x_i, y_i, z_i)\| \quad (11)$$

Similarly, the optical path length in air:

$$d_{air} = \|(x_i, y_i, z_i) - (x_o, y_o, z_o)\| \quad (12)$$

4 RESULTS AND DISCUSSION

This section focuses on the results of the study. We obtained actual data of four patients who have keratoconus eyes, and data is summarized in Table 1.

Then obtained the corresponding Zernike coefficients according to our method and direct approach. In the direct approach, the refraction through the lens is completely ingored assuming that light travels parallel to the z -axis. In addition, for simplicity and to clarification of ideas, a -1.5D contact lens was selected. Then it was identified that, original Zernike coefficients and Zernike coefficients after passes the lens are closer values but high

in magnitudes. However, it ws observed that the Zernike coefficients of direct approach are completely different from the sign.

Fig. 2, Fig. 3 and Fig. 4 given below illustrate the wavefront in based on three stages. They are the original wavefront of patients with HA, the distortion wavefront after passing through the contact lens and wavefront of direct approach of patients respectively. It was observed that there is a significant difference between each columns of the figures. Hence, there is a distinguished wavefront aberration after passing through the lens.

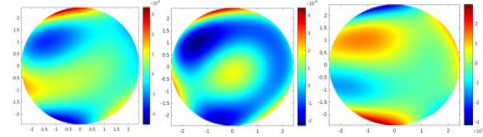


Figure 2: The original wavefront of HA, the distortion wavefront after passing through the contact lens and the wavefront of direct approach of patient 1 in sequence.

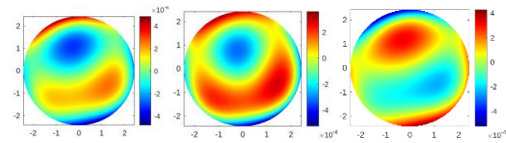


Figure 3: The original wavefront of HA, the distortion wavefront after passing through the contact lens and the wavefront of direct approach of patient 2.

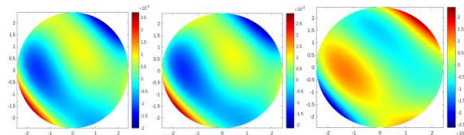


Figure 4: The original wavefront of HA, the distortion wavefront after passing through the contact lens and the wavefront of direct approach of patient 3.

Table 1: The Zernike coefficients of the wavefront of four patients in μm .

Double index	Patient 1	Patient 2	Patient 3	Patient 4
Z_3^{-3}	0.0111	-0.0330	-0.3511	0.0986
Z_3^{-1}	-0.0110	-0.0550	-0.0432	-0.1308
Z_3^1	0.0438	0.1428	-0.3374	-0.2594
Z_3^3	0.0551	0.0330	0.2934	0.5466
Z_4^{-4}	-0.0306	0.0104	-0.0620	0.0622
Z_4^{-2}	-0.0303	-0.0101	0.0484	-0.0309
Z_4^0	0.0753	-0.0269	0.2046	0.2655
Z_4^2	0.0101	0.0406	-0.1405	-0.0390
Z_4^4	-0.0000	-0.0206	0.0013	-0.0885

5 CONCLUSION

As the accuracy of corrections directly depends on measurements, this study is critical in the process of contact lens design. In general, as contact lenses are thin, it is assumed that light travels parallel to the z-axis. It simply suggests that the refraction of light within the contact lens is negligible (direct approach). But the refraction at each surface of the lens was observed. According to the quantitative representations, we have identified, that there are significant differences in the wavefront, between our approach and the direct approach, in which the wavefront after passes the contact lens. This work endeavors to make it easier to redesign contact lenses and enhance the accuracy of readings for highly aberrated eyes.

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Patterns Study in Obtaining Square and Cube of Positive Integers and the Generalized Combined Pascal Triangle

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ABSTRACT

Study of patterns plays important role in Mathematics. A mathematical pattern can be described by using numerical, logical or spatial relationships. Mathematicians have found a lot of patterns so far not only for improving the power of one's brain by means of structuring it but also for solving real world problems. The main purpose of this research is to identifying new general formulae for finding square and cube of positive integers studying their number patterns and to generalize the combined Pascal triangle. Square and cube are the fundamental mathematical operations with applications in various fields, such as calculus, algebra, number theory, statistics, engineering, geometry, etc. Although we have identified only formulae for square and cube, we can use these formulae for deriving new formulae for other powers of positive integers since the initial step of finding any positive integer power is finding square and cube first. As the third case, we approached to another general formula for finding square of any positive integer greater than 49 studying their number patterns. Finally, we approached to new triangle "the general combined Pascal triangle" which we identified using number patterns. Using this triangle we can find any power of 22, 33, ..., 99. This is not a representation of Pascal triangle. It is a new approach that we reached after identifying number patterns. By studying these identified patterns, methods and formulae, we can continue our research further. This shows the beauty of mathematics with numbers and their patterns.

KEYWORDS: Combined Pascal Triangle, Cube of a Positive Integer, Square of a Positive Integer

1 INTRODUCTION

Mathematics is the language of the universe and studying numbers and their patterns are very important. The search for pattern and the formulas in number sequences has a long history. Mathematicians in different cultures such as Greek, Egyptians, and Indians explored various number sequences and discovered mathematical patterns. Finding the power of any positive integer is one of the fundamental questions in mathematics. When increasing the exponent of an integer, it is harder to calculate its power. But using square and cube, we can generate any power.

Therefore, when finding formulae for square and cube of any positive integer, it will involve developing and testing the general formula on positive integers of varying sizes. Furthermore, through the study of patterns of triangular arrangement of numbers, we could offer new interpretations for the powers of some numbers.

2 LITERATURE REVIEW

In 1954, a New Zealand mathematician Aitken provided the following algebraic identity to square numbers. $A^2 = (A - d)(A + d) + d^2$.

We should choose d as the distance to a number, close to A (given number) that is easy to multiply.

In 2012, Benjamin introduced the following method for cubing two-digit numbers; $A^3 = (A - d)A(A + d) + d^2A$, where d is the smallest distance between A and the number with 10s factors.

Kumari (2016) introduced a triangle for powers of 11 up to the power of 8 as mentioned in Table 2.

Lorence et al. (2021) discovered new formulae given in Table 1 for finding squares by studying their own patterns.

Table 1 : Formulae Table with Last Digits

Last digit	Square of the number [N_n^2]
1	$N_{n-1}^2 + \left\lfloor \frac{N_{n-1}}{5} \right\rfloor, \text{lastdigit}(a_{n-1} \times 2), 1$
2	$N_{n-1}^2 + \left\lfloor \frac{2N_{n-1}}{5} \right\rfloor, \text{lastdigit}(a_{n-1} \times 4), 4$
3	$N_{n-1}^2 + N_{n-1} - \left\lfloor \frac{2N_{n-1}}{5} \right\rfloor, (\text{lastdigit}(a_{n-1} + 5) \times 6), 9$
4	$N_{n-1}^2 + N_{n-1} - \left\lfloor \frac{N_{n-1}}{5} \right\rfloor, \text{lastdigit}((a_{n-1} \times 8) + 1), 6$
5	$N_{n-1}^2 + N_{n-1}, 2, 5$
6	$N_{n-1}^2 + N_{n-1} + \left\lfloor \frac{N_{n-1}}{5} \right\rfloor, \text{lastdigit}((a_{n-1} + 1) \times 2) + 1, 6$
7	$N_{n-1}^2 + N_{n-1} + \left\lfloor \frac{2(N_{n-1} - 1)}{5} \right\rfloor, \text{lastdigit}((a_{n-1} + 1) \times 4), 9$
8	$N_{n-1}^2 + 2N_{n-1} - \left\lfloor \frac{3(N_{n-1} + 1)}{5} \right\rfloor, \text{lastdigit}((a_{n-1} + 1) \times 6), 4$
9	$N_{n-1}^2 + 2N_{n-1} - \left\lfloor \frac{2(N_{n-1} + 1)}{5} \right\rfloor, \text{lastdigit}((a_{n-1} + 1) \times 8), 1$
0	$N_{n-1}^2, 0, 0$

Table 2 : Magic 11's

	Multi-Digit number	Actual Row
11^0	1	1
11^1	11	1 1
11^2	121	1 2 1
11^3	1331	1 3 3 1
11^4	14641	1 4 6 4 1
11^5	161051	1 5 10 10 5 1
11^6	1771561	1 6 15 20 15 6 1
11^7	19487171	1 7 21 35 35 21 7 1
11^8	214358881	1 8 28 56 70 56 28 8 1

Here $N_n = (a_1 a_2 \dots a_{n-1} a_n)$, $N_{n-1} = (a_1 a_2 \dots a_{n-1})$ and $[X]$ denotes the floor function.

Senarath et al. (2020) found a novel method to find the n^{th} power of m -digit number. They used the concept of binomial expansion as follows:

$$(a_1 a_2 \dots a_m)^n = (a_1 a_2 \dots a_{m-1})^n \binom{n}{1} (a_1 a_2 \dots a_{m-1})^{n-1} a_m \dots \binom{n}{n-1} (a_1 a_2 \dots a_{m-1}) a_m^{n-1} | a_m^n$$

3 MATERIALS AND METHOD

3.1 New Approach for Square of a Positive Integer

We use the following procedure to obtain the square of a positive integer.

$$14^2 = (14) \times 1 + (1 \times 4 + 1), 6 = 19, 6$$

$$18^2 = (18) \times 1 + (1 \times 8 + 6), 4 = 32, 4$$

$$19^2 = (19) \times 1 + (1 \times 9 + 8), 1 = 36, 1$$

Now we can derive the general formula (1) for square of any two - digit integer ending with B , where $B = 0, 1, 2, \dots, 9$.

$$AB^2 = (AB) \times A + \binom{A \times B}{+ b_0}, b_1, \quad (1)$$

Where $A - 10^{\text{th}}$ digit of AB , $B -$ Unit digit of AB , and $B^2 = b_0 b_1$ (a two digit integer). Considering $n -$ digit positive integer AB , where $A = a_1 a_2 \dots a_{n-1}$ and $B = a_n$, the general formula for square of any $n -$ digit positive integer is,

$$\begin{aligned}
 a_1 a_2 \dots a_{n-1} a_n^2 & \quad (2) \\
 &= (a_1 a_2 \dots a_{n-1} a_n) \\
 &\times (a_1 a_2 \dots a_{n-1}) \\
 &+ (a_1 a_2 \dots a_{n-1} \times a_n \\
 &+ b_0), b_1
 \end{aligned}$$

3.2 New Approach for Cube of a Positive Integer

We use the following procedure to obtain the cube of a positive integer:

$$\begin{aligned}
 18^3 &= (18 + 8) \times (18 \times 1) + (1 \times 8^2 \\
 &\quad + 51), 2 = 583,2 \\
 19^3 &= (19 + 9) \times (19 \times 1) + (1 \times 9^2 \\
 &\quad + 72), 9 = 685,9
 \end{aligned}$$

Now we can derive the general formula for cube of any two digits integers ending with B .

$$AB^3 = \{(AB + B) \times (AB \times A) + (A \times B^2 + c_0 c_1)\}, c_2, \quad (3)$$

A – 10th digit of AB , B – Unit digit of AB and $B^3 = c_0 c_1 c_2$ (a three - digit number). Then we can consider above general formula for n - digit positive integer as follows:

$$\begin{aligned}
 a_1 a_2 \dots a_{n-1} a_n^3 & \quad (4) \\
 &= \{(a_1 a_2 \dots a_{n-1} a_n \\
 &\quad + a_n) \\
 &\times (a_1 a_2 \dots a_{n-1} a_n \\
 &\times a_1 a_2 \dots a_{n-1}) \\
 &+ (a_1 a_2 \dots a_{n-1} \times a_n^2 \\
 &\quad + c_0 c_1)\}, c_2
 \end{aligned}$$

3.3 A Different Approach to Find the Square of a Positive Number Greater Than or Equal to 50

Table 3 : Patterns Table (B=4)

Patterns	AB	AB ²	T
	04	00	16
	14	01	96
	24	05	76
	34	11	56
19 + 00	44	19	36
29 + 00	54	29	16
39 + 01	64	40	96
49 + 05	74	54	76
59 + 11	84	70	56
69 + 19	94	88	36

$t = 9$ $9-d=6$ $d = 3$ $B = 4$

Consider patterns in Table 3, that includes square of any positive integer with unit digit, $B = 4$.

In Table 4, it indicates all the set of T values that we can identify repeating above method for all B , $B= 0,1,\dots,9$.

Patterns introduce that next square value can be decided using previous squares.

The T table helps to find the square easily. Otherwise, we have to revise some steps.

The general formula for this method is AB^2

$$= \left\{ \begin{aligned} & \sum_{i=0}^{n-1} (A - d - 5i), t + \\ & \text{Integer part of } \left(\frac{[(A-n \times 5), B]^2}{100} \right) \end{aligned} \right\}, T \quad (5)$$

Here $n = \text{integer part of } \left(\frac{A}{5} \right)$, $AB = (a_1 a_2 \dots a_{m-1}, a_m)$, $(A - n \times 5) \in [0,4]$ and $B \in [0,9]$. Therefore, we should directly use $[(A - n \times 5), B]^2$.

Table 4 : Data Table (T, B, d, t values)

B	0	1	9	2	8	3	7	4	6	5
t	5	6	4	7	3	8	2	9	1	0
d	3	3	2	3	2	3	2	3	2	2
10 th digit of AB	T	T	T	T	T	T	T	T	T	T
	(B=0)	(B=1)	(B=9)	(B=2)	(B=8)	(B=3)	(B=7)	(B=4)	(B=6)	(B=5)
0, 5	00	01	81	04	64	09	49	16	36	25
1, 6	00	21	61	44	24	69	89	96	56	25
2, 7	00	41	41	84	84	29	29	76	76	25
3, 8	00	61	21	24	44	89	69	56	96	25
4, 9	00	81	01	64	04	49	09	36	16	25

Table 5: Comparison Table

Our formula	Formulae identified in (Lorence et al., 2021)
1. One general formula for any positive integer.	1. Ten number of formulae by considering last digit 0 to 9.
2. For large numbers this method is something complex. (The number of digits of the integer \propto The number of terms in formula).	2. For large number also can be used easily.
3. In programming, coding is simple. (One formula)	3. In programming, coding is something complex than ours. (Ten formulae)

When we receive two digits number as B^2 then leave only unit digit and shift the 10th digit to next summation term. (rule 1). Here we have used “ , ” with t and T , to separate the digits only at the (.) with B^2 .

5 CONCLUSION

As a result of this study, we reach to new approaches for square and cube of n - digit positive integers which are another representations for binomial expansion. Next method given under (3.3) is a replacement for the method in (Lorence et al., 2021). Now we compare our method given in (5) or (7) with the method that identified in (Lorence et al., 2021) in Table 5. We can state that our formula is an improvement of that method, since we have one formula to find the square of any positive integer greater than 49. However, the new method can be applied for integers greater than 49. We wish to continue this research to solve the identified issues.

The general combined Pascal triangle is a new method we identified. It is not another representation of binomial expansion or Pascal triangle. Although we can find any power of above two digits integers (AA) by using the combined Pascal triangle, we can't use Pascal triangle for this purpose. We will further study on those triangles for finding any power of any integer studying their patterns.

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Utilizing Graph Coloring Approach to Bus Scheduling

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ABSTRACT

This research focuses on enhancing bus scheduling efficiency at the Kurunegala South Depot, a critical element in public transportation systems. The objective is to minimize buses and scheduling complexities while maintaining service quality. Employing a graph coloring approach, the study seeks to revolutionize practices and reduce complications and time of the bus time tabling task. Historically reliant on manual timetabling, Sri Lanka Transport Board(SLTB) services faced challenges, prompting the development of a graph coloring algorithm. The approach resulted in reduced planning time and a smaller bus fleet. Applied to the Kurunegala South Depot, this methodology reduced the bus fleet complications of time tabling task, demonstrating significant potential for resource optimization. The research provides insights for modernizing bus scheduling globally, offering a viable solution for efficient scheduling and rostering processes. This research illuminates a path toward modernizing bus scheduling practices. The reduction in planning time and successful implementation of the graph coloring method presents a viable solution for scheduling buses in the Kurunegala South Depot.

KEYWORDS: Bus Scheduling, Graph Coloring, Vertex Coloring

1 INTRODUCTION

The research endeavored to improve the efficiency of bus scheduling, a crucial aspect of effective public transportation systems. Focusing on the Kurunegala South Depot, the objective was to minimize the number of buses and scheduling complexities required for daily operations while upholding service quality. The innovative approach employed graph coloring, with the intention of transforming scheduling practices and reducing the fleet size. Previously, the Sri Lanka transport board services utilized a manual assignment method for time tabling. This manual approach resulted in prolonged scheduling tasks, created conflicts, and necessitated the management of a large fleet of buses. Consequently, the research aimed to achieve benefits such as

reduced planning time, minimized bus fleet size, and the development of a graph coloring algorithm. By delving into the potential of the graph coloring approach, the research sought to serve as a guiding influence for the modernization of bus scheduling. The focus remained on optimizing resources and cutting costs without compromising service quality, providing insights relevant to transportation services. The objective was to function as a blueprint for addressing analogous challenges and ushering in a new era of efficient and economically viable bus scheduling practices.

2 LITERATURE REVIEW

Mnif et al. (2011) investigated a multi-objective graph coloring approach for bus driver timetabling. The paper also

described the existing system and its challenges. The research aimed to transition towards an automated software solution for addressing the timetabling problem by organizing all travel services into groups, referred to as classes. Each group represented the daily work of a driver.

Martello and Toth (1986) have presented "A heuristic approach to the bus driver scheduling problem," published in the *European Journal of Operational Research*. Their study focused on addressing the challenge of covering a set of trips by drivers with the objective of minimizing the number of drivers while adhering to company regulations. The researchers specifically tackled the problem of identifying a set of bus driver duties to cover a given set of running boards (bus schedule). Their aim was to minimize the number of drivers required and satisfy a set of constraints.

Burke et al. (1994) presented plans for a university timetabling system based on graph coloring and constraint manipulation. They described heuristic algorithms for graph coloring and room allocation, illustrating how these two could be combined to form the foundation of a timetabling system. The authors also discussed the handling of various common timetabling features within the system, with a primary focus on examination timetabling.

Ganguli and Roy (2017) have utilized the application of graph coloring on multiple datasets from an educational institute, considering various constraints. The objective was to properly color the course conflict graph and translate this

coloring into conflict-free timeslots for courses.

3 METHODOLOGY

A solution to the existing manual scheduling process for buses was proposed in this research by employing graph theory, specifically utilizing the vertex coloring approach. A software-based program was implemented to facilitate effective bus rostering. All buses were represented by vertices. The edges were connected between the buses, which travel on the same time schedule.

3.1 Method to Color a Graph

The steps required to color a graph G with 'n' number of vertices are as follows:

1. Graph Formulation

Formulated the problem as a graph (G) with buses as vertices.

2. Run Overlap Connection

Connected two vertices when corresponding runs overlap in time.

3. Initial Color Assignment

Assigned color 1 to the vertex with the highest degree.

Extended this color to non-adjacent uncolored vertices, considering break times.

4. Sequential Color Assignment

Assigned a new color to the next uncolored vertex with the next highest degree.

5. Color Optimization

If all adjacent vertices were colored with the current color, assigned a new color to the next node.

6. Iteration

Repeated steps 4 and 5 until all vertices are colored.

In response to the considerable volume of buses, following sub-grouping model also was employed as an additional strategy for coloring.

3.1.1 Graph Coloring Model

Let S be a set of trips with precedence relation $<$. We will say that the trips $s_1 \in S, s_2 \in S$ are incompatible if $s_1 \not\prec s_2$ and $s_2 \not\prec s_1$. Otherwise, we will say that the trips s_1, s_2 are compatible. Let $G = (V, E)$ be a graph with vertex set $V = S$ and edge set E defined

$E = \{(u, v) | u \in V, v \in V, u \not\prec v, v \not\prec u\}$. In other words, the edge set E is the set of all incompatible pairs of trips from S . Let $T = s_1 \rightarrow s_2 \rightarrow \dots \rightarrow s_m$ be a running board $s_i < s_j$ or $s_j < s_i$ and consequently $(s_i, s_j) \notin E$ – the set V_T of all trips from with the trips from S . Then for every couple $s_i, s_j, i = 1, 2, \dots, m, j = 1, 2, \dots, m, i \neq j$ it holds running board T is an independent subset of vertices in graph G . On the other hand, the given independent subset of trips $V_T \subseteq V$, for arbitrary pair $s_i \in V_T, s_j \in V_T$ it holds $s_i < s_j$ or $s_j < s_i$ – $<$ is a complete ordering of finite set V_T and hence the trips from V_T can be ordered into a linear ordered sequence – running board T . In the terminology of graph coloring problem the subset $V_T \subseteq V$ is a running board if and only if all vertices from V_T can be colored by the same color. Then this problem can be formulated as follows: To solve this problem with a minimum number of vehicles and find a

coloring of the graph G with a minimum number of colors.

4 RESULTS AND DISCUSSION

4.1 Apply Graph Coloring Approach to Minimize Number of Bus

The optimization and network analysis of Kurunegala South Depot's bus fleet was explored in this research report. A total number of 123 buses operated by the depot, with each being represented by a unique vertex in a complex network. The connections between buses established through edges, indicating simultaneous travel. The network underwent a comprehensive analysis, involving the creation of 7,582 edges, making manual visualization impractical.

Table 1 indicates the current time table for South Depot. This time table was created manually. Two columns present the bus number and their respective time slots.

Table 1: Existing Manual time table in Kurunegala south depot

Bus number	Time slots
1	5.20 -11.45
2	12.30-5.40
109	12.13-16.10
3	6.10-12.05
16	1.30- 19.05
4	1.10-5.45
14	5.50-11.55
.	.
.	.
.	.
123	5.40- 10.15

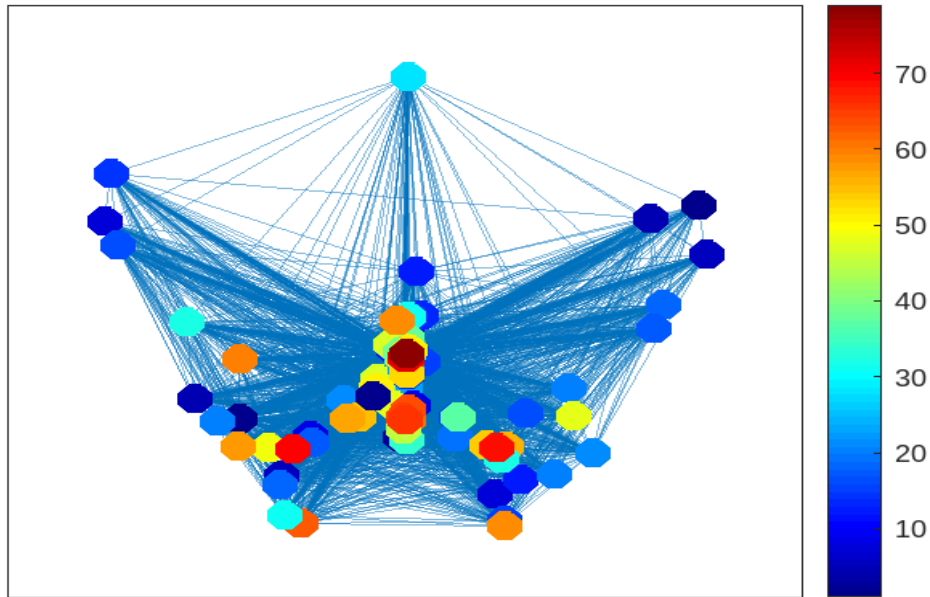


Figure 1: Graph with Proper Vertex Coloring Using Mathematical Software

In Fig. 1, a comprehensive graph was presented that encapsulated the intricate network of bus scheduling at Kurunegala South Depot. This graph comprised 123 distinct vertices, with each corresponding to an individual bus in the fleet, and a staggering 7582 edges that signified the interdependencies and connections between these buses. While the complexity of the network could be appreciated through the visual representation in the graph, identifying buses with the same assigned color became challenging due to the sheer volume of vertices. To overcome this challenge and enable a clearer understanding of the color-coded vertices, a color numbering method was implemented. In this system, a unique number was associated with each color, making it easier to identify and distinguish buses that shared the same color. Through this color-numbering scheme, the effectiveness of the graph representation was enhanced, facilitating a more precise analysis of the bus

scheduling patterns at Kurunegala South Depot.

Table 2: Color Numbers for relevant vertex (Bus Number)

Color Number	Vertex Number(Bus Number)
1	1, 2, 109
2	3, 16
3	4, 14
4	5, 6
5	7, 8
6	9, 38
7	10, 20
8	11, 66
9	12, 36
.	.
.	.
.	.
79	123

Table 2 exhibited two columns presenting color numbers paired with their respective vertex numbers, encompassing a total of 79 distinct colors. Significantly, our analysis indicated the possibility reducing 44

buses from a total fleet of 123 in the depot.

When compared with Table 1 and Table 2, it has been indicated that one bus can be used instead of two buses, respectively. As a proof of that, we can consider the time slots of the first three rows in Table 1. Considering the above example, setting bus timetables based on time intervals at eye level is an easy method, but as the number of buses increases, it becomes a complex task and takes more time. Therefore, we have utilized the graph coloring method to minimize time for the time tabling task and the number of buses.

5 CONCLUSION

Achieving the objectives of reducing planning time, the application of the graph coloring approach in graph theory to optimize bus scheduling at the Kurunegala South Depot was demonstrated significant potential for resource optimization and cost reduction while maintaining the quality of service provided to commuters. Through the careful orchestration of the daily operations of the depot's 123-bus fleet, the required number of buses were successfully reduced to 79 without compromising the reliability and efficiency of the service. This research illuminated a path toward modernizing bus scheduling practices, providing a beacon for transportation authority's worldwide facing similar challenges. The reduction in planning time, coupled with decreased fuel consumption contributing to a more environmentally sustainable operation and lower maintenance costs translating to budgetary savings for the depot was underscored the success of the

initiative. Furthermore, the judicious allocation of resources ensured that the depot's services remained reliable and accessible to the ever-evolving demands of the commuting public. In conclusion, the findings of this research emphasize the importance of innovative strategies in public transportation management. In the context of the Kurunegala South Depot, the implementation of the graph coloring approach not only minimized operational costs but also led to a more sustainable and efficient public transportation system, accomplishing the objective of reducing planning time.

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Validity of the Extrapolation of Zernike Coefficients

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ABSTRACT

In the field of vision science, researchers often face challenges in extracting reliable data from single measurements due to factors such as pupil size variations, aberrometer misalignment, eye accommodation, and the presence of mucus. Pupil size is a crucial factor, and to address its variability, multiple measurements are taken at different pupil radius during a single session. The common practice here is to average Zernike coefficients as numerical outcomes in optometric studies. However, Zernike coefficients can change with pupil size variations, leading to the assumption of constant pupillary diameter during averaging. To overcome this limitation, the current study explores the validity of scaling Zernike coefficients through extrapolation. Using a ray-tracing approach and accurate modelling of the cornea (Conic model), responsible for a significant portion of eye refraction, the study extrapolates wavefronts up to 2.75 mm pupil size, starting from the actual pupil size of 2.5mm with a step size of 0.05mm. Unlike previous methods, this approach considers the cornea's influence on wavefront magnitude, accounting for variations in Zernike coefficients based on corneal shape. We have considered secondary data from four patients, such as astigmatic 1, myopic 1, keratoconus 1, and keratoplasty 1, for the numerical simulation that were conducted using MATLAB and compared the results with those from the existing approach. In the existing approach, the magnitude of the Zernike Coefficients increases as the pupil radius expands, whereas in our approach, the magnitude of the Zernike Coefficients changes in a random manner as the pupil radius expands due to the cornea's effect on ocular aberrations.

KEYWORDS: Ray Tracing, Wavefront, Zernike Coefficients

1 INTRODUCTION

The human eye is the amazing visual sensory organ which plays a pivotal role in our lives. Mainly the cornea, lens and vitreous contribute to refract and concentrate the light into the retina. However, the optical structural shape of the eye, size, and distortions lead for vision defects. In vision science, the ocular aberrations (OAs) are used to describe the vision defects resulted by irregular shape of the cornea and the crystalline lens rather than the retina. The Shack-Hartmann Aberrometer (SHA) is the most essential and widely used aberrometer to measure OAs since it is the most accurate and consistent aberrometer (Thibos et al.,2002). Moreover, the SHA

responds quickly and precisely. In this work, in this work, the measurements taken by SHA are used. Also, the SHA constructs the ocular aberrations using Zernike polynomials which are orthogonal over the unit circular domain and reports the expansion coefficients (Zernike coefficients) for each measurement. In addition, particularly, pupil radius and spot location are also reported. In clinical practice, extracting data from a single measurement leads to make deceptive conclusions. Repeated measurements are therefore taken from the patient in each sitting. In addition, as Zernike polynomials are orthogonal over the unit circular domain, the magnitudes of Zernike coefficients alter when pupil

size changes. Therefore, it is necessary to have these measurements over a common pupil size for clinical applications. However, it is not practical to take measurements from a patient over a common pupil size since the pupil size changes during the measurements. Consequently, different mathematical techniques are used to scale the Zernike coefficients into a fix pupil size (scaling from smaller pupils to bigger pupils, and vice versa). In particular, scaling up (extrapolation) has been controversial. Different studies based on clinical measurements were therefore carried out to investigate the validity of scaling formulas. Accordingly, the aim of our study is to explore the validity of scaling up theoretically by taking account the corneal shape. As the cornea induces approximately two thirds of total refraction of the eye, our study uses the ray-tracing through a 3D corneal model for carrying out the above explorations.

2 LITERATURE REVIEW AND THEORETICAL BACKGROUND

Repeatability of ocular wavefront measurement was assessed (Davies et al., 2003), and the study concluded that repeated measurements exhibited statistically significant differences in a larger number of Zernike coefficients, particularly, for the measurements taken without pupil realignment. Ginis et al. (2004) studied the variability of wavefront aberration measurements as measured by the SHA at different pupil sizes. In particular, they compared the variation of individual Zernike coefficients in a reduced size pupil. This study concluded that the variance of wavefront aberration is considerable at the

periphery of the pupil and carried out over the smaller pupil. However, wavefront-guided refractive surgery uses an optical zone larger than the wavefront diameter. Dai (2011) investigated the validity of scaling up wavefront diameters using 4256 preoperative wavefront examinations. The study found that scaling down has no error while scaling up is safe to 0.5mm in diameter. However, it was stressed that the error was noticeable when Zernike coefficients scaled by 0.75mm larger in diameter. Ommani et al. (2014) conducted the research to validate the mathematical Zernike pupil size scaling from larger pupil to smaller pupils and vice versa by comparing the estimates of the Zernike coefficients with corresponding clinical measurements obtained at different pupil sizes. They revealed that when scaling up to a larger pupil size, the differences between measured and estimated coefficients were considerable and less compared to scaling down to a smaller pupil size.

2.1 Zernike Representation of Ocular Aberrations

In Zernike representation, the ocular aberrations $W(r, \theta)$ with pupil radius R can be expanded in terms of Zernike polynomials:

$$W(r, \theta) = \sum_{i=0}^{\infty} C_i Z_i(\rho, \theta), \quad (1)$$

where $\rho = r/R$ is the normalized pupil radius, $Z_i(\rho, \theta)$ is the i^{th} Zernike mode, and C_i is the i^{th} Zernike coefficients.

2.2 Mathematical Representation of Corneal Shape

There are numerous approaches that have been developed over the years for parametrically simulating the eye mathematically. Under those mathematical models, the following conic

model has been selected as the 3D cornea shape in our study (Consejo et al., 2021).

$$Z(x, y) = \frac{\sqrt{R^2 - (x^2 + y^2) * (Q + 1)} - R}{(Q + 1)}, \quad (2)$$

where Q represents the asphericity coefficients, the curvature of the eye surface was controlled using this. where, when $Q < 0$, the surface becomes flatter in the direction of the periphery. R denotes the radius of the conic model.

3 METHODOLOGY

3.1 Data Collection

This study made use of secondary data extracted from the reference ranges that correlate with the ocular aberration data (μm) in the group of study for a 5mm pupil diameter for Astigmatic 1, Myopic 1, Keratoconus 1, and Keratoplasty 1 (López-Gil et al., 2009).

3.2 Wave Propagation

Let $S(x, y)$ be the cornea surface, $W(x, y)$ be the selected wavefront. First, unit normal vectors to the surface of the wavefront (\hat{n}_1) and corneal surface (\hat{n}_2) were computed.

$$\hat{n}_1 = \frac{[-W_x(x, y) \quad -W_y(x, y) \quad 1]^T}{\sqrt{(W_x(x, y))^2 + (W_y(x, y))^2 + 1}}, \quad (3)$$

where W_x and W_y denotes the partial derivatives of the wavefront surface.

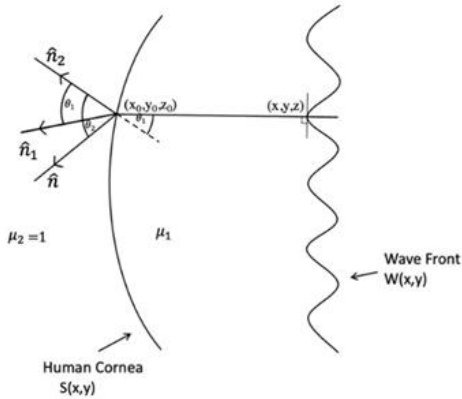


Figure 1: Wave propagation through the human cornea is illustrated.

$$\hat{n}_2 = \frac{[-S_x(x, y) \quad -S_y(x, y) \quad 1]^T}{\sqrt{(S_x(x, y))^2 + (S_y(x, y))^2 + 1}}, \quad (4)$$

where S_x and S_y denotes the partial derivatives of the cornea surface.

The light ray hits the surface S , and the angle that the incidence ray makes with the normal of $S(x, y)$ is referred to as the angle of incidence θ_1 , which was calculated by the dot product of $\hat{n}_1(x, y)$ and $\hat{n}_2(x_0, y_0)$ as follows;

$$\theta_1 = \cos^{-1}(\hat{n}_1(x, y) \cdot \hat{n}_2(x_0, y_0)). \quad (5)$$

Using Snell's law, the angle of refraction θ_2 can be obtained as follows;

$$\theta_2 = \sin^{-1}(\mu_1 \sin \theta_1 / \mu_2). \quad (6)$$

Using an orthogonal basis for the plane spanned by \hat{n}_1 and \hat{n}_2 , the direction of the ray in the air could be obtained as follows;

$$\hat{n} = \hat{n}_2 \cos \theta_2 + \frac{\hat{n}_1 - \hat{n}_2 \cos \theta_1}{\|\hat{n}_1 - \hat{n}_2 \cos \theta_1\|} \sin \theta_2. \quad (7)$$

The equation of the normal line from the wavefront to the cornea surface $S(x, y)$ denoted by $T(\alpha, x, y)$ and is given:

$$T(\alpha, x, y) = (x, y, W(x, y)) + \alpha \hat{n}_1(x, y). \quad (8)$$

The value of α can be evaluated such that $T(\alpha, x, y)$ meets S at $\alpha = \alpha_0$. Therefore, α_0 is given by solution of (9)

$$S(x - \alpha_0 \frac{W_x}{p}, y - \alpha_0 \frac{W_y}{p}) - W(x, y) - \frac{\alpha_0}{p} = 0. \quad (9)$$

Equation (9) is a nonlinear equation of α_0 . It was computed using the numerical approach (bisection method).

Next the equation of the normal line from the cornea surface $S(x, y)$ to the plane $z = \bar{z}$ was denoted by $L(\beta, x, y)$ and was given by,

$$L(\beta, x, y) = (x_0, y_0, S(x_0, y_0)) + \beta \hat{n}_2(x_0, y_0). \quad (10)$$

The following equation was used to compute the β_0 , and which may lead to obtaining the $(\bar{x}, \bar{y}, \bar{z})$,

$$\bar{z} = S(x_0, y_0) + \beta_0 \hat{n}_3(x_0, y_0). \quad (11)$$

The optical path length from the wavefront to the cornea's surface is given by,

$$d_{\text{medium}} = \mu_1 \| (x, y, z) - (x_0, y_0, z_0) \|$$

The optical path length from cornea to the measurement plane is given by,

$$d_{\text{air}} = \mu_1 \| (x_0, y_0, z_0) - (\bar{x}, \bar{y}, \bar{z}) \|$$

Total Optical Path length = $d_{\text{air}} + d_{\text{medium}}$

Finally, each ray traces so that it has the same optical path length. The collection of points yields the new wavefront surface that was used in this study as the distortion. Here, the numerical simulations were conducted using MATLAB software.

4 RESULTS AND DISCUSSION

In this study, we considered four patients whose original(actual) pupil size was 2.5mm and had vision defects such as astigmatic 1, myopic 1, keratoconus 1, and keratoplasty 1. In here the vision defects related to our study were discussed based on the magnitude of the Zernike coefficients of the new wavefronts created as a result of the refraction of light rays through the human cornea by extrapolating the size of the pupil radius up to 2.75mm with 0.05mm intervals starting from the original(actual) pupil size of 2.5mm.

The scaling up of Zernike coefficients currently relies on mathematical formulas that do not incorporate information from outside the domain. In our study, the shape of the cornea was utilized in the extrapolation process, allowing for additional information in the extrapolation region.

In the existing approach, the magnitude of Zernike coefficients increases as the pupil radius expands, as mentioned in Table 1.

Table 1: For Astigmatism 1 patient (Existing Approach)

Zernike Modes	R=2.55mm	R=2.60mm
z_3^{-3}	0.013	0.0138
z_3^{-1}	-0.0108	-0.0114
z_3^1	0.041	0.0434
z_3^3	0.053	0.0561
z_4^{-4}	-0.0395	-0.0427
z_4^{-2}	-0.0198	-0.0214
z_4^0	-0.0126	-0.0136
z_4^2	0.0013	0.0014
z_4^4	-0.0011	-0.002

Table 2: For Astigmatic 1 patient (Our Approach)

Zernike Modes	R=2.55mm	R=2.60mm
z_3^{-3}	0.0115	0.0105
z_3^{-1}	-0.0102	-0.0112
z_3^1	0.0407	0.0436
z_3^3	0.0517	0.0565
z_4^{-4}	-0.0315	-0.0461
z_4^{-2}	-0.0115	-0.0081
z_4^0	-0.0218	-0.0301
z_4^2	-0.0054	-0.0088
z_4^4	-0.0002	-0.002

In our approach, the magnitude of the Zernike Coefficients changes in a random manner as the pupil radius expands, as mentioned in Table 2. Here, we present the results of astigmatic 1 patient for pupil radii of 2.55mm and 2.60mm, as we have limited space. Other patients also followed the same pattern.

5 CONCLUSION

In clinical practice, multiple measurements are taken from a patient in each setting, and it is essential to average these measurements for increased efficiency. The scaling up of Zernike coefficients currently relies on mathematical formulas, which, however, do not incorporate information from outside the domain. In our study, a novel

approach was employed wherein the shape of the cornea was utilized in the extrapolation process, potentially providing additional insights into the extrapolation region. In the existing approach, the magnitude of the Zernike Coefficients increases as the pupil radius expands, whereas in our approach, the magnitude of the Zernike Coefficients changes in a random manner as the pupil radius expands. Finally, researchers who are interested in this field can also conduct further research on how this ray tracing approach affects the quality of vision and vision correction procedures for further investigations.

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Statistics



A Comparison of Performance of Classification Models in Predicting Life Insurance Policy Lapse – A Case Study

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ABSTRACT

The Sri Lankan insurance industry, a crucial economic component, is grappling more than ever before with challenges associated with policy lapses, significantly affecting its financial stability. Focusing on life insurance, the purpose of this research was to develop two classification models and compare their performances to identify the best fitted model to predict life insurance policy lapses, addressing a critical issue in the life insurance sector in Sri Lanka. The study utilized data from 1605 policies initiated in 2019, issued by a prominent insurance company in Sri Lanka. This dataset encompassed predictor variables such as insurance type, sum assured, age at entry, annual premium, policy term, gender, and premium frequency, while the valuation status was considered as the response variable for the Binary Logistic Regression (BLR) and Random Forest (RF) classification models. Univariate and bivariate analyses were conducted to understand policy lapses, while the Variance Inflation Factor was calculated to assess multicollinearity among predictors. The classification performance of the two models was compared based on the accuracy, precision, recall, f1-score and AUC-ROC. It was revealed that 81.25% of the total policies lapsed during a three-year period from the date of commencement. The evaluation metrics of the predictive models demonstrate that RF outperforms BLR, achieving an accuracy of 86% compared to 80%, in identifying policy lapses, particularly influenced by annual premium, premium frequency, age at entry and policy term. This model serves as a guide for insurers to proactively retain policyholders and minimize financial risks.

KEYWORDS: Lapse, Life Insurance, Logistic Regression, Random Forest

1 INTRODUCTION

Insurance is a contract between a policyholder and an insurer in which the policyholder pays a premium to transfer the risk of potential financial loss to the insurer, who underwrites this uncertainty. Insurance policies have terms, conditions, and exclusions that specify what is covered and what isn't. Therefore, it is crucial for policyholders to be aware of these details before purchasing a policy in order to reduce the likelihood of policy terminations before the agreed-upon term. In the insurance industry, the term “lapse” is defined as the cancellation of a policy cover due to non-payment of a premium (Financial Sector Conduct Authority,

2015). However, the policyholder is given a grace period to settle the payment before the lapse; otherwise, the policy is considered lapsed. The primary purpose of life insurance is to provide financial security to beneficiaries in case of the policyholder's demise. When a policy lapses, this protection is no longer available, leaving dependents financially vulnerable. Changes in financial situations, economic hardships, a lack of knowledge about terms and conditions and poor customer service are some of the key factors that lead to lapse decision (Subashini & Velmurugan, 2015).

The life insurance industry, being one of the highly competitive sectors in Sri

Lanka, faces the issue of an increasing lapse rate. When policies lapse, insurance companies lose the steady stream of premium payments. This loss directly affects their revenue and profitability, especially if a substantial number of policies lapse simultaneously. The study is to address the pressing issue of policy lapses in life insurance by identifying the best predictive model that can be used to identify and control future risk and uncertainties due to policy lapses.

2 LITERATURE REVIEW

In recent years, there have been several studies concerning the life insurance policy lapses and related factors. Reck et al. (2023) employed an automated Lasso approach revealing that policy features, customer demographics, and economic factors significantly contribute to lapse behavior. The automated Lasso approach allowed for a precise identification of these factors, enhancing the industry's ability to predict and manage lapse rates effectively. Fier & Liebenberg (2013) identified the adverse consequences for insurers when life insurance policy lapses deviate substantially from expectations. The study highlighted the importance of age as a moderating factor in lapse decisions. Their findings revealed a relationship between age, income changes, and lapse decisions. Subashini & Velmurugan (2015) employed a Garrett Ranking analysis which identified miss-selling of the product, financial burden to the policyholders, and high premium rates as the major determinants contributing to the high rate of lapsation in the insurance sector in India. Koju et al. (2020) investigated the impact of lapse rate and revival rate on net worth, profitability, life

fund, and total premium income of life insurance industries in Nepal over the period 2010-2019. The study employed Generalized Method of Moments for empirical estimation. Their research uncovered the socio-economic factors influencing lapse rates in Nepal, emphasizing the need for region-specific strategies. On the other hand, Dias et al. (2020) was focused on understanding lapsation in life insurance policies in Kandy, Sri Lanka, a qualitative approach was adopted. The findings highlighted financial strain among business clients, seasonal income patterns leading to lapses, mis-selling by agents under target pressure, and poor customer-agent relationships causing distrust and policy lapses. Jayetileke et al. (2017) explored factors influencing the persistency of life insurance policies in Sri Lanka, focusing on policyholder characteristics. Using survival analysis, it identifies age, gender, marital status, and mode of payment as significant factors affecting policy persistency. Fernando et al. (2015) investigated factors influencing life insurance policy lapses from the perspective of agents at XYZ Life Insurance. Focusing on education and experience, a multiple regression model is built, revealing a negative correlation between agent education/experience and policy lapse percentage. The model suggests that increasing education and experience reduces lapses. Amid the growing problem of policy lapses in Sri Lanka, there remains a dearth of studies aimed at categorizing policies as lapses upon their commencement using policyholders' information. Addressing this gap could potentially mitigate future lapse rates by directing greater attention toward such policies.

3 METHODOLOGY

This research aims to build and compare the performance of two classification models, namely the Binary Logistic Regression (BLR) model and the Random Forest (RF) model, to determine the best model for predicting policy lapses. Initially data were pre-processed and undergoes thorough cleaning to ensure its quality. Subsequently, univariate analysis is conducted, employing descriptive statistics and visualizations to understand the distribution and patterns of individual variables. Next, the Chi-square test of association was conducted to observe the relationship between the response variable and each of the categorical predictor variables. Then, multicollinearity among the predictor variables were tested using the Variance Inflation Factor (VIF). This approach ensures a comprehensive understanding of variable dynamics, relationships, and potential multicollinearity issues that might impact the subsequent model building process. The One-hot encoding technique is employed to convert categorical predictor variables into numerical ones. Subsequently, a binary logistic regression model and a random forest model were constructed, trained, and evaluated using their respective training and testing datasets. The performance of the two classification models was evaluated on the testing set using established metrics such as accuracy, precision, recall, the confusion matrix, and the AUC-ROC curve. Finally, the model with higher values for these metrics was selected as the best model for predicting policy lapses. Additionally, the

most influential factors for policy lapses were identified.

4 DATA COLLECTION AND ANALYSIS

A secondary dataset comprising 1605 life insurance policies issued by ABC insurance company over the 2019 calendar year was collected from the company's database. This dataset consisted of the valuation status (Lapse/Active), which served as the response variable, and predictor variables including Insurance Product Type, Sum Assured, Policy Term, Annual Premium, Premium Frequency, Age, and Gender of the policyholder. The dataset was divided into 80%:20% and 70%:30% ratios for training and testing. Both BLR and RF models were trained and tested on both splits to determine the model performance based on test data size. Moreover, the quantitative predictor variables, Sum Assured, Annual Premium and Age were rearranged to make them categorical to perform Chi-square test of association.

5 RESULTS AND DISCUSSION

It was revealed that the most popular insurance policy types among the policyholders were AIP 7 and AIP 4 in the year 2019. However, a higher lapse rate can be observed for those policies. Almost all customers who commenced policies in the year 2019 preferred monthly premium frequency over quarterly, bi-annual, and annual payments. Additionally, within the pool of customers, 65% were male, and out of this group, 85% experienced lapses in their policies. Furthermore, it was observed that a total of 81.25% of the policyholders who commenced in 2019 had lapsed within the three-year period

Table 1: Comparison of models’ prediction performance

Test data size	Model	Accuracy	Precision	Recall	F1-score	AUC-ROC
0.2	BLR	0.80	0.74	0.80	0.77	0.61
	RF	0.86	0.88	0.85	0.80	0.94
0.3	BLR	0.79	0.74	0.80	0.76	0.59
	RF	0.86	0.87	0.84	0.79	0.94

from the commencement date. The chi-square test revealed that all predictor variables have a significant relationship with the valuation status. Additionally, the absence of multicollinearity among the predictor variables was confirmed, as all VIF values associated with these variables were below 10. The BLR model for policy lapses is given in (1).

$$\begin{aligned}
 \text{Logit}(\text{Valuation status}) = & 1.960 - \\
 & (0.0027 \text{ Sum Assured}) - \\
 & (0.0278 \text{ Age at Entry}) + \\
 & (0.0059 \text{ Annual Premium}) - \\
 & (0.0081 \text{ Policy Term}) + \\
 & (0.5488 \text{ Insurance Type_AIP2}) - \\
 & (1.0790 \text{ Insurance Type_AIP3}) + \\
 & (0.3250 \text{ Insurance Type_AIP4}) + \\
 & (1.2054 \text{ Insurance Type_AIP5}) - \\
 & (0.2305 \text{ Insurance Type_AIP6}) - \\
 & (0.4208 \text{ Insurance Type_AIP7}) + \\
 & (0.8575 \text{ Premium Frequency_2}) - \\
 & (0.0347 \text{ Premium Frequency_4}) + \\
 & (0.9497 \text{ Premium Frequency_12}) \quad (1)
 \end{aligned}$$

According to the BLR model, it can be observed that insurance type, premium frequency, age at entry, policy term, and annual premium are significantly contributing to the policy lapse decision. Table 1 shows the performance evaluation metrics of the two models (BLR and RF) for test sizes of 0.2 and 0.3. It was observed that the RF model consistently achieved an 86% prediction accuracy for both test sizes, surpassing the BLR model, which attained 80% accuracy for a test size of 0.2. Moreover, the AUC-ROC

score for the RF model remained unchanged (0.94) across both test sizes, while BLR model scored 0.61 and 0.59 for the test sizes 0.2 and 0.3 respectively. The higher AUC-ROC values indicate that the RF model achieves a better balance between true positive and false positive rates, emphasizing its effectiveness in distinguishing between active and lapsed policies. The precision, recall, and F1-score metrics further affirm the robustness of the RF model in capturing and predicting lapses in the life insurance policies. Moreover, based on the feature

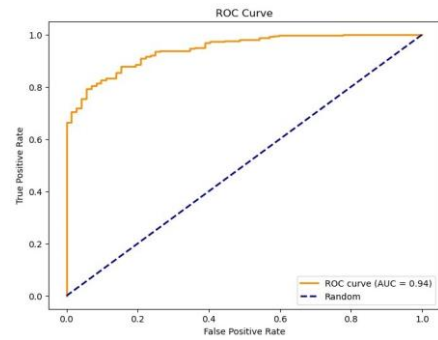


Figure 1: AUC-ROC curve of RF model (test size = 0.2)

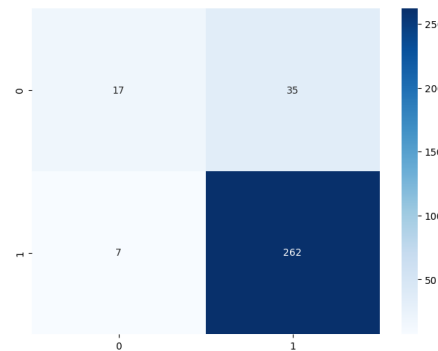


Figure 2: Confusion matrix of RF model (test size = 0.2)

importance of the RF model, annual premium, premium frequency, age at entry, and policy term were identified as the most influential factors for policy lapsation. Fig. 1 and Fig. 2 show the AUC-ROC Curve and the Confusion Matrix of the RF model, respectively, for a test size of 0.2, which showed better performance than a size of 0.3. In Fig. 1, a high AUC-ROC value of 0.94 demonstrated strong discriminatory power in distinguishing between lapsing and active policies. In Fig. 2, the model correctly identified 17 "Active" instances and 262 "Lapse" instances but misclassified 7 "Lapse" instances as "Active" and 35 "Active" instances as "Lapse. In summary, it is evident that the Random Forest model consistently provides superior predictive capabilities for identifying policy lapses compared to the Binary Logistic Regression model. Thus, affirming the Random Forest as the optimal algorithm for predicting policy lapses.

6 CONCLUSION

The lapse of a life insurance policy can have significant impacts on both the policyholder and the insurer. Therefore, understanding the causes of lapses and predicting lapses is crucial for both policyholders and insurers to maintain a healthy relationship and ensure financial stability. It was found that over a three-year period from the commencement of policies, 81.25% of policyholders lapsed. Furthermore, it was observed that lapses are more likely to occur with higher annual premiums, more frequent payment frequencies, an older age at which policyholders enter the insurance contract, and specific policy types. The RF model outperformed the BLR model

in predicting lapses, making it the chosen classifier for lapse classification. This information aids insurers in formulating customer retention strategies aimed at reducing future lapse rates.

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Analysis of Stock Market Reactions to Quarterly Financial Results in Banking Sector of Colombo Stock Exchange

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ABSTRACT

This research was conducted using daily stock prices of the CSE in the banking sector spanning from 2013 to 2020. The primary aim of the research was to determine whether positive indications in quarterly financial results lead investors to buy and increase demand for a stock, and conversely, whether negative indications result in decreased demand. The focus of the study was on detecting any discernible relationship between a company's financial success in a specific quarter and the subsequent returns observed in its stock. Under this main objective, the volatility pattern of stock returns was analyzed using both symmetric and asymmetric models. Additionally, appropriate Generalized Autoregressive Conditional Heteroscedastic (GARCH) family models were constructed with using event study method for S & P SL 20 companies in the banking sector, with a particular focus on five major banking sector companies within the S & P SL 20 index. Considering 2 days around the event, the Mean equation indicates that the effect of the event has been distributed between -4% to +27%, and the volatility of the effect of the event has ranged between -10% to +10%. When considering other cases (n=5 days, n=10 days, n=15 days) the Mean equation reveals that the effect of the event has varied between -7% to 10%, with the volatility of the effect ranging from -8% to 6%. The quarterly financial results, which serve as indicators of the financial health and growth of the company, were highlighted as crucial factors influencing investors' strategic decisions. Investors are aided by quarterly financial results in making informed and strategic decisions.

KEYWORDS: Generalized Autoregressive Conditional Heteroscedastic Models, Quarterly Financial Results, Weak-form Efficiency

1 INTRODUCTION

Literature for the past decade has, to a certain extent, addressed modeling stock return and EPS in Sri Lankan context. But most of them had been analyzed using linear regression model only for small time periods.

So, the purpose of this study is to identify the behavior of the stock return and volatility around quarterly financial results announcement in CSE, using event study methodology and ARCH/ GARCH/ GJR- GARCH/ EGARCH with dummy variables for during the days before, before and after, after the

quarterly financial results announcement date.

This is a state of the art study that intends to use Time Series Analysis identify the stock return patterns close to quarterly financial results announcements.

2 LITERATURE REVIEW

A study conducted in Iran by Shabani et al. (2013), identifies correlation among earnings per share (EPS) and returns predicted for each share with stock price. The findings indicated positive correlation between earnings per share and stock price of

randomly selected companies in Iran's stock market from 2000 to 2010.

Jerris (2011) has examined the association between stock returns and dilutive earnings per share numbers. Analyzing 392 pooled observations on 101 firms from 1976 to 1979, the findings indicated a positive correlation between EPS and diluted stock returns, highlighting the association between these financial metrics.

Tamuntuan (2015) examined the impact of EPS on share prices using data from 12 food and beverage companies listed on the Indonesian stock exchange from 2010 to 2014. The findings showed a significant positive effect of EPS on share prices, as well as on return on equity and return on assets, emphasizing its importance in investors' decision-making and potential for higher returns.

Ramesh & Rajumesh (2015) have conducted research to determine investors react to political events. The study used a sample of 40 significant political events that took place on the CSE's emerging market between 2008 and 2012 to analyze market efficiency and the market's response to political events. The study examined market efficiency and the investor's reaction to political events using a sample of 40 key political events that occurred on the CSE's developing market between 2008 and 2012. The findings were derived using standard event study methodology. The outcomes were determined by using standard event study technique. The results showed that there were significant negative Average Abnormal Returns (AARs) of -2.27 percent on the date of the political event, with strong negative significance ($t=-3.27$) at the 1% level. This was indicated that political events

provide unfavorable information to the CSE, resulting in adverse market reactions. These negative CAARs have shown that investors anticipate negative future cash flows for the Sri Lankan stock exchange following political events. Furthermore, the rapid market response to political risk information indicates the effective communication of information to investors.

Morawakage & Nimal (2015) have conducted a study to identify the volatility of CSE. The complicated volatility features are identified by using the GARCH, EGARCH, and TGARCH models. Leverage effect and volatility clustering have been identified at CSE. Furthermore, negative shocks cause more volatility than positive shocks in the CSE. This study evaluated different models by using the Akaike and Schwarz information criteria and the TGARCH model with a student-t probability distribution function which is considered appropriate for explaining the volatility in the models presented above.

Silva et al. (2016) have conducted this research to identify the effect of the day of the week on ASPI of CSE and compared prediction ability of GARCH model and 'Nonlinear Autoregressive model with inputs' (NARX), for the period of 1st of January 2007 to 28th of February 2015. The research included additional exogenous parameters, including the gold price, world crude oil price, Sri Lanka Inter Bank Offer Rate (SLIBOR), exchange rate, and the day of the week effect, in calculating the conditional return and conditional volatility. According to the findings, the CSE is influenced by the day of the week. It appears that the first two days of the week have thin trading behavior, but

the last three days of the week have active trading behavior. According to findings of this study, it is shown that purchasing shares on Tuesday and selling them on Thursday and Friday tends to yield favorable results.

Gunathilaka & Kongahawatte (2011) have conducted a study to examine the market's reaction to the announcement of 40 stock splits on the Colombo Stock Exchange (CSE) between 2007 and 2010. It has been discovered that stock split announcements significantly improve the market. Irrespective of the firm's current situation, the split's intended outcome, or future prospects for the firm, the size of the split is positively correlated with abnormal returns. Following the announcement, the stock's trading volume increased dramatically. The liquidity hypothesis was proposed as a comprehensive explanation for the occurrence of stock splits. According to findings from this study, it was observed that there were quick changes in stock prices and the conclusion was that the market operated efficiently

3 METHODOLOGY

The key focus of this research is to analyze the behavior of stock return and volatility around quarterly financial result announcement in the banking sector of CSE. Hence, the focus is to determine the potential relationship between stock returns and quarterly financial results. The event window was considered as 2 days, 5 days, 10 days and 15 days before, after, before and after the date of the release of quarterly financial information in the Colombo Stock Exchange. Selecting the log return as the dependent variable in this study stems from the necessity to meet stationary condition. The analysis were begun by

fitting the Ordinary Least Squares (OLS) model with three independent variables (dummy variables): "Pre event," "Post event," and "Pre and Post event". The dependent variable was calculated as given in the following Equation (1).

$$\begin{aligned} \text{Stock Return (in day } T) \\ = \log \frac{[Price(T)]}{[Price(T-1)]} \end{aligned} \quad (1)$$

The dataset was analyzed first to determine the existence of the Autoregressive Conditional Heteroskedasticity (ARCH) impact. If no ARCH effect as identified, the fitted model was examined for residual autocorrelation.

If there was no indication of autocorrelation in the residuals, testing for normality was done next. If the residuals were shown a normal distribution, the model was considered the best fit for describing the dataset. If autocorrelation was found in the residuals, the model was modified by inserting lag values of the dependent variable into the regression model. The residual of the new model was checked again for normality. If the residuals were normally distributed, the new model was considered as offering the best accurate representation of the data. If the ARCH effect existed in the dataset, different GARCH (Generalized Autoregressive Conditional Heteroskedasticity), EGARCH (Exponential GARCH), or GJR-GARCH (Generalized Autoregressive Conditional Heteroskedasticity) models were fitted till the ARCH effect was removed and there were no autocorrelation in the residuals. The residuals of the chosen GARCH-type model were finally checked for normality.

4 DATA COLLECTION AND ANALYSIS

S&P SL20 companies are dynamic. Hence, it is not possible to define a set of companies for a horizon of eight years. When compared, banking sector is the most stable sector in Colombo Stock Exchange. Hence, for the mere study purposes, the current S&P SL20 companies in the banking sector with a particular focus on five major company data were considered from 2013 to 2020.

S&P SL 20 banking sector companies are given below.

- Commercial Bank
- DFCC Bank PLC
- Hatton National Bank PLC
- National Development Bank
- Sampath Bank PLC

Data sources used for this study are as follows;

- CSE publications
- Quarterly Financial Results of S&P SL20 companies.

5 RESULTS AND DISCUSSION

This study is based on a statistical analysis of stock return and quarterly financial results in CSE banking sector during the period of 2013 to 2020. The main objective of this research was to identify investors 'reaction' direction to the broad 'earnings' of a given quarter for a company.

Under this main objective, volatility pattern of the stock return was analyzed by using symmetric and asymmetric model. Apart from that, appropriate Generalized Autoregressive Conditional

Table 1: Summary of (n=2) event window

Company Name	n=2						
	Mean equation			Variance equation			
	Pre Event	Post Event	Pre & Post	Pre Event	Post Event	Pre & Post	
Commercial	0.98%	4.52%	5.37%	-	10.47%	2.55%	-8.75%
Sampath	27.17%	23.99%	20.31%	10.71%	-2.26%	4.23%	-
NDB	1.81%	14.90%	-	2.85%	7.73%	-	-
DFCC	-	-4.30%	0.42%	-	4.42%	5.65%	-

Heteroscedastic (GARCH) family models were built for S & P SL 20 companies in banking sector. This study was included five main banking sector companies in S & P 20 companies.

Table 2: Summary of (n=5) event window

Company Name	n=5					
	Mean equation			Variance equation		
	Pre Event	Post Event	Pre & Post	Pre Event	Post Event	Pre & Post
Commercial	-1.27%	-2.11%	-	-2.43%	+5.17%	-
Sampath	-	-	-	-	-	-
NDB	+1.61%	-	-	+1.02%	-	-
DFCC	+4.45%	-3.37%	-	+5.78%	-0.32%	-

ANALYSIS OF STOCK MARKET REACTIONS TO QUARTERLY FINANCIAL RESULTS IN
BANKING SECTOR OF COLOMBO STOCK EXCHANGE

Table 3: Summery of (n=10) event window

n=10						
Company Name	Mean equation			Variance equation		
	Pre Event	Post Event	Pre & Post	Pre Event	Post Event	Pre & Post
Commercial	+2.02%	-5.23%	-2.60%	-7.90%	+4.63%	-0.68%
Sampath	+9.71%	+2.69%	+1.53%	-0.64%	+2.85%	+2.09%
NDB	-	-3.64%	-0.27%	-	+4.23%	+3.77%
DFCC	-	7.37%	-	-	0.45%	-

Table 4: Summery of (n=15) event window

n=15						
Company Name	Mean equation			Variance equation		
	Pre Event	Post Event	Pre & Post	Pre Event	Post Event	Pre & Post
Commercial	+0.38%	-3.89%	-4.05%	+2.10%	+2.73%	+0.06%
Sampath	-	-	-	-	-	-
NDB	-	-	+0.09%	-	-	+5.77%
DFCC	-	-8.42%	-	-	-0.17%	-

This study finds that the market has weak-form efficiency. In that event (n=2), Mean equation shows that the effect of event has spread between -4% to +27% and also volatility of effect of

event has spread between -10% to +10%. Considering other events, mean equation shows that the effect of event has spread between -7% to 10% and also volatility of effect has varied between -8% to 6%.

Commercial Bank and Sampath Bank have shown significant variations in mean and variance equations before and after the event, especially in n=2 event window and n=5 event window. DFCC Bank and NDB also exhibit sensitivity to the event, with changes in mean and variance equations across different events. Considering the Table 1 to Table 14 event windows given above, it was noted that when the event dates have increased, event effect would go down and most of investors have responded in short time period. Significant effect has shown only in event day and day after event (event window n=2). Other events (n=5,n=10,n=15) have shown low effect range. Quarterly financial results are helping investors to make smart strategic decisions. This effect sensitivity range is not a good sign for investors.

According to the literature review, most of the researchers are in an attempt to find the relationship between stock return and earnings per share using correlation as the indicator and have shown a positive correlation.

6 CONCLUSION

This study reveals that a significant number of investors have exhibited notable reactions over a two day event window in Sampath and Commercial banks. However, when considering the overall performance of the banking sector, most of investors are responded in small time periods. Considering all the

details in this study, it is concluded that the investors do not efficiently react to the quarterly financial results. This evidence supports the week form efficiency of the Colombo Stock Exchange. Overall, it is important for investors to consider a variety of factors when making investment decisions, including both short-term and long-term performance and, other market factors and trends as well.

In line with many theories related to capital markets, this study also shows that it is impossible to limit the behavior of the stock prices only to one variable announcement at a given day and the movement of the T day stock prices. These observations may be due to a number of reasons namely news, fiscal and monetary decisions announced in a given day, actions of foreign investors in different countries, movement of exchange rates and etc. As future studies, there is a greater possibility in using Multivariate Analysis to further improve the sensitivity of the results.

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Analysis of Time Series Model for LKR/USD Exchange Rate Volatility

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ABSTRACT

The exchange rate refers to the value at which one currency can be exchanged for another currency. The most common and widely referred exchange rate in Sri Lanka is the LKR/USD exchange rate. This study was conducted in order to analyze and model the daily LKR/USD exchange rate volatility based on time series analysis. In this study, the symmetric Generalized Autoregressive Conditional Heteroskedasticity(GARCH) model was employed to assess and model the volatility of the daily LKR/USD exchange rate in Sri Lanka. Stationarity of the data was assessed by using the Augmented Dickey-Fuller (ADF) test. Following this, a conditional mean model, ARIMA(4, 1, 2) was applied to the differenced series. After checking residuals of the ARIMA(4, 1, 2) model, conditional heteroscedasticity in residuals of fitted ARIMA(4, 1, 2) model was detected using Autoregressive Conditional Heteroskedasticity Lagrange Multiplier(ARCH LM) test. In response to these findings, a conditional variance model, GARCH(1,1) was developed for forecasting LKR/USD exchange rate volatility. Finally, the ARIMA(4, 1, 2)-GARCH(1,1) was selected as the best model for the volatility forecasting. The accuracy of the model was measured by using Mean Absolute Percentage Error (MAPE), Root Mean Square Error (RMSE) and Mean Absolute Error (MAE) which results in 9.18%, 2.61233 and 2.17356 respectively.

KEYWORDS: ARIMA, GARCH, MAE, MAPE, RMSE

1 INTRODUCTION

Exchange rates play a pivotal role in the economic landscape of Sri Lanka, as they do in countries around the world. Sri Lanka has experienced periods of exchange rate volatility and stability, influenced by both internal and external factors. The country's exchange rate policy has evolved over time in response to changing economic conditions and government priorities.

1.1 Significance of the Study

Understanding and managing exchange rate volatility contributes to overall financial stability, reducing financial crises and supporting sustainable economic growth. And also it helps businesses, investors and policymakers make informed decisions, manage risks and formulate effective

strategies in the dynamic foreign exchange market.

1.2 Objective of the Study

The objective of the study is to analyze the behavior of the daily LKR/USD exchange rate volatility to construct a more appropriate time series model for daily LKR/USD exchange rate volatility and evaluate the forecasting performance of the model.

2 LITERATURE REVIEW

In past studies, few researchers have analyzed the exchange rates and importance of the modeling exchange rate volatility. They have proposed different modeling methods for forecasting exchange rate volatility.

Thevakumar and Jayathilaka (2022) has investigated the possibility of modeling the exchange rate volatility of

the LKR/USD currency pair and analyzed whether macroeconomic factors such as inflation, interest rate, remittances, gross official reserve, money supply growth and trade balance influence the exchange rate. This study was based on the average monthly data over the period from January 2009 to May 2021. He has identified ARIMA(1,0,0)-ARCH(1) as the best fitted model to fit volatility.

Lingaraja et al. (2020) investigated the long-term volatility and causality effects of the LKR and nine Asian emerging countries' currencies against the USD. Utilizing descriptive statistics, GARCH (1,1) model, correlation and Granger Causality test, the analysis reveals significant currency movements.

Kandearachchi (2018) has analyzed the changes in volatility of exchange rates focused on LKR/USD for the period of January 2000 to August 2018. He has proposed AR(2)-GARCH(1,1) model for measuring the LKR/USD daily exchange rate volatility. This findings highlight the dynamic nature of LKR/USD exchange rate returns, which appear to respond swiftly to global market fluctuations.

Abdalla (2012) has investigated the exchange rate volatility in nineteen Arab countries using daily observations. He has examined modeling and forecasting performance of GARCH (1, 1) and asymmetrical EGARCH(1, 1) models. Finally, he concluded that the exchange rate volatility can be adequately modelled by the class of GARCH models.

3 METHODOLOGY

This study was based on the secondary data that were collected from

the Central Bank of Sri Lanka official website over the period of five years from January 2018 to February 2023. The analysis was done by using R software.

The Box-Jenkins method was employed to formulate a mean model. Initially, stationary of the series was checked by using ADF test. The findings of ADF test prove that the t-statistics of the series is greater than the critical value at the 5% significance level, outlining that the series is not stationary. Difference method should be done to create a trend or seasonally adjusted time series of daily time series data. The ACF and PACF were used to identify mean model. Significant ACF and PACF lags suggest MA terms (q) and AR terms (p) respectively.

Following the assessment of parameter significance, it is imperative to evaluate the goodness of fit for the model. In order to check randomness and normality of residuals, serial Correlation LM test and Jarque-Bera test can be employed.

3.1 GARCH Model

Bollerslev (1986) generalized Engle's model to make it more realistic, called GARCH model. The GARCH model is an extension of the ARCH model. It is a widely used statistical model in time series analysis and econometrics to model and forecast the volatility, or the time-varying variance, of financial returns or other time series data. The GARCH model was introduced to address some limitations of the ARCH model by incorporating lagged conditional variances in the modeling process. GARCH model cannot capture the asymmetric performance.

4 RESULTS AND DISCUSSION

Table 1 depicts descriptive statistics of the daily exchange rates. It shows the maximum and minimum rates are Rs.369.03 and Rs.152.87 respectively.

Fig. 1 shows the time series plot and it illustrates that there is an upward trend pattern in daily LKR/USD exchange rate series. And also, it shows that data are not stationary. Within this period, there is a considerable growth in the exchange rate noted after February 2022. Such fluctuations happen due to various economic, political, and environmental factors, both domestic and international.

According to Table 2, ADF test confirms that original series is not stationary (P-value > 0.05). After the first order differencing, ADF test reveals that differenced data are stationary (P-value < 0.05).

Fig. 2 shows ACF and PACF plots for the first differenced series.

Table 1: Descriptive Statistics of Daily LKR/USD Exchange Rate 2018-2023

Mean (Rs.)	SD (Rs.)	Max (Rs.)	Min (Rs.)
214.69	69.28	369.03	152.87

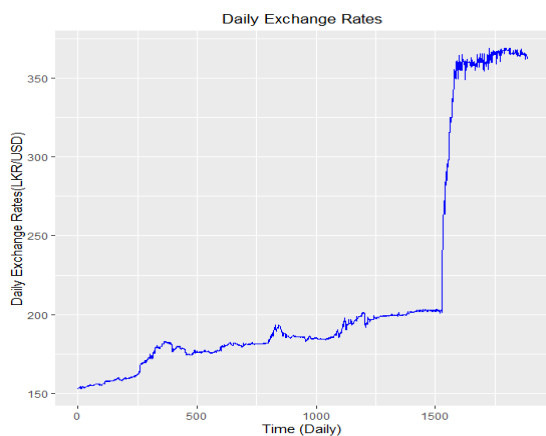


Figure 1: Time series plot

Table 2: Augmented Dickey-Fuller test

	Original	Differenced
P-value	0.99	0.01

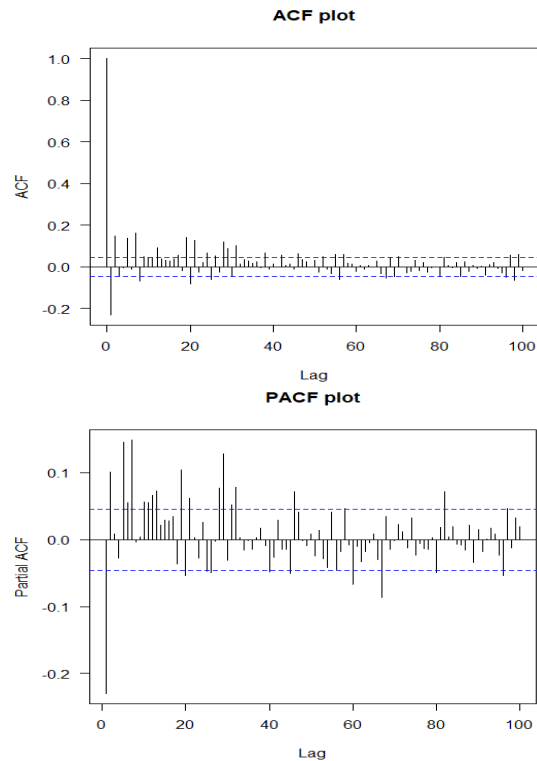


Figure 2: ACF and PACF plots

According to Fig. 2, significant ACF and PACF suggest $q = 2$ and $p = 2$ respectively. Based on the Akaike Information Criterion(AIC), Bayesian Information Criterion(BIC) values, ARIMA (4,1,2) is the most suitable model among the suspected models to forecast the exchange rate volatility where all the parameters are significant at their respective significance levels.

Table 3 shows the results of residuals diagnostic tests. According to ARCH LM test result, conditional heteroscedastic behavior is present and there exist volatility clusters among residuals. The GARCH model must be fitted to remove this impact.

Table 3: Residuals Diagnostic Tests on ARIMA(4,1,2) Model

Test	P-value	Conclusion
Serial correlation	0.1298 > 0.05	Residuals are random
LM test		
Jarque-Bera test	0.5269 > 0.05	Residuals are normal
ARCH LM test	2.2e-16 < 0.05	Residuals have volatility

Here, four GARCH models were fitted as GARCH(1,1), GARCH(1,2), GARCH(2,1) and GARCH(2,2). Table 4 depicts the values of AIC, BIC and Hannan-Quinn Criterion(HQC) for the above GARCH models. Hence, ARIMA (4,1,2) – GARCH (1,1) was selected as the best conditional variance model which has the minimum value for all three information criterion.

Thereafter, asymmetric effect on this model was examined via a sign bias test and results are shown in Table 5. P-value of sign bias test exceeds 0.05. This result is leading to the conclusion that there is no asymmetric effect in residuals.

Table 4: GARCH(p,q) model related to ARIMA(4,1,2)

Model	AIC	BIC	HQC
GARCH(1,1)	1.9328	1.9590	1.9428
GARCH(1,2)	1.9348	1.9599	1.9437
GARCH(2,1)	1.9359	1.9631	1.9459
GARCH(2,2)	1.9339	1.9640	1.9450

Table 5: Sign Bias Test

	P-value
Sign Bias	0.4227186
Negative Sign Bias	0.4841210
Positive Sign Bias	0.9914034

Table 6: Parameter Estimation of ARIMA(4,1,2)- GARCH(1,1)

	Estimate	Pr(> t)
ar1	-1.163267	0.00000
ar2	-0.245559	0.00000
ar3	-0.025955	0.02948
ar4	-0.008146	0.04391
ma1	0.942999	0.00000
omega	0.003612	0.00000
alpha1	0.136615	0.00000
beta1	0.862385	0.00000

As indicated in Table 6, the probabilities associated with the coefficients in both the mean equation and the parameters of the variance equation are all below 0.05. Therefore all the parameters are significant at 5% level of significant in the fitted model. By comparing the results, ARIMA(4,1,2)-GARCH(1,1) was selected as the most preferable model.

Normal Q-Q plot and density plot of the fitted ARIMA(4,1,2)-GARCH(1,1) are shown in Fig. 3. Normal Q-Q plot reveals that residuals are well fitted with the straight line. And also density plot visualizes distribution of the residuals very close to bell shape, which means residuals are normally distributed.

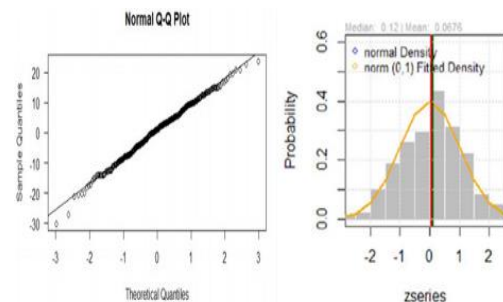


Figure 3: Normal Q-Q Plot and Density Plot of Residuals

Table 7: Forecasting Performance

Performance Metrics	Result
MAPE(%)	9.18
RMSE	2.61233
MAE	2.17356

Therefore, normality of residuals are confirmed by both plots in Fig. 3. After checking the adequacy of the model, it is proved that the ARIMA(4,1,2)-GARCH(1,1) model is the best for modeling exchange rate volatility.

Forecast performance of the fitted ARIMA(4, 1, 2)-GARCH(1,1) model was measured by using MAPE, RMSE and MAE and the results are shown in Table 7 and it is clear that the all error values are very low indicating a higher accuracy of the identified model.

5 CONCLUSION

This study mainly focused on the analysis and modeling of the daily LKR/USD exchange rate volatility. Overall, it revealed a noticeable upward trend in the exchange rate over 5 years from 2018 to 2023. Within this period, numerous upward and downward trend patterns were observed. These fluctuations serve as the basis for constructing the univariate model, which seeks to capture and understand the complexities of these exchange rate movements. The novelty lies in the inclusion of the most recent data could provide insights into the exchange rate's behavior under the latest economic conditions, including pandemic effects(covid-19), policy changes and other macroeconomic factors that were not present in previous studies. The ARIMA(4, 1, 2)-GARCH(1,1) model was chosen for forecasting the daily

LKR/USD exchange rate volatility due to the market's inherent volatility. This model, with its symmetric GARCH component, effectively captures the fluctuations in the exchange rate, accounting for the changing conditional variance and errors over time.

Moreover, the forecast performance of the model was evaluated and MAPE, RMSE and MAE were found to be 9.18%, 2.61233 and 2.17356 respectively. These results show ARIMA(4, 1, 2)-GARCH(1,1) is the best fit model and can be used for modeling and forecasting of daily LKR/USD exchange rate volatility in Sri Lanka.

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Application of an Automated Threshold Selection Method for Modelling Extreme Precipitation: A Case Study

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ABSTRACT

Extreme rainfall events, while infrequent, do manifest in various regions across the globe. By analyzing extreme rainfall, researchers and policymakers gain insights into the frequency and intensity of such events, which aids in risk assessment, infrastructure planning, and disaster preparedness. The Peak-Over-Threshold (POT) approach of Extreme Value Theory (EVT) is widely used for modeling extreme events, yet traditional threshold selection methods for POT can be subjective and inconsistent. The aim was to model daily extreme precipitation using an automated, computationally efficient threshold selection method and calculate return levels. The daily rainfall data from 2013 to 2023 in Katunayake, Sri Lanka, was utilized for this study. A graphical method was combined with an automated threshold selection technique to determine the optimal threshold for the POT approach. Then the goodness of fit for the Generalized Pareto distribution (GPD) on extreme rainfall data obtained from EVT was assessed using probability and quantile plots. Finally, return levels were calculated using the best fitted model. It was revealed that the daily rainfall over the last decade was heavy tailed. The best-fitted probability distribution for extreme rainfall in Katunayake was GPD (shape=0.33 and scale=22.33). Moreover, return levels provide information on the anticipated average rainfall for this area at different times in the future. For instance, magnitudes of 160 mm and 407 mm could be expected in the Katunayake area once every 2 years and 30 years, respectively. This information helps relevant authorities develop preparedness plans and execute timely responses to mitigate the future adverse effects of heavy rainfall.

KEYWORDS: Extreme Rainfall, Extreme Value Theory, GPD, Threshold

1 INTRODUCTION

Rainfall is the primary means by which water from the skies descends to Earth. It is an important element of earth's water cycle and plays a major role in supporting life on the earth. Extreme precipitation refers to heavy or intense rainfall events that occur over a relatively short period of time, often resulting in significant impacts such as floods in lowlands and landslides in hilly or mountainous areas due to soil saturation and destabilization. These events are associated with a higher risk of loss of life and disruptions to day-to-day activities, particularly in areas where flood preparedness and early warning

systems are inadequate. Severe weather conditions, and their effects on aviation, degrade aircraft performance, ground operations, and passenger services (Cao et al., 2014). This leads to negative economic consequences, particularly as aviation serves as one of the primary sources of income for a developing country like Sri Lanka. Sri Lanka's rainfall has fluctuated notably in recent years, with increased extremes linked to rising global temperatures, leading to more severe weather events and heightened risks of extreme precipitation. Therefore, the necessity of continuous monitoring and preparedness for extreme rainfall and its associated hazards is

highlighted for the country's resilience. This study aims to apply Extreme Value Theory (EVT) along with an automated threshold selection method to identify the best distribution for extreme rainfall in Katunayake, Sri Lanka and thereby to provide return levels that could assist in preparedness for extreme rainfall in the future.

2 LITERATURE REVIEW

A profound understanding of the distribution of extreme rainfall is essential for effective risk management and informed decision-making. However, modeling extreme rainfall is particularly challenging due to the intricate, limited, and dynamic nature of the data, requiring sophisticated techniques to accurately capture and predict these extreme weather events. EVT is a better approach to deal with the challenges in modeling data with extremes (McNeil, 1997). Pickands (1975) has shown that, the excess values over sufficiently high threshold can be approximated by the GPD. Coles et al. (2001) provided an important overview of statistical methods for analysing extreme events, focus on the GPD and the Peaks Over Threshold (POT) method of the EVT. Also interprets the common graphical diagnostics for threshold choice. Min & Halim (2020) applied EVT to model maximum monthly rainfall within 30 years using Generalized Extreme Value (GEV) distribution. The return level is then computed using the fitted GEV model.

The selection of an appropriate threshold for the POT approach in EVT is challenging. Scarrott and MacDonald (2012) outlined diverse threshold selection methods in EVT's POT

approach, noting no single method as superior due to varied strengths and weaknesses in each. Thompson et al. (2009) focus on extreme value modeling for flood risk and coastal design, using EVT. They propose an automated threshold selection method based on changes in parameter estimates, aiming to address the subjectivity in threshold determination through the use of graphical methods. In a comprehensive analysis of rainfall was conducted by Malmgren et al. (2003) found distinct fluctuations associated with the four climatic seasons. These fluctuations included a reduction in rainfall in higher elevation areas and an augmentation of rainfall in the lowlands of the southwestern region of Sri Lanka during the southwest monsoon season. Riflan et al. (2022) identified several significant rainfall trends in Katunayake region in Sri Lanka, including positive trends in the mid-future, and negative trends in the far-future. Wickramagamage (2016) found that the second phase of the Northeast Monsoon and the Inter-Monsoon seasons have positive trends of rainfall in Katunayake. Thevakaran et al. (2019) focused on examining trends in extreme rainfall across 13 stations in Sri Lanka from 1961 to 2010. They utilized linear regression analysis to assess trend magnitudes and the Mann-Kendall test to evaluate statistical significance. Their findings revealed no discernible increasing or decreasing trends in extreme rainfall and are isolated events. Despite the significant impacts of extreme rainfall on Sri Lanka, studies in this area have been relatively scarce or limited in focus. This study aims to bridge this research gap by applying EVT alongside an automated threshold

selection method to accurately model extreme precipitation and provide valuable insights for the future.

3 METHODOLOGY

This study aims to model extreme precipitation behavior in Katunayake, Sri Lanka over the last decade, employing EVT along with an automated threshold selection method for return level calculations. Descriptive statistics were initially computed to grasp the rainfall patterns. Then, a two-step procedure was employed to identify the optimal threshold for the POT approach of the EVT. As a first step, a Mean Residual Life (MRL) plot was created to identify the linear range. This range was divided into 100 equally spaced intervals, and the cutoff points were chosen as the tentative thresholds. As the second step, automated threshold selection method was applied to find the optimal threshold (Thompson et al., 2009). Let u_1, u_2, \dots, u_n be $n(=100)$ equally spaced increasing tentative thresholds. Then define $\tau_{u_j} = \widehat{\sigma}_{u_j} - \widehat{\xi}_{u_j} u_j$ and $\sigma_{u_j} = \sigma_u + \xi(u_j - u)$ for each tentative threshold u_j where σ_{u_j} and ξ_{u_j} be maximum likelihood estimators of scale and shape parameter of the GPD fitted to data above each u_j and $u(\leq u_{j-1} < u_j)$, be a appropriate threshold, that is one for which values of $y > u$ can be modelled using the GPD with shape and scale of ξ and σ_u . Then the differences $\tau_{u_j} - \tau_{u_{j-1}}$ were calculated. The conclusion was that these differences follow a Normal distribution centered at 0 if u represents the optimal threshold. The shapiro test was used to check the normality of these

differences at 5% level of significance. The first threshold that accepted the null hypothesis of differences following a normal distribution, was considered as the optimal threshold (u), and the GPD fitted for this threshold was selected as the best model. The diagnostic plots, such as probability plot and quantile plot were used to test the goodness of fit of the GPD. Finally, return values were calculated using best fitted GPD for return periods 2, 5, 7, 10, 15, and 30 years.

4 DATA COLLECTION AND ANALYSIS

The daily rainfall data spanning from 2013 to 2023 for the Katunayake area in Sri Lanka were collected from the Department of Meteorology, Sri Lanka. Katunayake is one of the important cities in Sri Lanka, as it is home to the main international airport in the country. Extreme rainfall events in the vicinity of an airport can disrupt flight schedules, compromise the integrity of runways, and lead to ground-level flooding. These effects not only inconvenience travellers but also have broader economic and

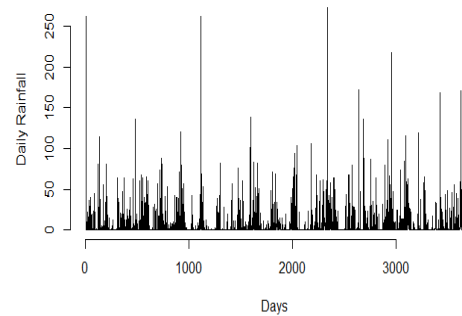


Figure 1: Time Series Plot of Daily Rainfall Data in Katunayake area.

Table 1: Return level along with return period

Return Period	2 year	5 year	7 year	10 year	15 year	30 year
Return Level(mm)	160.0859	220.8493	248.1240	280.4931	322.1591	407.4601

safety implications. Understanding the intensity and frequencies of these events is crucial for airport management and disaster preparedness. The POT approach of the EVT was chosen over the Block Maxima approach as it provides more extreme data for analysis. Since threshold selection from graphical methods can be subjective, this study employs both graphical and automated techniques to select the robust optimal threshold.

5 RESULTS AND DISCUSSION

Fig. 1 above represents the time series plot of daily rainfall in the Katunayake area, Sri Lanka. It depicts the existence of extreme rainfall events throughout the period considered for this study. It was revealed that the maximum and minimum daily rainfall during the study period were 272.3 mm and 0 mm, respectively. The positive skewness of 6.64 and the kurtosis of 72.35 signify a heavy-tailed distribution suitable for the daily rainfall data in Katunayake area during the period of study. The MRL plot was observed to be linear within the range from the 3rd quantile (3.625 mm) to the 98.65th quantile (67.4 mm). The 100 equally spaced points within this range were chosen as the tentative thresholds. The Shapiro test confirmed that the differenced data followed a Normal distribution after the threshold of 54.00725 mm. Consequently, this threshold was chosen as optimal for the

POT approach, identifying 88 days with rainfall above 54.00 mm as extreme. The best-fitted distribution for the precipitation over the optimal threshold of 54 mm was the Generalized Pareto distribution, with shape and scale parameters of 0.33 and 22.33 along with standard errors of 0.1363 and 3.7861, respectively. The shape parameter of GPD less than 1 implies that the distribution has heavy tail. The model diagnostic plots confirmed the appropriateness of the GPD for extreme daily rainfall received during the last decade in the Katunayake area. Table 1 above provides return levels in millimeters associated with different return periods, ranging from 2 to 30 years. For instance, when considering a 10-year return period, the anticipated magnitude of the event would be approximately 280.1240 mm. This signifies that an event of this magnitude can be expected once every 10 years on average in Katunayake area in Sri Lanka.

6 CONCLUSION

Extreme rainfall often leads to flooding, landslides, and severe impacts on the environment, infrastructure, and communities. Additionally, it has the potential to harm local economy, water quality, and transportation systems. Understanding and predicting the patterns and magnitudes of extreme rainfall are crucial for preparedness, infrastructure planning, and disaster mitigation efforts. It was found that the

daily rainfall data in the Katunayake area of Sri Lanka over the last decade exhibited a heavy-tailed distribution. During the study period, there were 88 days that had rainfall over 54 mm and were identified as extreme rainfall. The best fitted probability distribution for the extreme rainfall in Katunayake area during the study period was GPD with shape and scale parameters of 0.33 and 22.33 respectively. The return level after 2 years was found to be around 160 mm, whereas after 30 years, it will be about 407 mm. That is extreme rainfall with magnitudes of 160 mm and 407 mm could be expected in the Katunayake area once every 2 years and 30 years, respectively. This information is instrumental in mitigating the impact of extreme rainfall, facilitating the implementation of timely precautionary measures. With this understanding, airport authorities have the opportunity to craft protective measures for airport infrastructure, guaranteeing the continual safety and operational effectiveness of air travel. Concurrently, local communities can strategize by developing preparedness plans, reinforcing infrastructure, and implementing prompt responses to alleviate the detrimental impacts of intense rainfall events in future.

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Discovering Influential Factors in Employee Attrition using Multivariate Analysis of Variance

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ABSTRACT

Employee attrition poses a significant challenge for organizations, affecting productivity, team morale, and the financial bottom line. Understanding the causes of attrition and quantifying its effects is crucial for managers to develop effective strategies for minimizing its occurrence. Our research is based on a comprehensive examination of an organization's employee dataset, with a focus on numerous factors associated with attrition, including personal and professional attributes alongside available resources. The objective is to unravel the key contributors to employee attrition and devise targeted measures to curtail this phenomenon using Multivariate Analysis of Variance (MANOVA). Our extensive study attempts to uncover complicated connections between various factors - daily rate, distance from home, work experience, training frequency, and tenure since the last promotion - and their impact on attrition risk. Preliminary findings indicate that higher daily rates and longer commuting distances are related with a higher probability of attrition. Furthermore, persons with a track record of frequent job changes or limited training opportunities appear to exhibit signals of prospective dissatisfaction which may be associated with higher attrition risks. Employing these results, managers may design targeted interventions aimed at increasing employee retention and building a workplace culture that encourages long-term commitment and satisfaction among employees.

KEYWORDS: Employee Attrition, Factors Influencing Attrition, MANOVA

1 INTRODUCTION

Employee attrition, a prevalent challenge faced by organizations, refers to the departure of employees from their current positions for various reasons, including voluntary resignations, retirement, or involuntary terminations. High rates of attrition can significantly impact organizational stability, productivity, and overall performance, making it a critical concern for businesses across industries. Traditional approaches in studying employee attrition often involve exploring individual factors including job satisfaction, compensation, work-life balance, and organizational culture. However, employing advanced statistical methods including Multivariate Analysis of Variance (MANOVA) and binary

logistic regression provides a more holistic and nuanced understanding of the complex interplay among these factors and their collective impact on attrition.

The research provides vital implications for organizations combating employee attrition by exploring multifaceted factors. It aims to offer practical insights for tailored retention strategies, enhancing job satisfaction, workplace conditions, and organizational culture. These findings intend to help businesses create employee-friendly environments, ensuring stability, productivity, and enduring success.

2 LITERATURE REVIEW

Researchers have approached the subject of employee attrition from varied angles. Some investigations have scrutinized employee behaviors,

uncovering the motivations for their choices to remain with or depart from an organization. Conversely, other studies have employed to forecast employee attrition based on their historical records.

Barpanda et al. (2022) investigated employee attrition through structured and post-resignation interviews. Their study employed diverse analytical methods including correlation, paired sample t-tests, chi-square, and ANOVA, affirming human resource factors' significant impact on attrition and advocating continued post-resignation engagement. They emphasized the importance of developing relationships, providing enhanced work roles, and fostering chances for continuous learning to boost employee engagement and preserve organizational stability in information technology enabled-services.

Ersöz et al. (2021) employed seven algorithms, achieving 80% accuracy in identifying attrition factors. Limitations encompass dataset specificity and the need for nuanced comprehension beyond predictive accuracy to understand attrition complexities effectively.

Al-Darraji et al. (2021) emphasized decision-making's crucial role in managing employee attrition. The research enhanced attrition prediction using Artificial Intelligence (AI) and preprocessing approaches. It achieves 91% and 94% prediction accuracy employing balanced datasets and cross-validation, validating its practical utility.

Vinit and Dhruvesh (2013) highlighted evaluation, honesty, training, and resilience as vital for employee performance and retention using machine learning, but the study lacked exploration into contextual variations impacting these aspects.

Zahra et al. (2013) delved into the escalating impact of educational advancements on faculty turnover. The burgeoning number of universities has created abundant opportunities, leading to a noticeable paradigm shift and subsequently contributing to higher staff turnover rates.

Saleem et al. (2014) investigated how fairness in awards and growth opportunities affect employee departure. Using surveys and interviews, the study discovered these factors' impact, yet acknowledged limitations in potentially biased self-reported data and contextual scope.

George (2015) differentiated between two categories of retention factors. Organizational elements encompassed management practices, conducive work environments, social support mechanisms, and developmental prospects. Job-related factors included salary structures, autonomy in tasks, task satisfaction, and a balance between professional and personal life. The findings indicated that organizational factors had a greater influence on employee retention than job-related factors.

Our research uncovers how human resource factors collectively impact attrition, filling prior study gaps. Vital for tailored retention strategies and industry-specific interventions.

3 METHODOLOGY

In the research methodology, a comprehensive approach is adopted, starting with data preprocessing to ensure data quality. This included handling missing values, outliers, and normalizing variables for uniformity. Correlation analysis is conducted to explore relationships among variables, and highly

correlated variables are identified and, if necessary, removed to mitigate multicollinearity. Assumptions required for subsequent analyses are tested rigorously: Bartlett's test examined equality of covariance matrices across groups, while Shapiro-Wilk test evaluated normality assumptions of the dataset.

The choice of MANOVA for the research is driven by its capacity to assess whether significant differences exist between groups, while simultaneously considering the relationships among multiple dependent variables. This approach facilitates a more comprehensive understanding of the interplay between various factors and their collective impact on the outcome measures under investigation.

Afterwards, binary logistic regression is conducted with careful predictor selection and model fitting to analyze the impact of these predictors on a binary outcome variable. Thorough diagnostic checks, including assessments of model goodness-of-fit and predictive performance, are carried out. Result interpretation focuses on identifying significant predictors that influence the binary outcome, contributing to a nuanced understanding of the research problem.

4 DATA COLLECTION AND ANALYSIS

This study utilizes a dataset of 1,470 employees from two business types to predict employee attrition rates. Initially containing 35 independent variables—comprising categorical and continuous attributes—four attributes with identical values across all samples are removed. The remaining attributes serve as independent variables, while employee

Table 1: Correlations for correlated variables

Variables	Correlation
TW : MI	0.77
YM : YR	0.77
YC : YR	0.76
TW : AG	0.68
TW : YM	0.63
YM : MI	0.62

attrition classification, represented in binary format, acts as the dependent variable. Table 1 displays positive correlations among employment variables: Age (AG) moderately correlates with Total Working Years (TW); Monthly Income (MI) strongly correlates with TW. TW correlates with Years at Company (YC), while YC and Years in Current Role (YR) show a robust correlation. YR moderately correlates with Years with Current Manager (YM). Eliminating correlated variables above 0.60 (Johnson & Wichern, 2007), exploring hidden patterns becomes easier, reducing dataset complexity significantly. This process streamlines analyses, providing a more concise representation of crucial information and trimming redundancy in data dimensionality.

Table 2: Summary of Bartlett's K-squared Test results

Variables	K squared	Df	P Value
DR : DH	10.17	26	0.9977
MR: HR	22.986	70	1.0000
NC : PS	21.981	14	0.079
NC : TL	8.0769	6	0.2325
DR : PS	5.4805	14	0.9779
DR : TL	1.8862	6	0.9299
TL : YP	15.807	15	0.395

Notably, the evaluations between Daily Rate (DR) and Distance from Home (DH), Monthly Rate (MR) and Hourly Rate (HR), Daily Rate (DR) and Percent Salary Hike (PS), as well as Daily Rate (DR) and Training Times Last Year (TL), all exhibit notably high p-values, signifying negligible or absent associations. Although the test concerning the Number of Companies worked (NC) and Percent Salary hike (PS) displays a slightly lower p-value, hinting at a potential moderate relationship, this association doesn't meet standard significance thresholds (0.05). Overall, these results suggest a general absence of significant correlations between the evaluated variable pairs within the dataset.

The Shapiro-Wilk test for the independent variables ($W = 0.9738$, $p = 0.1902$) indicates reasonable adherence to normality ($p > 0.05$), supporting MANOVA's assumption. However, comprehensive checks for larger or non-normally distributed datasets remain crucial for robust analysis.

Table 3: Summary of Shapiro Test

Test Statistic (W)	P Value
0.9738	0.1902

Table 4: Summary of VIF values

Variables	VIF values
DR	1.006236
DH	1.006938
HR	1.004064
MR	1.002598
NC	1.009447
PS	1.003392
TL	1.004860
YP	1.004641

The VIF (Variance Inflation Factor) values provided indicate the level of multicollinearity among predictor variables in a regression model. The values, ranging from approximately 1.002 to 1.009, suggest minimal multicollinearity concerns. Typically, VIF values above 5 indicate problematic multicollinearity, but none of the variables here exceed this threshold. All variables exhibit VIF values relatively close to 1, implying low inter correlation among predictors. These results indicate that the predictors are not highly correlated, signifying that the regression model may be robust against multicollinearity issues, thereby allowing for reliable estimation of coefficients and inferences regarding the relationships between predictors and the outcome variable.

Table 5: Summary of MANOVA table

	Df	Pillai	approx F	Pr(>F)
DR	1	0.0038	2.794	0.041
DH	1	0.0061	4.506	0.011
HR	1	0.0001	0.083	0.919
MR	1	0.0005	0.350	0.704
NC	1	0.0034	2.524	0.040
PS	1	0.0002	0.172	0.841
TL	1	0.0076	5.628	0.003
YP	1	0.0012	0.920	0.028
Residuals	1461			

Table 6: Summary of the model

Variable	Estimate	Standard Error	z value	Probability(> z)
	-1.3293	0.2445	-5.437	5.41e-08
DR	-0.5644	0.2489	-2.267	0.02338
DH	0.6918	0.2343	2.953	0.00315
NC	0.4176	0.2504	1.668	0.0053
TL	-0.7171	0.3458	-2.074	0.0081
YP	-0.4690	0.3555	-1.319	0.0071

$\log(p/(1-p)) = -1.3293 + (-0.5644) * \text{DailyRate} + 0.6918 * \text{DistanceFromHome} + 0.4176 * \text{NumCompaniesWorked} + (-0.7171) * \text{TrainingTimesLastYear} + (-0.4690) * \text{YearsSinceLastPromotion}$ (1)
;where $p=P(\text{success})=P(\text{Attrition}=1)$.

Equation (1) reveals significant associations for daily rate, distance from home, number of companies worked and training times last year suggesting their potential impact on the outcome variable. However, years since last promotion demonstrated a borderline significance ($p = 0.0071$), while the intercept was highly significant ($p < 0.001$).

5 CONCLUSION

The study emphasizes significant factors of employee attrition. Daily Rate (DR) and Distance from Home (DH) showcase potential dissatisfaction triggers, potentially fueling attrition. Moreover, a higher count of previously Number of worked Companies (NC), fewer training sessions, and prolonged time since the last promotion correlate with heightened attrition likelihood, hinting at potential dissatisfaction or engagement issues. These multifaceted insights shed light on the interrelation between these factors, revealing their collective influence on employee attrition

within the specific organizational context studied, emphasizing the complexity and multifactorial nature of attrition dynamics.

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Employee Satisfaction in Fast Moving Consumer Goods Industry: A Case Study

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ABSTRACT

Employee satisfaction is a vital factor which reflects the development of any company. This study was carried out to identify the effect of employee's age, gender, educational level, work experience and number of family members on employee satisfaction in a company related to Fast Moving Consumer Goods (FMCG). The data was collected through questionnaires from all 200 employees in the company and Binary Logistic Regression (BLR) was used to identify the factors affecting employee satisfaction. It was found that there were notable disparities in the likelihood of satisfaction across different age groups and gender categories. The odds of employee satisfaction was found to be, 5.407 times higher for employees aged 18-25 years than the employees above 45 years and 14.726 times higher for employees aged 31-35 years than the employees above 45 years. Also, the odds of employee satisfaction was 0.264 times higher for Males than Females. The accuracy of the BLR model was found to be 85.5%.

KEYWORDS: Binary Logistic Regression, Employee Satisfaction, FMCG

1 INTRODUCTION

An organization's success depends heavily on employee satisfaction which is critical component that impacts an organization's efficacy and efficiency. As food and soap processing company's which is categorized under fast moving consumer goods (FMCG) industry, the success depends heavily on employee satisfaction. This study investigates the effect of demographical factors on the employee satisfaction of the employees working in a company under FMCG industry. Binary logistic regression approach is adopted to test the influence of demographical factors namely Age, Gender, Educational Level, Work Experience, and Number of family members on employee satisfaction.

2 LITERATURE REVIEW

Ayyagari and Lathabhavan (2020) conducted a study on Employee Satisfaction and Organizational Commitment to examine the satisfaction level of staff and its impact on

commitment. The collected primary data has been prepared on the basis of a questionnaire through online links survey form filled by 50 respondents. According to findings of this study the employee satisfaction effects commitment of management and staff. Factors affecting employee satisfaction and commitment were rewards, stress, leave, benefits and compensation given to the staff by the management which are important to improve the motivation level and employee satisfaction.

Cavusoglu et al. (2021) conducted a study on Modelling job satisfaction using a logistic regression model to investigate the explanatory factors influencing job satisfaction such as gender, age, education, overall experience in teaching, experience at their current workplace (school), and marital status and model the satisfaction of employees (teachers) using logistic regression. Analysis results indicated that current workplace experience had a positive influence on teacher job satisfaction.

However, as the teachers' education level and their overall years of experience in teaching increased their satisfaction levels decreased.

Dziuba et al. (2020) conducted a research on Employees' job satisfaction and their work performance as elements influencing work safety. They distributed a questionnaire and filled by 47 employees of the chosen metallurgical enterprise. The employees defined their job satisfaction by referring to 20 statements and three factors has been evaluated that were used to compute the satisfaction index. According to their findings it was found that, employees rated on average the statements affecting their job satisfaction at the level of 3.88. This means that they were satisfied with their work to a moderate level.

3 METHODOLOGY

Primary data were considered in this study, which were collected through a structural questionnaire using emailing and interviewing the employees, filled out by the 200 respondents. The influence of different factors on employment satisfaction was examined through binary logistic regression analysis, which was performed by SPSS software. Stepwise variable selection approach was used to determine the significant predictors of employment satisfaction.

4 RESULTS AND DISCUSSION

Table 1 indicates that 200 cases were evaluated without any missing cases.

Table 2 shows that the employee satisfaction has encoded as "NO" (0) and "YES" (1) to analyze the factors effecting for employee satisfaction.

Table 1: Overview of Case Processing

Case Processing Summary			
Unweighted Cases ^a		N	Percent
Selected Cases	Included in Analysis	200	100.0
	Missing Cases	0	.0
	Total	200	100.0
Unselected Cases		0	.0
Total		200	100.0

Table 2: Encoding Criterion for Dependent Variables

Dependent Variable Encoding	
Original Value	Internal Value
No	0
Yes	1

H₀: The regression coefficients for all predictors collectively do not have a significant impact on the outcome.

H₁: At least one regression coefficient for a predictor has a significant effect on the outcome.

Based on the results of Table 3, it suggests substantial evidence against the null hypothesis as the obtained p-values are below the 0.05. Thus, H₀ is rejected signifying that at least one predictor in the model is significant at 5% level of significance.

The results of Table 4 indicates that 46% of the variation in the dependent variables is explained by the logistic model, and the Nagelkerke that does range from 0 to 1 is more reliable measure of the relationship and it is normally higher than Cox and Snell's measure, in this case it is 0.615 indicating a moderately strong relationship of 61.5% between independent and dependent variables.

H₀: There is no significant difference between the observed and expected outcomes in the logistic regression model.

Table 3: Assessment of Model Coefficients

Omnibus Tests of Model Coefficients				
		Chi-square	df	Sig.
Step	Step	123.235	8	.000
1	Block	123.235	8	.000
	Model	123.235	8	.000

Table 4: Summary Statistics of the Model

Model Summary			
		Cox & Snell R Square	Nagelkerke R Square
Step	-2 Log likelihood		
1	152.021 ^a	.460	.615

H₁: There is significant difference between the observed and expected outcomes in the logistic regression model

By looking at the results of Table 5 it is clear that H₀ is not rejected since p value is greater than 0.05 and can be concluded that there is no significant difference between observed and expected outcomes at 5% level of significance. Based on the results of Table 6, it is clear that the overall predictive accuracy of the BLR model is 85.5%. According to the results of Table 7, it is clear that Age Categories (1) (0.04), Age Categories (2) (0.002), Age Categories(3) (0.028) and Gender(1) (0.006) are statistically significant at 5% level of significance. According to the values in the Exp (B) column of the Table 7, the odds of employee satisfaction is,

- 5.407 times higher for age group 1(18-25) than they are in the age group 5 (above 45).
- 0.127 times higher for age group 2 (26-30) than they are in the age group 5 (above 45).
- 14.726 times higher for age group 3 (31-35) than they are in the age group 5(above 45).

Table 5: Assessment using the Hosmer-Lemeshow Test

Hosmer and Lemeshow Test			
Step	Chi-square	df	Sig.
1	7.331	7	.395

Table 6: Classification Performance Overview

Classification Table ^a				
		Predicted		
	Observed	Employment satisfaction		Percentage
		No	Yes	Correct
Step 1	Employment satisfaction	No	Yes	
		79	11	87.8
		18	92	83.6
	Overall Percentage			85.5

- 0.264 times higher for gender group 1(Male) than they are in the gender group 2(Female)

5 CONCLUSION

The findings of this study indicate notable disparities in the likelihood of satisfaction across different age groups and gender categories. Younger age, specifically individuals aged 18-25 demonstrate substantially higher odds of satisfaction compared to those aged above 45. Similarly, individuals aged 31-35 exhibit markedly elevated odds, approximately 14.726 times higher, portraying a substantial likelihood of satisfaction compared to the above 45 age group. Moreover, the analysis highlights gender differences, with males displaying odds approximately 0.264 times higher than females regarding satisfaction levels. These findings collectively underscore the significance of age and gender dynamics in influencing employee satisfaction, signaling that younger age groups and

Table 7: Variables of the Final Model

		Variables in the Equation					95% C.I.for	
		B	S.E.	Wald	df	Sig.	Exp(B)	EXP(B)
						Lower		Upper
Step	Work							
1 ^a	Experience			5.774	4	.217		
	Work Experience(1)	-.471	.607	.601	1	.438	.625	.190 2.053
	Work Experience(2)	.514	.685	.563	1	.453	1.673	.436 6.411
	Work Experience(3)	-.933	.657	2.013	1	.156	.393	.108 1.427
	Work Experience(4)	-.754	1.445	.272	1	.602	.471	.028 7.991
	Age Categories			42.484	3	.000		
	Age Categories(1)	1.688	.823	4.209	1	.040	5.407	1.078 27.112
	Age Categories(2)	-	.658	9.835	1	.002	.127	.035 .461
	Age Categories(3)	2.690	1.226	4.812	1	.028	14.726	1.332 162.846
	Gender(1)	-	.486	7.508	1	.006	.264	.102 .685
	Constant	2.034	.709	8.230	1	.004	7.643	

males are more predisposed to higher satisfaction levels compared to their older counterparts and females within the surveyed employee population.

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Forecasting Annual Land Loss in Paddy Cultivation in Sri Lanka

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ABSTRACT

Paddy cultivation stands as a cornerstone of Sri Lanka's agricultural sector, contributing significantly to the nation's economy and food security. Despite being a vital source of livelihood for millions, the sustainability of paddy cultivation faces formidable challenges, primarily the loss of cultivable land. This study aims to predict future changes in the national annual sown and harvested paddy land for Yala and Maha seasons separately, forecasting the amount of land that goes as wasteland without being able to harvest (unable to cultivate) in each season. Data from 1952 to 2022, obtained from the Department of Census and Statistics, were analyzed using the Box-Jenkins methodology for forecasting based on historical data. Well-fitted ARIMA models were developed for Yala and Maha seasons. The well-fitted ARIMA models for the Yala season sown and harvest paddy land extent were ARIMA (0, 1, 1). Also, the well-fitted ARIMA models for the Maha season sown paddy land extent was ARIMA (2, 1, 0), and the Maha season harvest paddy land extent was ARIMA (0, 1, 1). The performances of these models were evaluated with the Mean Absolute Percentage Error (MAPE) values and accuracy. Predicted paddy land loss values for the next twelve years showed higher losses in the Maha season than that of the Yala season. Finally, the results found in our study possesses wider consequences for policy makers and researchers who are striving to adjust the pressing question of how to accurately predict the annual land loss of cultivable land, which in turn is vital for promoting sustainable agricultural practices in Sri Lanka.

KEYWORDS: ARIMA Model, Box-Jenkins Methodology, MAPE Values, Paddy Land Loss

1 INTRODUCTION

Paddy cultivation is a vital component of Sri Lanka's agricultural sector, providing livelihoods to a significant portion of the population and contributing to the nation's food security. However, the sustainability of paddy cultivation in Sri Lanka faces many challenges, the chief of which is the loss of cultivable land due to various factors such as industrialization, urbanization, climate change, and land use change. Conservation of agricultural land, especially for paddy cultivation, is critical to ensuring food security and sustaining the livelihoods of millions of Sri Lankans. As the world's population continues to grow and environmental conditions shift, the imperative of safeguarding cultivable

land for paddy cultivation has never been more pronounced. To address this critical issue and ensure food security for the nation, it is crucial to predict and comprehend the dynamics of annual land loss in paddy cultivation at the national level. The ability to forecast the extent of land loss that is lost and cannot be utilized for cultivation is paramount to sustainable agricultural planning, efficient resource allocation, and the formulation of policies that safeguard the future of Sri Lanka's agricultural sector. This study seeks to shed light on the complex dynamics of paddy sowing and harvesting processes by integrating advanced statistical methods with empirical analysis. It aims to address the pressing question of how to accurately predict the annual land loss of cultivable land, which in turn is vital for

promoting sustainable agricultural practices in Sri Lanka.

1.1 Research Objectives

- To predict future changes in the national annual sown and harvested paddy land for the Yala and Maha seasons separately.
- To forecast the amount of land that goes as wasteland without being able to harvest (unable to cultivate) in each season.

2 LITERATURE REVIEW

The following is a summary of some of the research that has been carried out on paddy cultivation around the world and in Sri Lanka.

Vanitha (2012) developed a time series model to predict the long-term trends and overall changes in the overall paddy production in the Batticaloa District for the three leading years by using the secondary data published by the Department of Census and Statistics and the annual report of the Central Bank of Sri Lanka covering the period of 1952 to 2009. The developed model for paddy production in the Batticaloa District was found to be ARIMA (2, 1, 0).

Raghavender (2010) analyzed yearly rice production data in Andhra Pradesh for the period of 1956 to 2008 using the ARIMA model. The developed model for rice production was found to be ARIMA (2, 2, 0).

Silva & Yamao (2009) employed time series forecasting analysis on secondary data and discovered an upward trend in the areas that were cultivated and harvested as well as in yields. The analysis also revealed an upward tendency in retail prices, which can be explained using a straightforward time

series model in a better manner. These findings contribute to the understanding of agricultural and economic dynamics, underscoring the need for comprehensive strategies to harness and manage these trends effectively.

Sivapathasundaram & Bogahawatte (2012) developed a time series model to detect the long-term trend and prediction for future changes of total paddy production in Sri Lanka for the three leading years by using the secondary data of the Department of Census and Statistics of Sri Lanka from 1952 to 2010. ARIMA (2, 1, 0) was the selected model in this study with the lowest Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) values. This study was limited to finding a predictive model for total paddy production in Sri Lanka from 1952-2010.

Munasinghe & Napagoda (2021) investigated the present trends of paddy production and developed time series models for paddy production in the Yala and Maha seasons using secondary data from 1952 to 2010. The Shapiro-Wilks test was applied to check the normality of the data set. According to their results, the Mann-Kendall trend test and Cox-Stuart trend test were used to detect the trends in the data. The result of this study depicts increasing tendency in both seasonal models, with a higher slope of paddy production in Maha season. Based on the historical data, the well-fitted ARIMA model for paddy production in seasons Yala and Maha was ARIMA (2,1,1) and ARIMA(2,1,0), respectively. The performances of these models were mainly validated with the AIC, Root Mean Square Error (RMSE), and Mean Absolute Percentage Error (MAPE) values. This study is important since it is

the first research that predicted paddy production in Sri Lanka for separate seasons.

Even though these research studies have been carried out to forecast the national annual rice production in the country, no work has been done to forecast the national annual paddy land loss in Sri Lanka. This matter is considered as a critical aspect in solving significant problem of yearly paddy land degradation, which yields major impact on the entire food supply chain of the country.

3 METHODOLOGY

3.1 Data Collection

The national annual sown and harvested amount of land in Sri Lanka was selected for this study, and secondary data was used for the analysis. Seventy-one data points (yearly data) on the annual sown and harvested amount of land in Sri Lanka was used for time series forecasting. The data for the study was collected from the agriculture and environment statistics divisions of the Department of Census and Statistics, covering the period from 1952 to 2022. The entire amount of national annual sown and harvested land for both Yala and Maha seasons, covering the period from 1952 to 2022 separately, has been taken in kilohectares for this study.

3.2 Data Analysis

A statistical software package, Minitab was used in developing the time series forecasting analysis. The time series analysis was done to fulfil the objective of predicting future changes in the national annual sown and harvested amount of paddy, thereby forecasting the amount of land that goes as wasteland

without being able to harvest (unable to cultivate). The econometric model of ARIMA was used to fit the data set. Modelling was done in four stages of the Box-Jenkins methodology, such as identification of the preliminary specification of the model, estimation of the parameters of the model, diagnostic checking of the model's adequacy, and forecasting future realization. In this study, based on the difference between predicted sown and harvested paddy land extent values, the national annual paddy land loss values for the Yala and Maha seasons were predicted separately over the next twelve years.

4 RESULTS AND DISCUSSION

4.1 Time Series Analysis for Yala Season Sown and Harvest Land Extent

The time series plots of paddy sown and harvest extent in kilo hectares for the yala season is shown in Fig. 1 and Fig. 2 respectively.

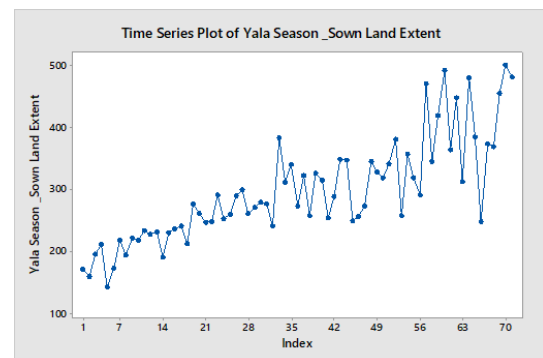


Figure 1: Time series plot of yearly paddy sown extent in kilo hectares for the Yala Season

According to Fig. 1 and Fig. 2, it is clear that there is an upward trend and no any seasonal variation which indicates that the series is not stationary.

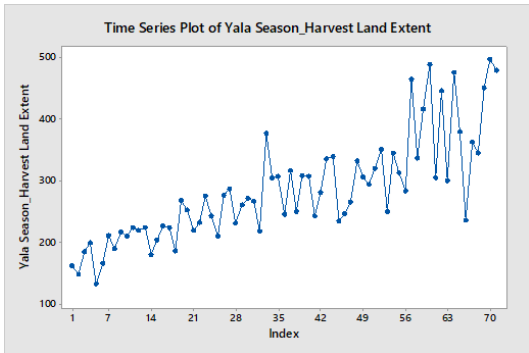


Figure 2: Time series plot of yearly paddy harvest extent in kilo hectares for the Yala season

The ARIMA models were developed based on the autoregressive (p), moving average (q), and the order of differencing (d), for making the data stationary. The values of p and q were obtained with help of the significant spikes in the ACF and PACF plots (Fig. 3 – Fig. 6). Using those results tentative models were created. These models were checked using the Box-Jenkins methodology.

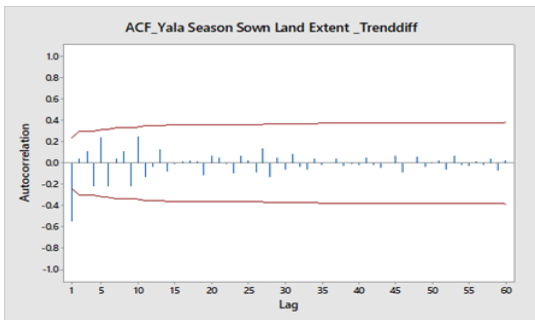


Figure 3: ACF for Paddy Sown Land Extent Values in Yala Season

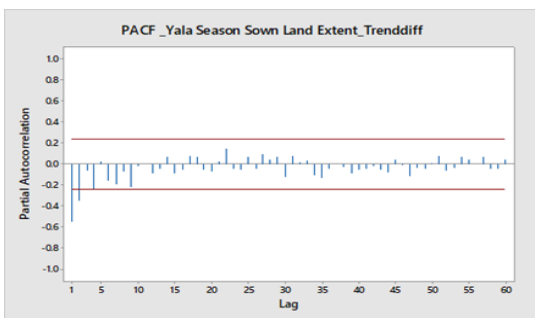


Figure 4: PACF for Paddy Sown Land Extent Values in Yala Season

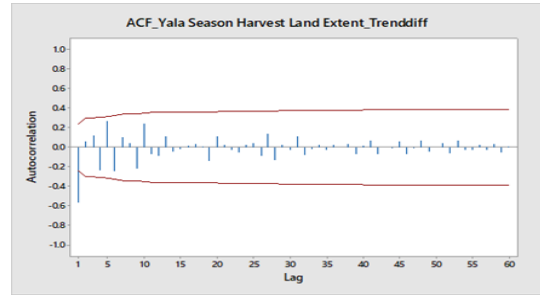


Figure 5: ACF for Paddy Harvest Land Extent Values in Yala Season

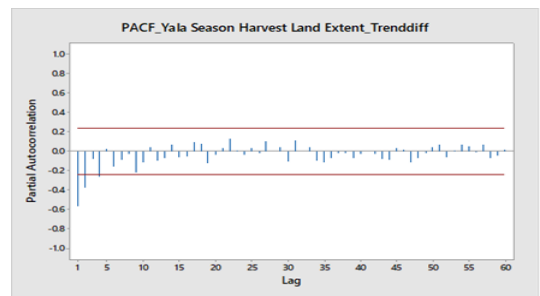


Figure 6: PACF for Paddy Harvest Land Extent Values in Yala Season

An identified tentative model for both Yala season sown and harvest land extent values separately is, ARIMA (2, 1,1). Based on this tentative model, four more suitable tentative models, namely, ARIMA (1, 1, 1), ARIMA (0, 1, 1), ARIMA (2, 1, 0), and ARIMA (1, 1, 0) could be obtained.

Table 1: Accuracy Measures for Forecast – Yala Sown

Model	MAPE Value	Accuracy
ARIMA (2,1,0)	17.4282	82.5718
ARIMA (1,1,0)	18.0170	81.9830
ARIMA (0,1,1)	17.0351	82.9649

According to Table 1, the best model is ARIMA (0, 1, 1) as it has the lowest MAPE value & the highest accuracy.

Table 2: Accuracy Measures for Forecast – Yala Harvest

Model	MAPE Value	Accuracy
ARIMA (2,1,0)	20.6944	79.3056
ARIMA (1,1,0)	21.4863	78.5137
ARIMA (0,1,1)	19.9237	80.0763

According to Table 2, the best model is ARIMA (0, 1, 1) as it has the lowest MAPE value & highest accuracy.

Table 3: Forecast Land Loss Value-Yala Season (In kilohectares)

Year	Forecast values (For the amount of land sown)	Forecast values (For the amount of land harvest)	Forecast land loss values (In kilohectares)
2023	421.775	409.890	11.885
2024	425.199	413.333	11.886
2025	428.624	416.776	11.848
2026	432.049	420.218	11.831
2027	435.474	423.661	11.813
2028	438.899	427.104	11.795
2029	442.324	430.546	11.778
2030	445.749	433.989	11.76
2031	449.174	437.431	11.743
2032	452.599	440.874	11.725
2033	456.024	444.317	11.707
2034	459.449	447.759	11.681

Based on the difference between predicted sown and harvested paddy land extent values, the national annual paddy land loss values for the Yala season were predicted in Table 3.

4.2 Time Series Analysis for Maha Season Sown and Harvest Land Extent

An identified tentative model for both Maha season sown and harvest land extent values separately is, ARIMA (2, 1,1). Based on this tentative model, four more suitable tentative models, namely,

ARIMA (1, 1, 1), ARIMA (0, 1, 1), ARIMA (2, 1, 0), and ARIMA (1, 1, 0) could be obtained.

Table 4: Accuracy Measures for Forecast – Maha Sown

Model	MAPE Value	Accuracy
ARIMA (2,1,0)	9.90374	90.0963
ARIMA (1,1,0)	13.0021	86.9979
ARIMA (0,1,1)	10.5806	89.4194

According to Table 4, the best model is ARIMA (2, 1, 0) as it has the lowest MAPE value & the highest accuracy.

Table 5: Accuracy Measures for Forecast – Maha Harvest

Model	MAPE Value	Accuracy
ARIMA (2,1,0)	16.6303	83.3697
ARIMA (1,1,0)	15.9564	84.0436
ARIMA (0,1,1)	15.3786	84.6214

Table 6: Forecast Land Loss Value-Maha Season (In kilohectares)

Year	Forecast values (For the amount of land sown)	Forecast values (For the amount of land harvest)	Forecast land loss values (In kilohectares)
2023/24	779.970	726.327	53.643
2024/25	788.681	732.672	56.009
2025/26	795.708	739.017	56.691
2026/27	802.078	745.363	56.715
2027/28	802.295	751.708	57.587
2028/29	816.303	758.053	58.25
2029/30	823.148	764.398	58.75
2030/31	830.139	770.743	59.396
2031/32	837.109	777.088	60.021
2032/33	844.044	783.433	60.611
2033/34	851.002	789.778	61.224
2034/35	857.960	796.123	61.837

According to Table 5, the best model is ARIMA (0, 1, 1) as it has the lowest MAPE value & the highest accuracy.

Based on the difference between predicted sown and harvested paddy land extent values, the national annual paddy land loss values for the Maha season were predicted in Table 6.

5 CONCLUSION

Based on the forecasted national annual paddy land loss values, the Maha season national annual paddy land loss values were higher than the Yala season. It is more convenient and accurate, as paddy land loss can be predicted for each season using two separate models. However, it should be updated from time to time with the incorporation of current data. Researchers who are interested in this field can also conduct regression analysis by incorporating the external factors that may influence the national annual paddy land loss in Sri Lanka, such as industrialization, urbanization, the impact of climate change, and evolving land use patterns, and using advanced time series analysis (machine learning-based methods) to forecast the national annual land loss of other crops with necessary alterations.

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Forecasting Particulate Matter 2.5 (PM2.5) Concentration in Kandy

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ABSTRACT

Investigating the quality of air in Kandy is very important as it is one of the ancient cities in Sri Lanka which has been declared a UNESCO world heritage as well. The particulate matter 2.5 (PM2.5) are tiny particles that possess a 2.5 Micro meter diameter and can penetrate deep into the respiratory system causing severe health risks. As PM2.5 is one of the most harmful atmospheric pollutants, accurate forecasting of PM2.5 concentration is essential in implementing timely measures and policies to safeguard public health and improve the overall management of air quality. Therefore, this study is based on forecasting PM2.5 on an Artificial Neural Network (ANN) approach; Recurrent Neural Network (RNN), Convolutional Neural Network (CNN), and Combined Model (RNN+CNN) by using hourly data obtained from the Central Environment Authority of Sri Lanka covering December 10, 2022, to March 15, 2023, comprising 2300 observations. RNN model and the Combined Model demonstrated the best model achieving the lowest Root Mean Square Error (RMSE) of 0.09 compared to the CNN model highlighting the capability in contributing to accurate predictions, essential for public health and environmental monitoring.

KEYWORDS: ANN, CNN, PM2.5, RMSE, RNN

1 INTRODUCTION

Pollution from particulate matter (PM2.5) is a major global hazard, especially in urban areas like Kandy. Kandy's cultural significance, tourism appeal, and urban challenges underscore the importance of forecasting PM2.5 concentration to protect public health, preserve heritage, and address air pollution effectively. The study innovates by using advanced neural networks to forecast PM2.5 in Kandy, Sri Lanka, addressing unique challenges and advancing existing research. PM 2.5 refers to the atmospheric particulate matter that has a diameter of 2.5 micrometres. The study's novelty lies in its pioneering use of advanced CNN, RNN, and combined models for PM2.5 prediction in Kandy, a method not previously explored in recent statistical research. This innovative approach

promises to enhance the understanding and management of air quality in the region, offering valuable insights for future studies and policymaking initiatives. These fine particles in the air reduce visibility and the air seems hazy. By penetrating PM2.5 particles deeply into the lungs, respiratory and cardiovascular diseases may occur due to exposure to high concentrations of PM2.5. The goal of this research is to forecast the PM2.5 concentrations in Kandy by using three types of sophisticated neural network models: CNN, RNN, and a Combined model. Through the use of these models, Kandy's PM2.5 dynamics will be forecasted and it will be helpful to make well-informed decisions on environmental and public health. Deep learning models, such as CNN, RNN, and combined architectures, were chosen because they were better than typical machine learning techniques at

identifying complex temporal and spatial patterns in PM_{2.5} data.

2 LITERATURE REVIEW

Ventura et al. (2019) conducted a study on forecasting daily PM_{2.5} concentrations applying artificial neural networks and Holt–Winters models by using the hourly data collected from January 2011 to December 2013. The RMSE for each model has been calculated and found that ANN was the most appropriate model.

Grivas and Chaloulakou (2006) conducted a study on prediction of PM₁₀ hourly concentrations, in the Greater Area of Athens with the use of a ANN models by using hourly PM₁₀ data from 2001 to 2002 and found that the ANN models were superior with R^2 value ranging from 0.50 to 0.67 in comparison with multiple linear regression models developed in parallel whose R^2 value ranging from 0.29 to 0.35.

Babu and Binu (2021) applied RNN model based on Long Short-Term Memory(LSTM) technique to forecast daily PM_{2.5} concentration level in Southern Kerala by using the daily data from 1st July 2017 to 31st December 2019 and found that the model is capable of forecasting the daily PM_{2.5} concentration with a R^2 value of 0.872.

He et al. (2022) conducted a study on forecasting PM_{2.5} concentration in Liaocheng, China using ANN. There has been a steady decrease in PM_{2.5} levels in Liaocheng from 2014 to 2021. In Liaocheng, the air quality during and following lockdown times in 2020 was noticeably better than during the corresponding periods in 2019. The ANN used in the study has three layers: an output layer, an input layer with eleven

parameters, and a hidden layer with six neurons. 80% of the data has been used for training the ANN while 10% of the data used for verification. The ANN model with the Bayesian regularization (BR) approach (trainbr) was shown to have achieved the best predicting performance for the forecast period in terms of R^2 (0.9570), Mean Absolute Error(MAE) (4.6 $\mu\text{g}/\text{m}^3$), and RMSE (6.6 $\mu\text{g}/\text{m}^3$), respectively. Accurate findings have been achieved by the ANN model. These findings has shown the efficacy of the ANN in forecasting monthly PM_{2.5} concentrations.

3 METHODOLOGY

As the first step, the missing data was imputed by calculating the average from existing values to maintain dataset consistency and facilitate analysis. Then the visualisation and chronological sorting of hourly PM_{2.5} concentration was carried out.

The data was divided into training and testing sets with a ratio of 3:1, where 75% of the data was allocated for training and the remaining 25% for testing. This dataset undergoes preprocessing steps including reshaping and scaling to ensure uniformity. To create the temporal sequences that are necessary for time series forecasting, the data set was arranged into input-output pairs according to a predetermined look-back period. Three distinct neural network architectures; Simple RNN, CNN, and combined model were developed using TensorFlow's Keras (Application Programming Interface) API and different layer configurations were used to capture complex temporal trends in the series. The models were trained with the Adam optimizer and the mean squared error as

the optimization criterion. The performance of the models were evaluated using evaluation metrics, specifically RMSE, on both the training and testing datasets. After training, the PM2.5 concentration was forecasted for all models on the test dataset. Then predictions were compared with original data after inverse scaling, providing a clear visualization of each model’s predictive performance.

4 RESULTS AND DISCUSSION

Table 1 demonstrates the descriptive statistics of the PM2.5 concentration. It is clear that the maximum PM2.5 concentration was recorded as 119 µg/m3 whilst the minimum was 0 µg/m3. The average PM2.5 concentration in Kandy during the period of study was 19.54 µg/m3.

Fig. 1 shows the raw data of PM2.5 concentration against time. It provides an overview of how the concentration values changed over time.

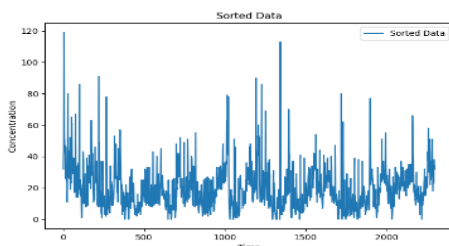


Figure 1 : Time vs. Concentration Plot over time

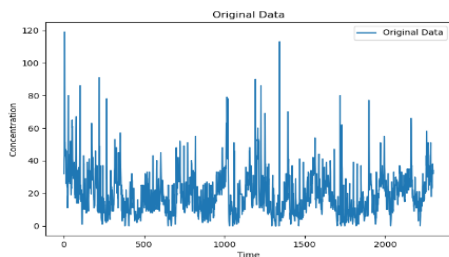


Figure 2: Time vs. Concentration Plot sorted in descending order

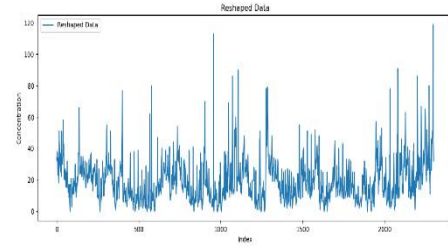


Figure 3: Concentration vs. Index Plot

Fig. 2 is the same as the Fig. 1 but sorted in descending order. Sorting the data might reveal patterns or trends that were not immediately apparent in the original order. Fig. 3 displays the reshaped PM2.5 concentration data into a column vector. It can be useful visualize the entire dataset as a time series.

4.1 RNN Model (Recurrent Neural Network)

RNNs are specialized in processing sequential data by maintaining an internal memory state. This enables them to capture temporal dependencies and long-range patterns in sequential data, making them suitable for time series forecasting. The predictions of the trained RNN model are shown in Fig. 4. It inversely scales the predictions to the original data range and plots them alongside the original data.

RNN model was developed as a recurrent neural network architecture using a 10-step look-back window. 32 Simple RNN units made up the first layer of this model, which is followed by a dense layer with a linear activation function. The results are shown in Table 2.

The Adam optimization technique was used to train the model during three epochs with a batch size of 1. A train RMSE of 0.07 and a test RMSE of 0.09 were found in the training procedure. This RNN model accurately predicts PM2.5

Table 1: Descriptive statistics of PM2.5 Concentration

	PM2_5_CONC
Mean	19.54474
Median	17.00000
Maximum	119.0000
Minimum	0.000000
Std. Dev.	13.16082
Observations	2300

Table 2: Output of RNN Model

Layer	Output	Param#
Reshape	(None,10,1)	0
SimpleRNN	(None,32)	1088
Dense	(None,1)	0
Activation	(None,1)	0

concentrations, identifies relationships over time in the data and offers reasonably low RMSE values.

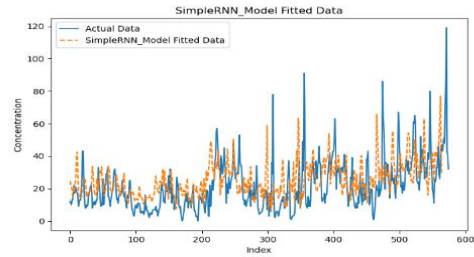
4.2 CNN Model (Convolutional Neural Network)

CNNs excel at capturing spatial patterns in data, making them ideal for image recognition tasks. They apply filters across input data to extract features, allowing them to identify complex patterns. CNN model was created especially for sequential data with a 10-step look-back window and the results are shown in Table 3.

A convolutional layer with five filters is the first layer in the architecture. Max-pooling and flattening layers are next, and

Table 3: Output of CNN Model

Layer	Output	Param#
Reshape	(None,10,1)	0
Conv1D	(None,6,5)	30
Maxpooling1D	(None,1,5)	0
Flatten	(None,5)	0
Dense	(None,1)	6
Activation	(None,1)	0

**Figure 4:** RNN Model Predictions

the last layer is a dense layer with a linear activation function. The Adam optimization technique was used to train the model throughout 5 epochs with a batch size of 1. For this model, the train RMSE was 0.08 while the test RMSE was 0.10. The RMSE values of RNN model are slightly lower than that of the CNN model, which extracts spatial characteristics from the input data while performing better as well. The predictions of the trained CNN model are shown in Fig. 5.

4.3 Combined Model(RNNs+CNN)

Combined models integrate CNNs and RNNs to leverage their respective strengths. CNNs are used for spatial feature extraction, while RNNs handle temporal modeling. By combining these architectures, these models can capture both spatial and temporal dependencies in data, improving forecasting accuracy. The combined model has two hidden layers: a Simple RNN layer with 32 neurons and a Conv1D layer with 5 filters as shown in Table 4.

Table 4: Output of the Combined Model

Layer	Output	Param #
Reshape	(None,10,1)	0
Conv1D	(None,8,5)	20
SimpleRNN	(None,32)	1216
Dense	(None,1)	0
Activation	(None,1)	0

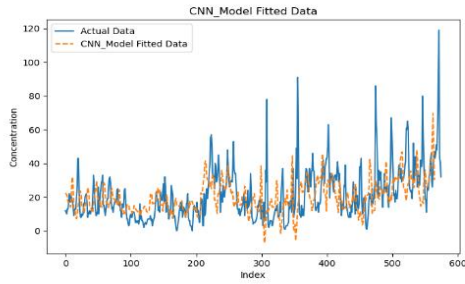


Figure 5: CNN Model Predictions

It similarly makes use of a dense layer with a linear activation function, comparable to the earlier models. The Adam optimization technique was used to train the model throughout three epochs with a batch size of 1. The predictions of the trained combined model are shown in Fig. 6. For this model, the test RMSE was 0.09, and the train RMSE was 0.08. By using both spatial and temporal dependencies in the data, the combined model strives to produce competitive RMSE values that are on par with the RNN model.

As per the results of Table 5, the RNN model has the lowest RMSE on the testing data, which is frequently a crucial parameter for assessing model performance. Based on the RMSE values, it can be concluded that both the RNN and combined models demonstrate superior performance compared to the CNN model for forecasting PM2.5 concentration in Kandy.

The exclusion of traditional forecasting methods like SARIMA in favor of CNN, RNN, and combined models was justified by their superior performance with the actual dataset used in this research. SARIMA models did not demonstrate satisfactory results, prompting the selection of neural network approaches, which proved more effective in capturing the dataset's complex relationships.

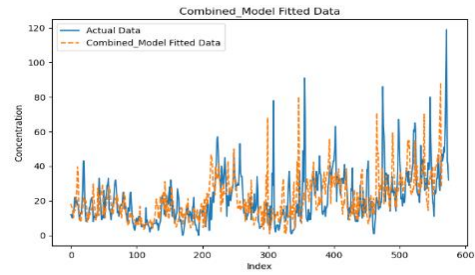


Figure 6: Combined Model Predictions

5 CONCLUSION

According to the findings, the CNN model displayed significantly higher RMSE values of 0.08 during training and 0.10 during testing. The CNN model consists of an input layer (Reshape), Conv1D, MaxPooling1D, Flatten, and Dense layers. Even yet, the model's effectiveness was obvious with just 36 parameters. The combined model, which used 1,269 parameters and included Conv1D, SimpleRNN, and Dense layers produced excellent results with a RMSE of 0.08 during training and 0.09 during testing.

By comparing the results of all three models, the most efficient models to forecast PM2.5 concentration in Kandy was found to be the RNN model and combined model. It demonstrated forecasting PM2.5 by having the lowest RMSE 0.09 during testing.

The use of artificial neural network models, which could have biases and limits of their own when it comes to dynamics, is the main source of this study's problems. Furthermore, future research should look at different machine learning approaches, include more environmental factors, and evaluate the long-term effects of air quality forecasting on public health outcomes by capturing complicated environmental factors. These

Table 5: Comparison of neural network models

Model	Architecture	No of Parameters	No of Epochs	Train RMSE	Test RMSE
RNN Model	Input Layer (Reshape) -> SimpleRNN ->Dense	1,121 (4.38 KB)	3	0.07	0.09
CNN Model	Input Layer (Reshape) -> Conv1D -> MaxPooling1D -> Flatten - > Dense	36 (144.00Byte)	5	0.08	0.10
COMBINED Model	Input Layer (Reshape) -> Conv1D -> SimpleRNN -> Dense	1,269 (4.96 KB)	3	0.08	0.09

factors are critical to raising the accuracy and reliability of PM_{2.5} forecasting models, which in turn raises the standard for environmental management plans and public health initiatives.

Holt–Winters models. *Air Quality, Atmosphere & Health*, 12, 317-325.

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Modelling the Weather Parameters in Colombo Area using the Vector Autoregressive Model Approach

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ABSTRACT

Colombo functions as the administrative, legal, and primary urban center of Sri Lanka in terms of population. Colombo is well-known for its tropical climate, characterized by consistently heightened average temperatures, significant annual rainfall, and a variety of many other meteorological factors. The investigation analyzed fluctuations in weather parameters and explored their interdependencies. It focused on five parameters: Rainfall, Minimum Relative Humidity, Maximum Relative Humidity, Wind Speed, and Temperature, using monthly data from January 2007 to May 2022 obtained from the Department of Meteorology in Colombo. Understanding the correlations among these parameters is essential for grasping Colombo's climate dynamics. The study identified a seasonal pattern in Minimum Relative Humidity and noted significant fluctuations in Wind Speed and Rainfall among the parameters studied. The study concluded that there is a moderate positive correlation ($r = 0.5$) between Rainfall and Minimum Relative Humidity, as well as between Rainfall and Maximum Relative Humidity ($r = 0.7$). Additionally, a moderate negative relationship ($r = -0.5$) between Wind Speed and Maximum Relative Humidity was observed in this study. The research utilized Vector Autoregressive (VAR) models to analyze relationships among weather parameters and identify Granger Causal relationships. Minimum Relative Humidity was found to predict Rainfall, Maximum Relative Humidity, Wind Speed, and Temperature. Additionally, Maximum Relative Humidity could predict Minimum Relative Humidity, Wind Speed, and Temperature. These findings would essentially be beneficial for policymakers, urban planners, businesses, and communities in Colombo to develop climate-resilient strategies and adaptation measures, fostering a more sustainable and resilient city.

KEYWORDS: Correlation, Cross Correlation, Granger Causality, Meteorological Parameters, VAR Model

1 INTRODUCTION

Nestled along the vibrant western coastline of Sri Lanka, the Colombo area stands as a captivating blend of tradition and modernity, influenced by both its rich historical tapestry and its contemporary urban development. This bustling metropolis, with its sprawling urban landscape, plays host to a diverse array of cultures, industries, and ecosystems.

As the economic and cultural heart of the nation, Colombo's climate assumes a pivotal role in shaping the daily lives of its inhabitants and the region's overall dynamics. In an era of ever evolving

climatic patterns, understanding the intricate dynamics of local weather phenomena is of paramount significance. By delving into the analysis of diverse weather parameters, including temperature, humidity, rainfall, and wind patterns, this study seeks to provide invaluable insights into the complex relationships that govern the weather patterns experienced in the Colombo area.

There are very few studies that have been conducted worldwide on weather parameters, and even fewer studies have been conducted in the area of predicting the weather parameters towards a

sustainable environmental growth (Perera & Rathnayake, 2019). Hence, comprehending the current state and envisioning the prospective condition of weather in Colombo area proves immensely advantageous for guiding the actions of pertinent authorities. A viable solution to address this concern involves the examination of factors impacting climate condition, with the aim of elevating it to a superior standard through the optimization of these influencing parameters. This study aims to check the correlations and cross correlations among the five weather parameters and also aims to obtain predictive models for predicting the parameters.

2 MATERIALS AND METHODS

2.1 Data Collection

The dataset pertaining to weather parameters of Colombo was meticulously procured from the Department of Meteorology. A judicious selection of five weather parameters of Colombo area was undertaken to facilitate the collection of pertinent information. Weather parameters namely Rainfall, Minimum Relative Humidity, Maximum Relative Humidity, Wind Speed and Temperature were considered under this study. Data was collected at monthly intervals from January 2007 to May 2022.

2.2 Correlation and Cross Correlation

Correlation, a pivotal statistical measure, is employed to quantify the degree of association or relationship between two or more variables. By calculating correlation coefficients, it was possible to gauge both the linear relationship and the potential trends between these weather parameters. Cross-correlation as valuable analytical

technique within the realm of time series analysis, plays a pivotal role in exploring the synchrony and temporal relationships between two distinct variables. By computing cross-correlation functions, it aimed to identify any patterns of similarity or dissimilarity between the parameters across different time lags.

2.3 Granger Causality

Granger causality is a fundamental concept in time series analysis serving as a crucial tool to assess the causal relationship between two variables within a dynamic system (Sanchez, 2010). This statistical technique examines whether the past values of one variable can provide valuable predictive information about another variable's future values.

2.4 Vector Autoregressive Model

The Vector Autoregressive (VAR) model is a powerful framework within the field of time series analysis, instrumental in comprehending the dynamic relationships and interdependencies among multiple variables over time (Hou et al., 2023). In this research, under methodology, VAR (p) models are employed, where 'p' represents the order of lag, to explore the intricate interactions among the weather parameters of interest.

The lag length for the VAR (p) model is determined using model selection criteria. The general approach is to fit VAR (p) models with orders $p = 0, \dots, p_{\max}$ and choose the value of p based on a suitable model selection criterion. The three most common information criteria used in this study are the Akaike (AIC), Schwarz-Bayesian (BIC) and Hannan-Quinn (HQ) (Ehelepola et al., 2021).

3 RESULTS AND DISCUSSION

Fig. 1 contains the time series plots for the original series of Temperature and Rainfall. Fig. 2 contains the time series plots for the other three weather parameters namely Minimum Relative Humidity, Maximum Relative Humidity and Wind Speed. According to the plots it is evident that all the five time series have irregular patterns.

Fig. 3 contains the correlation plot for the five parameters. According to the figure it was found that there is a strong positive correlation between Rainfall and Minimum Relative Humidity ($r = 0.5$) and as well as between Rainfall and Maximum Relative Humidity ($r = 0.7$). A strong negative relationship between Wind Speed and Maximum Relative Humidity ($r = -0.5$) was also found in this study.

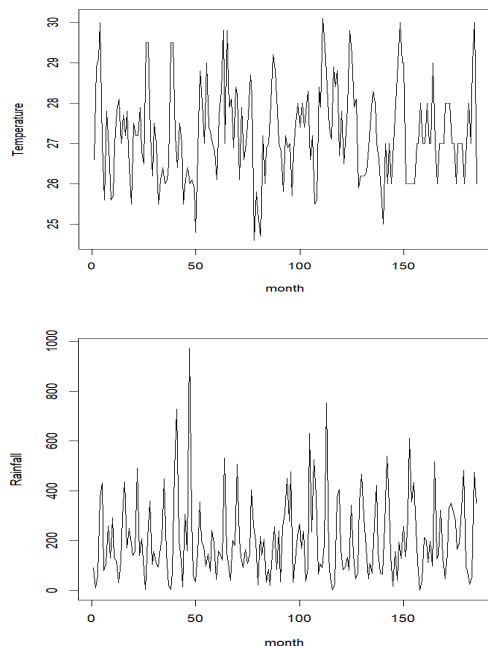


Figure 1: Time Series Plots for Temperature and Rainfall

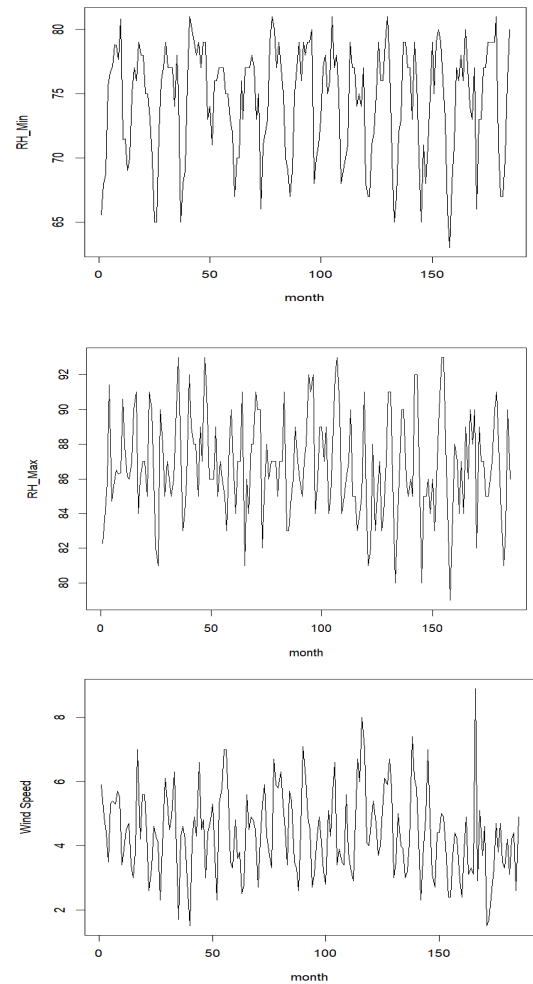


Figure 2: Time Series Plots for Minimum Relative Humidity, Maximum Relative Humidity and Wind Speed

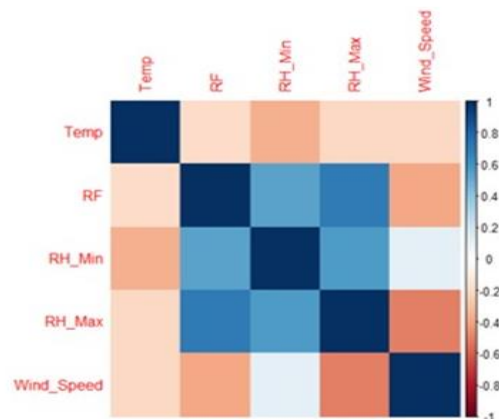


Figure 3: Correlation Plot for five Weather Parameters

Table 1: Correlation matrix for five Weather Parameters

	Temperature	Rainfall	RH_Min	RH_Max	Wind Speed
Temperature	1.00	-0.18	0.36	0.21	0.20
Rainfall	-0.18	1.00	0.54	0.70	0.39
RH_Min	-0.36	0.54	1.00	0.57	0.11
RH_Max	-0.21	0.70	0.57	1.00	0.50
Wind Speed	-0.20	0.39	0.11	0.50	1.00

In this study it was also found that Minimum Relative Humidity could also be used to predict the other four parameters i.e. Rainfall, Maximum Relative Humidity, Wind Speed and Temperature. Maximum Relative Humidity could be used to predict Minimum Relative Humidity, Wind Speed and Temperature as well. Wind Speed can also be used for predicting all other four weather parameters concerned in this study. It has found that Temperature has the potential to serve as a predictive factor for all three of the weather parameters except Wind Speed under consideration in this investigation. Table 2 contains the summary status of the results of the Granger Causality test.

Table 3 shows the VAR models obtained for the respective pairs of weather parameters which were identified as Granger Causal pairs in the previous step. The R-squared value was used to measure the performance of the fitted VAR models. Notably none of the fitted VAR models indicated the violation of the assumptions.

Table 2: Summary Status of the Results of the Granger Causality Test

Time Series 1	Time Series 2	p value	Status
Rainfall	RH_Min	0.1446	Not Granger Causal
	RH_Max	0.1196	Not Granger Causal
	Wind Speed	0.0742	Not Granger Causal
	Temperature	0.1665	Not Granger Causal
RH_Min	Rainfall	<0.001	Granger Causal
	RH_Max	<0.001	Granger Causal
	Wind Speed	<0.001	Granger Causal
	Temperature	0.0233	Granger Causal
RH_Max	Rainfall	0.19	Not Granger Causal
	RH_Min	0.0027	Granger Causal
	Wind Speed	0.0319	Granger Causal
	Temperature	0.0469	Granger Causal
Wind Speed	Rainfall	<0.001	Granger Causal
	RH_Min	<0.001	Granger Causal
	RH_Max	<0.001	Granger Causal
	Temperature	<0.001	Granger Causal
Temperature	Rainfall	0.0015	Granger Causal
	RH_Min	<0.001	Granger Causal
	RH_Max	0.0004	Granger Causal
	Wind Speed	0.381	Not Granger Causal

4 CONCLUSION

This research has determined that a robust positive correlation exists between Rainfall and both Minimum Relative Humidity and Maximum Relative Humidity. Furthermore, this case study has identified a significant negative association between Wind Speed and Maximum Relative Humidity.

Table 3: Summary of the VAR models (with high R² values) obtained for Granger Causal Parameter pairs

VAR(p) Model	Equation	Lag	Significant Coefficients	R-squared
VAR(5)	$RF_t = 5.42RH_Min_{t-1} + 0.01RF_{t-1} + 4.41RH_Min_{t-2} - 0.2RF_{t-2} - 1.83RH_Min_{t-3} - 0.28RF_{t-3} + 3.76RH_Min_{t-4} - 0.23RF_{t-4} + 3.34RH_Min_{t-5} + 0.03RF_{t-5} - 808.26 + 0.28$	5	RF (lag 2) RF (lag 3) RF (lag 4) Const	0.17
VAR(6)	$RH_Max_t = 0.07RH_Min_{t-1} + 0.19RH_Max_{t-1} + 0.25RH_Min_{t-2} - 0.39RH_Max_{t-2} - 0.11RH_Min_{t-3} - 0.19RH_Max_{t-3} + 0.14RH_Min_{t-4} - 0.04RH_Max_{t-4} + 0.03RH_Min_{t-5} - 0.07RH_Max_{t-5} + 0.11RH_Min_{t-6} + 0.16RH_Max_{t-6} + 79.25 - 0.01$	6	RH_Min (lag 2) RH_Max (lag 2) Const	0.31
VAR(4)	$WS_t = 0.06RH_Min_{t-1} + 0.32WS_{t-1} + 0.01RH_Min_{t-2} - 0.1WS_{t-2} + 0.08RH_Min_{t-3} - 0.06WS_{t-3} - 0.13RH_Min_{t-4} + 0.001WS_{t-4} + 2.69 - 0.002$	4	RH_Min (lag 1) WS (lag 1) RH_Min (lag 3) RH_Min (lag 4)	0.33
VAR(1)	$Temp_t = -1.19e-01RH_Min_{t-1} + 2.85e-01Temp_{t-1} + 2.84e+01 - 2.51e-05$	1	RH_Min (lag 1) Temp (lag 1) Const	0.35
VAR(6)	$RH_Min_t = -0.08RH_Max_{t-1} + 0.39RH_Min_{t-1} - 0.3RH_Max_{t-2} + 0.29RH_Min_{t-2} - 0.25RH_Max_{t-3} + 0.05RH_Min_{t-3} + 0.02RH_Max_{t-4} - 0.15RH_Min_{t-4} + 0.1RH_Max_{t-5} - 0.21RH_Min_{t-5} + 0.51RH_Max_{t-6} - 0.17RH_Min_{t-6} + 61.04 - 0.002$	6	RH_Min (lag 1) RH_Max (lag 2) RH_Min (lag 2) RH_Max (lag 3) RH_Max (lag 6) Const	0.67

The discovery was made that Minimum Relative Humidity holds predictive utility for the remaining four parameters: Rainfall, Maximum Relative Humidity, Wind Speed, and Temperature. Similarly, Maximum Relative Humidity exhibits predictive capabilities for Minimum Relative Humidity, Wind Speed, and Temperature. Wind Speed's predictability extends to all four weather parameters examined in this study.

Notably, Temperature emerges as a predictive factor for three of the weather parameters excluding Wind Speed, which is under scrutiny in this investigation. Then Granger-causal parameter pairs were established for the five weather parameters through the utilization of Vector Autoregressive (VAR(p)) models.

5 LIMITATIONS

Several limitations are evident within this study. It is acknowledged that this case

study is focused exclusively on five weather parameters as of the precise data shortage. Notably, certain parameters such as Rainfall and Wind Speed exhibit distinct distribution patterns compared to the remaining weather parameters (Ekanayake et al., 2021). Thus, it is essential to recognize the necessity for employing novel statistical methods when analyzing the parameters. This approach would contribute significantly to enhance the comprehension of distributional trends concerning weather parameters in the Colombo area. And some other limitations were found in this study. A few of them are that only five weather parameters considered and the variations due to other reasons are not considered throughout this study.

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Multivariate Data Analysis Approach to Identify the Cause of Elephant Deaths Due to Human-Elephant Conflicts

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ABSTRACT

The North Central Province in Sri Lanka experiences frequent interactions and conflicts between elephants and human communities, highlighting the challenges of coexistence in areas with significant elephant populations. Although there is published research focusing on studying elephant deaths resulting from Human-Elephant Conflict (HEC), none of the identified studies utilized Multiple Correspondence Analysis (MCA) as a multivariate data analysis technique to predict the causes of such deaths based on Multinomial Logistic Regression (MLR). This method considers both environmental and physiological factors within the context of HEC, marking a gap in the existing research literature. In this context to evaluate the predictive ability of the MLR model based on MCA dimensions, two performance measures such as Overall Classification Accuracy (OCA), and Misclassification Percentage of Critical Cases (OMPCC) were considered. Significant factors were identified based on the Chi-square test and Fisher's exact test. The study revealed that gender, age group of elephants, place of death, rainfall season, and soft grass level are influential factors of elephant deaths in HEC at a 5% level of significance. The first seven dimensions of MCA achieved 94.72% for the cumulative variance and which was utilized to build the MLR model as the explanatory variables. The final MLR model based on the significant dimensions of MCA, achieved a lower OCA with a considerable OMPCC.

KEYWORDS: Elephant Deaths, Human Elephant Conflicts, Multiple Correspondence Analysis, Multivariate Data Analysis

1 INTRODUCTION

The issue of Human-Elephant Conflicts (HEC) represents a significant problem in Sri Lanka, impacting both elephants and humans. In examining the ratio of deaths between humans and elephants resulting from these conflicts, it becomes apparent that the number of elephant deaths exceeds that of human deaths. HEC continues to remain a significant issue in Sri Lanka. Hakka patas, electrocution, gunshots, and some other causes (cables, poisoning, and landmines) are the main causes for elephant deaths due to the HEC. Currently, HEC is a complex issue with severe consequences for elephants. In this research, the main objective was to study

elephant deaths due to Human-Elephant Conflicts (HEC), using Multinomial Logistic Regression (MLR) by incorporating important environmental factors and physiological factors with Multiple Correspondence Analysis.

2 LITERATURE REVIEW

2.1 Finding Affecting Factors

In Sri Lanka, the North Central Province has recorded the highest number of elephant deaths (Chandrasekara et al., 2023), displaying an upward trend over time, also Sri Lankan elephant (*elephas maximus maximus*) is considered as an endangered species in the world (Gunawansa et al., 2023). According to the study conducted by (Campos-Arceiz et al., 2009), in the South-Eastern region

of Sri Lanka an association has been identified between the rainy season and HEC. Furthermore, aside the rainfall, these conflicts have been observed to occur with increased frequency during paddy harvesting seasons. However, paddy is one of the main foods that elephants prefer to consume just before and during the harvesting seasons (Santiapillai et al., 2010). Despite paddy being favored, the primary diet of elephants consists of soft grasses such as Beru and Velang (Dharmaratne & Magedaragamage, 2014). In terms of elephant deaths, the number of male elephant fatalities surpasses that of females. It is observed that male elephants tend to live in solidarity in the forest where as females typically reside in small groups (Fernando et al., 2011). Based on the demographic data documenting annual elephant deaths between 2005 and 2010, the highest number of fatalities was recorded among adult male elephants, followed by adult female elephants. However, there were notably fewer deaths among juvenile elephants during that period. The location (inside or outside of the protected areas) where elephants die can provide crucial information about the areas where HEC occur most frequently, the types of habitats where these conflicts are prevalent, and the potential reasons contributing to these conflicts. Electrocutation, gunshots, and hakka patas are the primary causes of elephant deaths attributed to Human-Elephant Conflict (HEC). Additionally, there are other less frequent causes, including poisoning, cables, and landmines (Gunawansa et al., 2023).

2.2 Theories and Techniques

2.2.1 Multinomial Logistic Regression (MLR): Multinomial logistic regression is a type of generalized linear model (GLM) that is used when the dependent variable has more than two categories. It is an extension of binary logistic regression, which is used for binary classification problems.

2.2.2 Multiple Correspondence Analysis (MCA): MCA is designed to analyze contingency tables of categorical variables, where the variables can have more than two levels. MCA transforms the original categorical data into a lower-dimensional space where each point represents a combination of categories for all variables.

2.2.3 Eigenvalues and Eigenvectors: The eigenvalues and eigenvectors are used to transform the original categorical data into a lower-dimensional space. The eigenvalues represent the amount of variance explained by each dimension, and the eigenvectors represent the weights assigned to each categorical variable in each dimension.

3 METHODOLOGY

Elephant deaths in the North Central Province were considered for this study. MLR was employed initially to classify the cause of elephant death (namely electrocution, gunshot, hakka patas, and other causes) with the explanatory variables namely, gender, place of death, age group, rainfall season, and soft grass level. In the research, elephants were divided into three age groups: young (0-15 years old), middle-aged (15-30 years old), and older (above 30 years old). These groups were identified through comprehensive discussion with the officers and former assistant directors in the Department of Wildlife Conservation.

This approach was adopted due to potential significant differences in how elephants are grouped based on their ages. It was identified that the predictors are highly correlated based on the Generalized Variation Inflation Factor (GVIF). Hence, Multiple Correspondence Analysis was employed to overcome this problem as one of the multivariate data analysis methods. This paper discusses the utilization of Multiple Correspondence Analysis to identify of cause of elephant deaths due to HEC in NCP.

3.1 Data Collection

For model building, all the identified elephant deaths due to human impact from 2019 were considered because DWC tended to collect more information from 2019. The data contains a total of 264 identified elephant deaths as represented in Fig. 1, due to human impact with all the information from 2019 for the model building. Apart from these, the information on rainfall patterns in the North Central Province (NCP), soft grass levels in the forests in the NCP, and the information on the paddy harvesting seasons data were obtained from the Department of the Meteorology, The Natural Resources Management Unit of the DWC and the paddy crop calendar of the Department of the Agriculture.

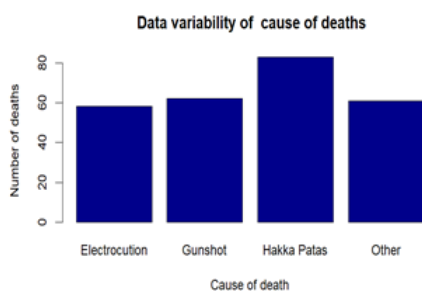


Figure 1: Response data variability

3.2 Association with the Response Variable

Pearson Chi-square test and Fisher's exact test were used to check the association between the dependent variable and predictors. Results revealed that age group, gender, place of death, rainfall season, and soft grass level were significant with the response variable at 5% level of significance while the predictor variable paddy harvest season was found to be non-significant.

3.3 Model Building

One important aspect of model fitting and evaluation is the selection of data. The process of selecting data for the model fitting and model evaluation can greatly impact the results. Therefore, it is crucial to use appropriate data selection methods. In this study, 90% of randomly selected records were utilized for fitting the model, while the remaining 10% was reserved for evaluating the fitted model. It was identified that all the predictors in the initial MLR model were highly correlated, as indicated by GVIF values exceeding five. However, by using MCA, we can create dimensions that do not consist of highly collinear variables, which can then be used to fit a Multinomial Logistic Regression model. The goal is to improve the accuracy and reliability of the model by reducing the impact of Multicollinearity.

3.4 Performance Measures

After several discussions with domain experts and field officers of the Department of Elephant Conservation, it was decided to use three performance measures to evaluate the model's effectiveness: the overall classification accuracy (OCA) of the model, the overall misclassification percentage of critical cases (OMPCC), and the overall

misclassification percentage of non-critical cases. Classification of electrocution or hakka patas as gunshot or other causes and classification of gunshot or other causes as electrocution or hakka patas were defined as misclassification of critical cases. Classification of electrocution as hakka patas or gunshot as other case and vice versa were defined as misclassification of noncritical cases. These misclassifications performance measures were defined based on the survival ability of an elephant according to the above death causes. However, OCA and OMPCC were utilized to evaluate the performance of the model as they were crucial measures in the performance measures. For the classification model, a confusion matrix can be used to evaluate its performance. The confusion matrix provides a detailed breakdown of the model's predictions and the actual class labels in the testing data. Now, consider below Table 1 of the confusion matrix for a particular testing data set.

Table 1: The confusion matrix for a particular testing data set

Expected	Predicted			
	H	E	G	O
H	HH	HE	HG	HO
E	EH	EE	EG	EO
G	GH	GE	GG	GO
O	OH	OE	OG	OO

H- hakka patas, E- electrocution, G – gun Shot, O – Other causes, where $T = (HH+HE+HG+HO)+(EH+EE+EG+EO) + (GH+GE+GG+GO)+(OH+OE+OG+O O)$.

Now the performance measures can be calculated as follow equations,

$$OCA = (HH + EE + GG + OO) / T, \text{ and}$$

$$OMPCC = (HG + HO + EG + EO + GH + GE + OH + OE) / T$$

4 RESULTS AND DISCUSSION

The proportion of variances retained by the different Dimensions can be illustrated in Table 2 and it contains important information regarding the eigenvalues, percentage of variance, and cumulative percentage of variance for the explanatory dataset's nine dimensions.

4.1 Building the Model

The MLR model was fitted using the first seven dimensions of the Multiple Correspondence Analysis (MCA), where "dimension" refers to the number of components used to represent the relationships between categorical variables in a dataset. In this context, dimensions sufficiently represented the data and explained more than 94% of the cumulative percentage of variance as represented in Table 2 and in Fig. 2. The response variable in this study was "cause of elephant deaths," with "Gunshot" being the reference level.

Table 2: The contribution of each Dimension

Dimension	Eigenvalue	Percentage of variance	Cumulative percentage of variance
Dim 1	0.389	21.613	21.614
Dim 2	0.338	18.791	40.405
Dim 3	0.262	14.569	54.975
Dim 4	0.224	12.499	67.475
Dim 5	0.186	10.385	77.860
Dim 6	0.155	8.621	86.482
Dim 7	0.148	8.237	94.720
Dim 8	0.064	3.567	98.287
Dim 9	0.030	1.712	100

The final model was obtained after dropping insignificant variables where the P-values were greater than 0.05. Dim1, Dim3, Dim4 and Dim5 were the

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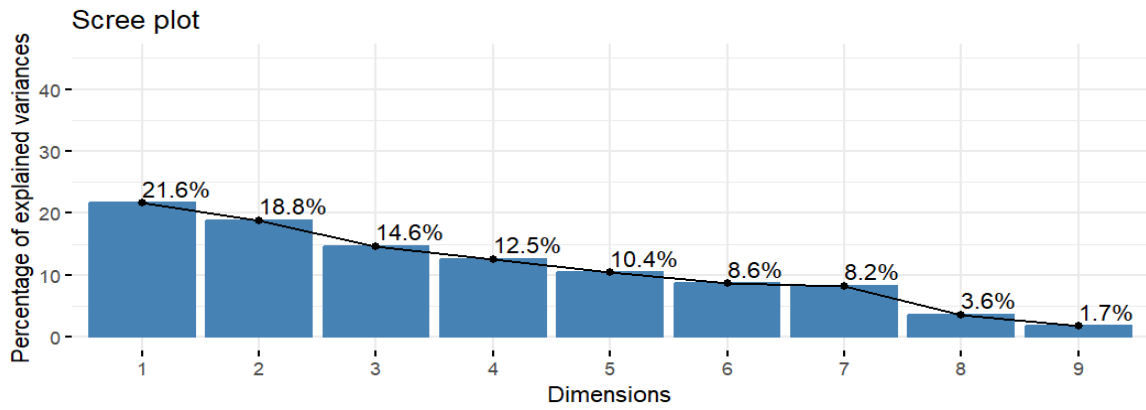


Figure 2: Scree plot to visualization the percentages of the variance of each MCA dimensions

significant variables in the final model according to the P values.

In the model, p-value less than 0.05 indicate a significant association between the predictor variables and the cause of elephant deaths, relative to the reference level of "Gunshot," the Multinomial Logistic Regression model was fitted with three equations representing the remaining three causes of elephant deaths. Below represents the MLR model, (1), (2) and (3) with significant predictors. For all models, the baseline category is "Gunshot".

$$\log(P(Y = Electrocutation)/ P(Y = Gunshot)) = -0.7455 + 0.838* \text{Dim1} - 2.3498* \text{Dim3} + 1.8336* \text{Dim4} + 0.0837* \text{Dim5} \quad (1)$$

$$\log(P(Y = Hakka Patas)/ P(Y = Gunshot)) = 0.2806 - 0.5472* \text{Dim1} + 0.1983* \text{Dim3} + 0.155* \text{Dim4} + 1.8721* \text{Dim5} \quad (2)$$

$$\log(P(Y = Others)/ P(Y = Gunshot)) = -0.1096 - 1.3544* \text{Dim1} + 0.108* \text{Dim3} + 0.1919* \text{Dim4} + 1.1889* \text{Dim5} \quad (3)$$

In this context, this Multinomial Logistic Regression, based on Dimensions of Multiple Correspondence Analysis, works as a predictive model.

4.2 Multicollinearity of the Dimensions

Based on the fitted model, the Variation Inflation Factor (VIF) values for all Dim1, Dim3, Dim4 and Dim5 are 1.34, 1.42, 1.89, and 2.02 respectively. Since VIF values for significant the predictors are less than 3, suggesting that multicollinearity is not a major concern in the fitted model. Additionally, the tolerance values for all the above dimensions are 0.75, 0.7, 0.53, and 0.49 indicating that each predictor variable is not highly correlated with the other predictor variables in the model.

4.3 The Goodness of Fit Test

The results of the goodness of fit test based on Pearson Chi-Square and Deviance statistic are 184.901 and 188.385, respectively. In terms of the P values, Pearson Chi-Square and Deviance are 0.509 and 0.43 respectively. Both of these tests imply that the null hypothesis of model adequately fits the data is not rejected. This suggests that the model fits the data well.

Table 3: The Goodness of fits test

	Chi-Square	Df	Sig
Pearson	184.901	186	0.509
Deviance	188.385	186	0.43

4.4 Pseudo R- Squared Values

Cox and Snell R Square, Nagelkerke R Square, and McFadden R Square values are 34.25%, 36.59%, and 15.24%, respectively. The above values were used to calculate the explained variation which are referred to as pseudo-R square values.

4.5 Performance Measures

The MLR Model with dimensions of MCA was evaluated based on a confusion matrix, using performance measures such as overall classification accuracy and misclassification percentage of critical cases where, misclassification percentage of critical cases were considerably higher. Also, the model achieved a poor overall classification accuracy.

4.6 Discussion

Importantly, no prior research has incorporated MLR with MCA dimensions to build a predictive model for understanding and predicting the causes of elephant deaths in HEC. The uniqueness of this approach lies in considering colinearity issues through MCA dimensions. The final model not only addresses multicollinearity concerns but also serves as a predictive tool, setting it apart from earlier studies that did not leverage this advanced modeling technique.

5 CONCLUSION

This research aimed to explore elephant deaths in HEC, considering significant factors such as gender, age group, rainfall season, place of death, and soft grass level. In the initial MLR model revealed a high correlation among explanatory variables, leading to the application of MCA to mitigate multicollinearity. In this study, MCA derived dimensions were used in the final

MLR model with the first seven dimensions. However, as a predictive model based on MCA dimensions, the MLR model represents rather lower accuracy compared misclassification percentage of critical cases.

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Segmentation Analysis for Enhanced Customer and Merchant Engagement in Private Banking

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ABSTRACT

In an ever-evolving banking landscape, understanding and effectively catering to the diverse needs of merchants is paramount to maintaining a competitive edge. This project report delves into the critical domain of merchant segmentation within the banking sector, aiming to provide insights that enable financial institutions to enhance their merchant-focused & customer-focused promotions. This study employs advanced data analytics and machine learning techniques to analyze a comprehensive dataset encompassing a wide array of merchant-related variables. Through a meticulous process, a classification segmentation model is developed, dividing the merchant base into distinct and actionable segments. These segments are defined not only by transactional behaviour but also by the Customer demographic data such as Gender, Income, Customer Age and also the transaction related data like Recency, Point and Merchant Category. The report presents a detailed analysis of each identified segment, and leads to what are their expectations from their banking partners. Additionally, it highlights the key drivers of merchant loyalty and satisfaction, providing a strategic roadmap for banks to optimize their merchant-centric and customer-centric offerings. In conclusion, this project not only offers a comprehensive customer and merchant segmentation framework but also provides actionable recommendations for financial institutions in the banking sector. By tailoring their services to meet the distinct requirements of each merchant segment, banks can foster stronger relationships, drive profitability, and maintain their relevance in an increasingly competitive marketplace.

KEYWORDS: Classification Model, Customer Segmentation, Merchant Segmentation

1 INTRODUCTION

Private banks are operating in a highly competitive environment, where the quality of customer engagement is a key differentiator. Many private banks still employ a one-size-fits-all approach when it comes to customer engagement, lacking the personalized touch that modern consumers expect. This approach often leads to suboptimal customer experiences and underutilized services like merchant engagement. In contrast, data-driven segmentation analysis can provide a solution to this problem.

With the advent of digital banking and fintech innovations, customers have become accustomed to highly

personalized and seamless experiences. They expect their banks to understand their unique financial requirements and provide tailored solutions. The traditional model of treating all customers equally no longer aligns with these expectations.

Private banks now have access to a wealth of data, including transaction histories, customer demographics, and behavioral patterns. This data can be harnessed to gain valuable insights into customer and merchant preferences, allowing banks to provide more relevant and valuable services.

The private banking sector is highly competitive. To differentiate themselves, banks need to go beyond basic services

and offer a personalized approach. Effective customer and merchant segmentation can be a key differentiator, enabling banks to stand out in a crowded market.

In this context, the research on segmentation analysis becomes crucial. It enables private banks to adapt to changing customer expectations, utilize their data resources efficiently, maintain a competitive edge, and meet regulatory demands. By conducting strategic segmentation analysis, private banks can enhance their customer and merchant engagement strategies, ultimately leading to improved customer satisfaction and business growth.

2 LITERATURE REVIEW

Based on the literature, this is a summary of how customer segmentation works in the context of a bank merchant segmentation project. These studies mainly focus on using machine learning and data mining techniques to segment customers based on their relationships with merchants.

By segmenting customers into targetable groups, businesses can better target their marketing efforts and tailor their messages to encourage purchases, using information such as demographic data (Gali, 2022). Data processing techniques were employed to determine the category, to which each customer belongs, comparing classifier predictions with the actual values for category assignment (Gali, 2022). The RFM model has been widely used in customer segmentation studies. It considers three key factors: Recency, Frequency, and Monetary value of customer transactions (Ahamad & Gunadi, 2022). And the

authors of “New approach to customer segmentation based on changes in customer value” classify customers based on their value using the RFM model and K-means clustering method, and an assessment of changes over several periods of time is carried out (Hosseini & Shabani, 2015). The Segmentation of Shopping Mall Customers Using Clustering paper explores the use of three different clustering algorithms, namely K-means clustering algorithm, mini-batch means, and hierarchical clustering algorithms, for customer segmentation (Deepa, 2022). Other than that, the classification models can also obtain clustering algorithms, such as Agglomerative clustering, Density Based Spatial clustering, Mean Shift clustering, and Balanced Iterative Reducing and Clustering using Hierarchies (Jabade & Ghadge, 2023). These algorithms are used to compare their results using Silhouette Coefficient and Davis Bouldin Index (Deepa, 2022; Jabade & Ghadge, 2023). The K- Means algorithm is a popular clustering method used to group customers and merchants (Ahamad & Gunadi, 2022; Deepa, 2022; Jabade & Ghadge, 2023; Kansal et al., 2018).

In conclusion, these research papers have provided a comprehensive overview of current research trends in customer segmentation within the banking sector. The synthesized knowledge serves as a valuable foundation for my upcoming research, enabling me to build upon existing insights and contribute to the evolving landscape of customer-centric strategies. As we embark on our investigation, the wealth of information gathered from this literature review will

guide our approach and shape the direction of our study.

3 METHODOLOGY

3.1 Introduction about Dataset

In this research project, our data collection strategy was predominantly quantitative in nature and collected for six seasons. The combined dataset used for this research project results from the integration of two distinct datasets. Customer demographic data, and Merchant dataset. The two individual datasets were merged based on common identifiers, such as customer IDs, to create a unified dataset for analysis. The merged dataset combines customer demographic attributes, and merchant interaction data into a single cohesive structure, facilitating holistic analysis. Dataset contains 43672 data with 10 variables.

3.2 Data Pre-processing

In NumPy, the “dtypes” attribute was used to obtain information about the data types of elements in dataset variables. All variables are in float, int and object types, it ensures compatibility with programming libraries and functions, reducing the likelihood of errors during analysis.

The number of null values in each variable was counted using `isnull()` function to handle null values. It shows data frame contains two null values in “Gender” column and other columns are free with null values. Compared to 43672 data 2 is very inconsiderable number and thus those 2 null data rows were deleted from the dataset.

Outliers may indicate real but unusual events or errors. The boxplot

method, is a popular graphical technique for identifying outliers in a dataset. Income variable data contains only 4 outliers, Recency data contains 2 outliers only, Frequency boxplot contain lots of outliers because it have 1-17 values as data. So many transactions have done only a one time. Thus the frequency is 1 for 75% of data so having outliers in certain variables, can be normal or expected in this case. The outliers of the dataset have handled using the Interquartile Range (IQR) method. After outlier handling there was 36482 data.

By duplicated() method verified that dataset does not contains any duplicate values. And the dataset was finally cleaned.

By using heatmap concept the visualized correlation matrix is given in Fig. 1. There is no dependent variable (y variable) in this classification model and all are considered as independent variables. Here you can see there is no multicollinearity.

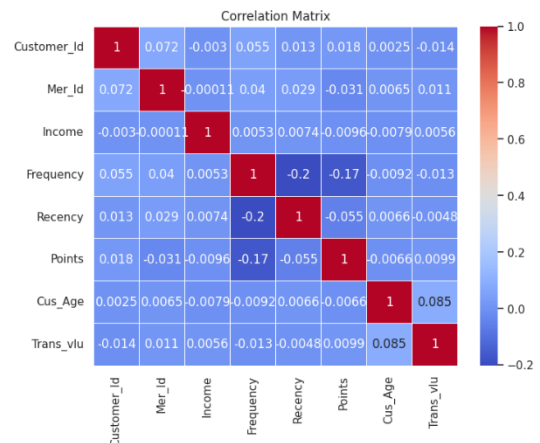


Figure 1: Visualization of correlation matrix

3.3 Dataset Analysis

Conducting various types of data analysis, including univariate and bivariate analyses, serves data

exploration and understanding about the variables in the dataset

Univariate analysis focuses on a single variable at a time. It involves the examination of the distribution, characteristics, and statistics of that variable. Bivariate analysis focuses on examining the relationships between two variables simultaneously. It aims to understand how one variable influences or is associated with another variable.

3.4 Final Score Analysis

For customer segmentation following analysis was done using recency, points and transaction values.

“pd.qcut” method in the pandas library, was used for performing quantile-based discretization of continuous data. And “r_score” and “p_score” were obtained.

“pd.cut” method in the pandas library was used to create discrete intervals for transaction value variable. And obtained the “tv_score”.

Then “Final_score” was calculated using a formula which is created according to the domain knowledge. The formula is as follows.

$$Final_{score} = 100 \times r_{score} + 10 \times p_{score} + tv_{score} \quad (1)$$

Then labeled Final_score as 'Bronze', 'Silver', 'Gold', 'Platinum' to segment customers. Most of the customers are in Bronze package.

3.5 Clustering and Segmentation Analysis

Data were scaled by Z-score Scaling and scaled dataset in order to bring all numerical features to a consistent and comparable scale.

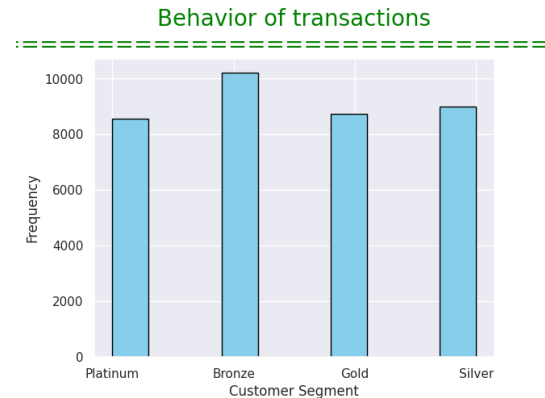


Figure 2: Package for Customer: Bar chart

3.6 K-mean Analysis

The optimal number of clusters was found by “Elbow method”.Based on the location of the elbow point, the most suitable number of clusters for dataset is 4. The K-means clustering algorithm was applied to partition the dataset into distinct clusters. The obtained clusters are shown in Fig. 4.

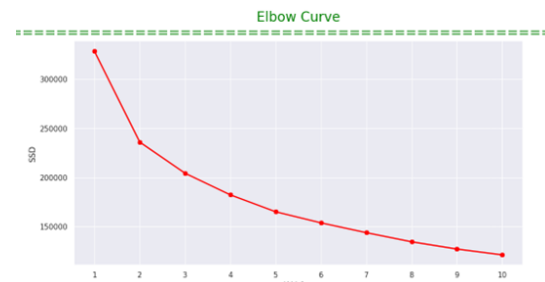


Figure 3: Elbow-curve of K-mean clustering



Figure 4: Scatter plot of clusters: K-mean clustering

3.7 Mini-batch K-mean Analysis

The optimal number of clusters was found by “Elbow method”. Based on the visual inspection of the plot and the location of the elbow point, the most suitable number of clusters for dataset is 3. The Mini-batch K-means clustering algorithm was applied to partition the dataset into distinct clusters. The obtained clusters are as in Fig. 6.

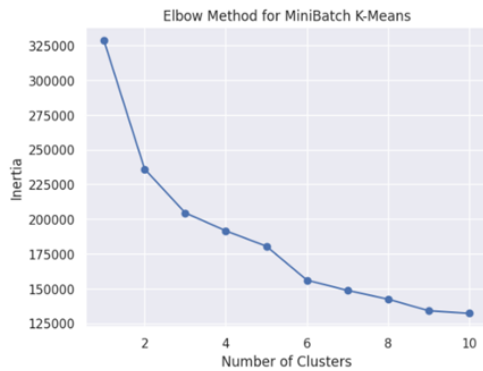


Figure 5: Elbow-curve of Mini-batch K-mean clustering

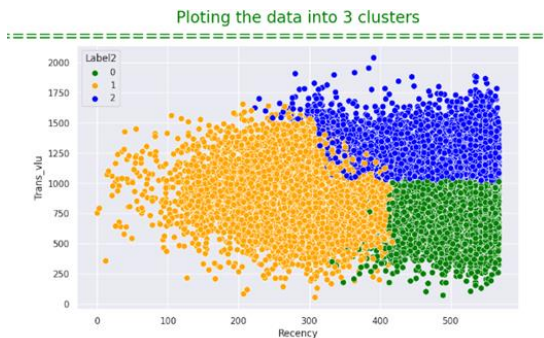


Figure 6: Scatter plot of clusters: Mini batch K-mean clustering

3.8 Hierarchical Clustering

The optimal number of clusters was found by “Dendrogram method” as shown in Fig. 7. Based on the visualization of Dendrogram, the most suitable number of clusters for dataset is 2. But using only two clusters might not provide enough granularity or capture the underlying complexity of the data. So decided to ignore Hierarchical Clustering method for my dataset.

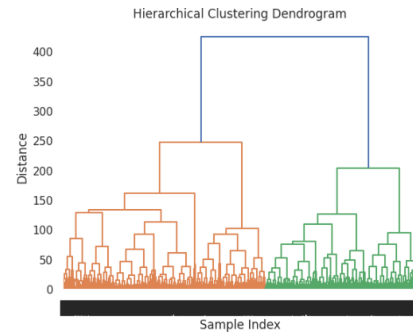


Figure 7: Dendrogram of Hierarchical clustering

3.9 Interpretation of Results

Silhouette Score can be used to decide the best clustering method among K-means clustering and Minibatch K-means. The obtained Silhouette Scores are as follows.

Silhouette Score of K-mean analysis -0.0154374335489

Silhouette Score of Mini batch K-mean analysis -0.0042379551614

4 RESULTS AND DISCUSSION

A high Silhouette Score indicates that the object is well matched to its own cluster and poorly matched to neighbouring clusters, suggesting a good clustering. Thus Minibatch K-means is the good method of among three algorithms for clustering. From the above we can see that the data has been clustered into 3 different parts.

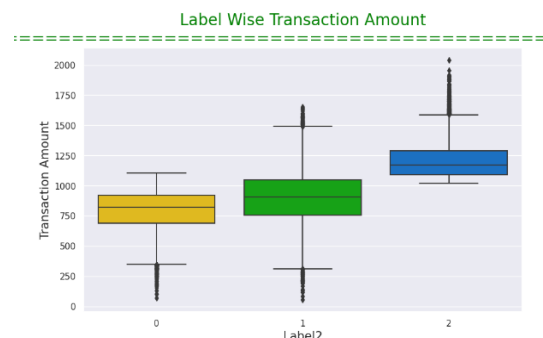


Figure 8: Transaction amount behavior of 3 clusters

The final and main output of this classification model is, obtaining the merchant Id s related to each clusters and examine how is the merchants have behaved in each clusters.

The number of customers in 1st group
13317

The number of customers in 2nd group
14305

The number of customers in 3rd group
8859

5 CONCLUSION

The initial dataset, containing 10 variables and 43,672 data points, was reduced to 36,482 data points after preprocessing. Analysis revealed a high prevalence of customers with "Bronze" packages and a low number of those with "Platinum" packages. The project's focus on clustering customers and merchants based on similar behaviors utilized k-means, mini-batch, and hierarchical clustering methods. The best clustering approach was determined to be mini-batch clustering, as indicated by the Silhouette Score. The final outcome involved identifying merchant and customer IDs within each cluster, showcasing similarities via mini-batch clustering, which could be leveraged for targeted promotional campaigns.

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The Best Statistical Approach to Forecast the Air Quality in an Urban Environment: A Case Study

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ABSTRACT

This study was aimed at identifying a reliable statistical approach to forecast the air quality in a typical urban environment of Sri Lanka, by means of PM10 concentration, a key air pollutant, in the presence of weather parameters. The hourly data spanning from December 10, 2022 to March 15, 2023 in the city of Kandy were utilized for this study. The models developed for predictions included Recurrent Neural Network (RNN), Non-Linear Autoregressive (NAR), Support Vector Regression (SVR), and Random Forest (RF). Weather was accounted by Barometric Pressure (hPa), Rain Gauge (mm), Wind Speed (ms^{-1}), and the Wind Direction. The performance of each model was evaluated in terms of the Mean Squared Error (MSE), Mean Absolute Percentage Error (MAPE), and R-squared (R^2) metrics. Results revealed varying degrees of accuracy among the models where both NAR and RNN yielded higher error values (MSE and MAPE) with an average R^2 value closer to 0.5. In contrast, the SVR produced exceptional performance, yielding an impressively low MSE and MAPE values and a very high R^2 value above 0.9. The RF Model outperformed the other models with the least MSE and MAPE values and an outstanding R^2 value of 0.9896. It could be concluded that both SVR and RF models possess superior predictive capabilities for forecasting the air quality in Kandy. Studies on air quality prediction in urban environments using such effective statistical models are lacking in Sri Lanka which provides valuable insights into aiding environmental management with policy decisions and emphasizes the importance of integrating weather parameters for enhancing prediction accuracy.

KEYWORDS: Air Quality, Machine Learning, Urban Environment

1 INTRODUCTION

The air we breathe, a fundamental necessity of life, is under siege. In an increasingly industrialized and urbanized world, air pollution has become a pervasive and pressing challenge. Air pollution is in fact a global challenge that significantly impacts not only human health but also ecosystems and climate change. According to the World Health Organization (WHO, 2022), exposure to a complex mixture of pollutants poses serious health risks, with 89% of related premature deaths occurring in low- and middle-income countries. In 2019 alone, outdoor air pollution was linked to 37% of premature deaths from heart disease and

stroke, 18% from chronic obstructive pulmonary disease, 23% from acute lower respiratory infections, and 11% from respiratory tract cancer (WHO, 2022). Among the BRICS Nations, China and India, in view of their rapid economic growth and urbanization, face severe air pollution issues. In South Asia, high population densities, industrial activities, burning of waste, and outdated cremation practices contribute to persistent air pollution, making it the most polluted region globally (Akhtar, 2023). Sri Lanka, though less impacted than some neighbors, face challenges from urbanization, industrialization, vehicular emissions, and improper waste

management. The country also experiences transboundary air pollution from neighboring countries, emphasizing the need for regional cooperation (Abdul Jabbar et al., 2022; Ileperuma, 2020). Sri Lanka must participate in regional accords to address transboundary pollution, monitor air quality, and exchange data. Weather conditions play a crucial role in air pollution dynamics influencing pollutant dispersion, chemical reactions, and accumulation. Weather parameters like temperature, wind speed, wind direction, humidity, and topography interact to impact local and regional air quality. The City of Kandy, surrounded by hills and mountains, experiences air pollution exacerbated by its topography, temperature inversions, increased urbanization, and various emission sources. Addressing these issues requires comprehensive strategies, including urban planning, transportation management, industry regulations, and the promotion of cleaner technologies (World Bank, 2023). Predicting the air quality in Kandy, Sri Lanka, is a challenging research problem due to the intricate and multifaceted nature of atmospheric processes, the complex interactions among various pollutants, and lack of comprehensive data on air pollutants. The study aims to develop reliable predictive models using machine learning approaches and, consequently, to select the best approach for forecasting air quality conditions in the region.

2 LITERATURE REVIEW

Air quality prediction, a crucial domain in environmental research and practical application, involves assessing and forecasting air pollutant levels and plays a pivotal role in addressing the complexities

of air pollution. Impact of air pollution on human health and the environment needs to be understood through the integration of diverse factors including atmospheric processes, pollutant interactions, and geographic features. Ding and Qie (2022) investigated the impact of meteorological factors on air pollutant concentrations in Ningxia, using mathematical models like Decision Tree Regressor and Feedforward Artificial Neural Network. They found that Random Forest Regressor significantly improved prediction accuracy and established useful relationships between influential factors and pollution levels, which emphasized the need of accurate forecasting for informed air quality management and public health protection. The study by Mampitiya et al. (2023) is the first in Sri Lanka to anticipate air quality levels in two urbanized areas in Sri Lanka, revealing that the LightBGM algorithm outperformed other models with remarkable accuracy, low error metrics, and high R-squared scores in forecasting PM10 levels for both regions.

Recurrent Neural Networks (RNNs) represent a category of artificial neural networks specifically designed for handling sequential data and capturing temporal dependencies. Freeman et al., (2018) used deep learning techniques, specifically a RNN with long short-term memory (LSTM), to forecast ozone (O₃) concentrations, a crucial aspect of air quality management. Non-linear Autoregressive (NAR) models are a type of predictive modeling approach that extends traditional autoregressive models by incorporating nonlinear relationships. These models aim to capture complex dependencies within data and make predictions based on past observations.

NAR models find applications in various fields including time series forecasting and system identification. Support Vector Regression (SVR) is a machine learning approach within the broader framework of Support Vector Machines (SVM) tailored for regression tasks. This differs from traditional regression models, making it adept at handling both linear and non-linear patterns in the data. Lei et al. (2022) used machine learning methods viz. Random Forest (RF), Gradient Boosting (GB), and Support Vector Regression (SVR), to forecast air quality. They showed that RF method yielded the best accuracy in terms of a higher coefficient of determination (R^2) and lower RMSE, MAE, and BIAS. Random Forest (RF) is a powerful learning algorithm used for classification (Breiman, 2001) and regression tasks in machine learning. The key idea behind Random Forest is to introduce randomness both in the data used for training each tree and the features considered at each decision point, which collectively results in a robust and accurate model that is less prone to overfitting compared to individual decision trees. Random Forest's effectiveness is supported by its ability to handle complex datasets and deliver superior performance.

3 METHODOLOGY

The main objectives of this study are to model the PM 10, the most prominent air pollutant in Kandy, Sri Lanka using four different machine learning techniques to capture complex non-linear structures in data and to identify the most accurate approach by systematically comparing the error and performance indicators. First, 44 numbers of missing data were imputed using the mice package in R software. The

variance inflation factor for each climatic variable was calculated to assess the multicollinearity among them, which can impede the performance of the machine learning models. Then followed by RNN machine learning method for predicting the PM10 concentration first. The completed data set with imputed values was normalized using the Min-Max Normalization Method. The simple RNN model used in this study was configured with one hidden layer, 64 neurons, sigmoid activation function, a batch size of one, and 100 epochs. The compilation of the model further involved the use of mean squared error as the loss function and the Adam optimization algorithm for efficient parameter updates during training. Then, the NAR prediction was carried out by testing various combinations of lag and degree values. It could be determined that the optimal combination with the lowest MSE value resulted from lag=2 and degree=3. The NAR model was thus built employing a polynomial regression with a lag of two and a degree of three. Next, the Unit Vector Normalization was conducted followed by an SVR analysis within the radial basis function kernel. By applying the grid search and cross-validation methods, the performance of the various combinations of hyperparameters (gamma and cost C) were tested and it could be identified that the smallest Root Mean Squared Error (RMSE) is the best hyperparameter selection criterion. The ultimate values chosen for the model parameters were gamma=0.23 and C=10. Finally, the RF analysis was performed after normalizing the data with the Unit Vector Normalization Method. In the Random Forest Algorithm, there are two crucial parameters, namely ntree and

mtry, which can be adjusted to fine-tune the algorithm (Zahedi et al. 2018). The optimal mtry values were determined by using the tuneRF method, which has the lowest Out-Of-Bag (OOB) error value. Then ntree value of 200 was used to train the model.

4 DATA COLLECTION AND ANALYSIS

Air quality data within the city limits of Kandy, Sri Lanka were collected from the Central Environmental Authority in Sri Lanka. There was a total of 2,304 hourly data points recorded from December 10, 2022 to March 15, 2023, with several missing values. This data set contained PM10 concentration, a major pollutant, and the four weather parameters mentioned in the Abstract. As the presence of PM10 is prominent in Kandy, this study developed an advanced predictive model specifically aimed at forecasting PM10 levels while providing a comprehensive understanding of the City's air quality dynamics. The RNN and the NAR were employed to model PM10 concentration, while SVR and RF incorporated four weather parameters to construct models for PM10. Subsequently, the PM10 concentration was predicted from these four models, and the performances were evaluated using MSE, MAPE, and R-squared values. Each model was trained using 80% of the data and then tested for performance using the remaining 20%.

5 RESULTS AND DISCUSSION

It was revealed from the study that there is no multicollinearity among the weather parameters. Also, Pearson's correlation coefficients indicated that there is no significant linear relationship

Table 1: Performances of the models

Method	MSE	MAPE	R ²
NAR	232.73	20.49%	0.5230
RNN	245.34	22.01%	0.4898
SVR	8.88e-06	6.05%	0.9830
RF	6.29e-06	4.3%	0.9896

between climatic variables and PM10 concentration. Table 1 provides insights into the performance of each model in predicting the PM10 concentration. According to the Table 1 figures, findings indicate widely different performances among the models constructed. Although NAR and RNN models showed less accuracy with higher error values and an average R-squared value close to 0.5, the SVR demonstrated remarkable performance with much less MSE and MAPE values and a very high R-squared value of 98.3%. Further, the RF model outperformed all the other models yielding the least MSE and MAPE values with an outstanding R-squared value of 98.96%. Finally, it can be inferred that both SVR and RF models possess superior predictive capabilities in forecasting PM10 concentration in the urban environment of Kandy, based on weather parameters, with RF being exceptional.

6 CONCLUSION

Modeling air quality plays a pivotal role in understanding, predicting, and mitigating the impacts of pollutants on human health, the environment, and various ecosystems. The significance of this study is to present a reliable statistical approach to forecast air quality in a densely populated urban environment of Kandy, Sri Lanka in terms of PM10 concentration in a background

characterized by key weather parameters. The MSE, MAPE, and R-square values were used to evaluate the aptness of the models in comparison to each other. The RF model emerged as the most robust performer, yielding the lowest MSE and MAPE values and the highest R-square value. Alternatively, the Support Vector Regression model also demonstrated low error values and a higher R-square value. Nevertheless, the RNN and NAR models could not be reckoned with, due to higher MSE and MAPE values and lower R squared values than the other models. In comparative terms, RF stood out with an impressive accuracy rate of 98.96%, making it the most suitable statistical tool for air quality prediction in an urban environment like Kandy in Sri Lanka.

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