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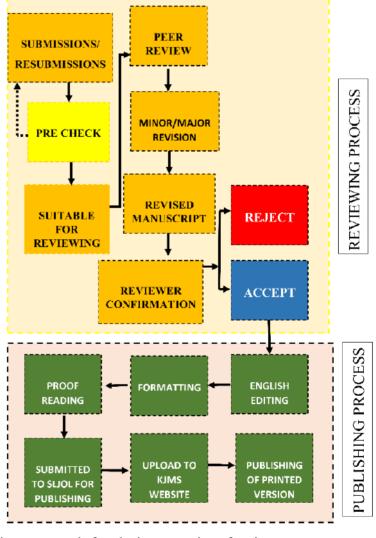
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CONTENTS

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COGNITIVE IMPAIRMENTS IN SUBSTANCE ADDICTION: NARRATIVE REVIEW

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ABSTRACT

Cognition is an intricate mechanism governing the executive functions in the human body and undergoes a developmental process influenced by genetic, biological, and ecological factors. The addicted substance can be denoted as a trigger of deteriorated cognition, impacting memory, decision-making, attention, and reasoning. Specific examination of alcohol, nicotine, cannabis, cocaine, opioids, and amphetamines elucidates the unique ways each substance impairs cognitive functions, ranging from memory deficits to impaired attention and psychomotor skills. Hence the relevant information was gathered by referring to Google Scholar, PubMed, and Elsevier databases. To extract the updated information selected journals were filtered up to the previous ten years. Dopaminergic dysregulation arises as a central theme, influencing reward schemes, motivational drives, and memory pathways, disseminating compulsive behaviors, and obstructing substance cessation. This inclusive exploration highlights the urgency of addressing these complications for informed prevention strategies, effective public health initiatives, and targeted interventions. By elucidating the cognitive impairment in substance addiction, this review strives to emphasize the danger of substance usage.

KEYWORDS: *Substance, Cognitive impairment, memory, processing speed*

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1. INTRODUCTION

Cognition is a complex set of mental processes incorporating the acquisition, storage, and retrieval of information. The developmental trajectory of cognition commences with birth associating genetic, biological, and ecological factors (Guez et al., 2021). Substances are emphasized as one of the most considerable triggering factors that can directly cause declined cognition including memory, decision-making, attention, and reasoning (Shau & Zhou, 2022). United Nations Office on Drug and Crime (UNODC) reported that 5.8% of individuals aged 15 to 64 habituated to use substances all over the world. Of them, 35 million were diagnosed with substance use disorders. Apart from the physiological damages according by the prolonged usage of substances, severe neurobiological changes can occur in the brain (Melugin et al., 2021). Due to the addictive properties of various substances including alcohol, nicotine, cannabis, cocaine, opioid, and amphetamine, cognitively compulsive behaviour will be manifest that inhibits the termination of the addictive substance. Thereby, observable changes become apparent within individuals' reward schemes, motivational drives, and related memory pathways linked to memory with the continuous craving for a particular substance (Lüscher & Janak, 2021). Consequently, performance in academics and occupations, mental health, and individual quality of life will drastically deteriorate. Hence, the main scope of this review is to elicit the harmful effects of various substances on human cognitive functions.

World Health Organization defines the substances as psychoactive drugs including alcohol and tobacco products. Previous research reveals that ages between 18 to 25 are the most vulnerable period to exposure to the substances (Nawi et al., 2021). A recent research done by using Canadian high school students to investigate the prevalence and correlates of youth poly-substance use revealed that 39% of the youth population engaged with substance use, 53% of them were poly-drug users (Zuckermann et al., 2020). Reviewing the recent literature on the Sri Lankan context, 57% of substance-related arrests were reported in 2021 and 36.5% of substance users were

reported among the emerging adult population in the Western Province (National Dangerous Drug Control Board [NDDCB], 2022). Of them, 3.8% of Advanced Level were at a high risk of engaging in tobacco products, 16.1% of them were reported at moderate risk of alcoholic beverages and 3.8% of them reported a high risk of Cannabis use in the Sri Lankan context (Charuni et al, 2023). Through exposure to media, commercial advertisements, and peer pressure, most adolescents are prone to initiate the substance with addictive properties , and they gradually become addicted to those substances. Some adolescents initiate substance by hearing myths regarding substance usage and end up with substance addiction. One of the studies revealed that openness and extravert personality traits can have a substantial correlation with the initiation of substance use among emerging adults (Thennakoon et al, 2023; Mezquita et al., 2018). Further denoted that the harmful use of substances by people mentioned above causes substance abuse after a longer period (World Health Organization [WHO], 2024). Alcohol, tobacco, cannabis, cocaine, opioids, and amphetamines are the widely used psychoactive drugs that can switch on dopamine neurotransmitters and dysregulate the functions of the brain (World Health Organization [WHO], 2024).

Dopamine is a neurotransmitter that regulates the sensation of pleasure, motivation, and self-satisfaction internalizing in the brain's reward system. (Heimgärtner, 2020; Conrad, 2018). Individuals utilizing addictive substances can increase the level of dopamine which can act as a reinforcing factor for the maintenance of a particular substance (Gould, 2010). Thus, chronic usage of substances dysregulates the brain reward system. Studies reveal that heavy use of substances cause impairment in the prefrontal cortex. Thereby substance-related impulsive behavior will increase declining self-regulation (Goldstein & Volkow, 2011). For this reason, most of the executive functions like decision-making, planning, and memory will be impaired (Martini et al., 2022). Considering memory, individuals who are addicted to substances will be unable to form new memories because of the impairment of the hippocampus (Kutlu & Gould, 2016).

Alcohol-related cognitive impairments

Alcohol is a substance that is quickly absorbed into the bloodstream and affects the brain, kidneys, lungs, and liver. Alcohol is capable of dysregulating neural function that leads to symptoms of intoxication, slurred speech, and poor memory (Cox & Klinger, 2022). Teenagers and adolescents are prone to binge drinking as per the developmental storm that they are experiencing at that time. With the continuous arguments with parents and being a part of society, they might start drinking (Aleixandre et al., 2011).

Even though the dopamine neurotransmitter increases happiness and motivation, continuous alcohol usage leads to the reduction of the number of dopamine receptors causing hopelessness and depression (Lath & Meshram, 2021). Along with that, alcohol reduces the level of glutamate leading to the feelings of low energy and lethargy. Prolonged and extreme alcohol usage may cause vitamin B deficiency and diminished appetite. Consequently, malnutrition associated with alcohol intake can contribute to cognitive impairment (Butler Center for Research [BCR], 2015). Moreover, it diminishes the sizes of both gray matter and white matter in individuals who are diagnosed with alcohol dependence (Daviet et al., 2022). If these conditions were untreated, serious memory and language damage including Wernicke-Korsakoff syndrome might appear in the future.

Nicotine-related cognitive impairments

Nicotine is the psychoactive compound in tobacco products that directly interacts with the central nervous system (Valentine & Sofuoglu, 2018). Once, individuals use tobacco products acetylcholine receptors get stimulated by nicotine compounds which dysregulate the formation of novel memory and memory consolidation. Despite the fact that a slight quantity of nicotine increases alertness and cognitive performance, enduring exposure causes desensitization of the neurotransmitters which can affect cognitive decline (Hahn et al., 2019). The toxic dose of nicotine is estimated to be 40-60 mg for adults, with a dose of 0.8-1 mg/kg body weight

(Tiwari et al., 2020). A study conducted among the Pakistani young population to investigate the smokers' and nonsmokers' variance of cognitive functions evoked a lack of attention-switching tasks within smokers (Riaz et al., 2021). Another research revealed that individuals who identified as severe smokers indicate damages of selective attention, alternating attention, and working memory (Nadar et al., 2021).

Cannabis-related cognitive impairments

Cannabis compounds with tetrahydrocannabinol, which consists 64 active isomers, leads to a psychoactive effect. Thus, different mental and behavioral reactions can appear with each 64 isomers (Atakan, 2012). Despite some countries implementing harsh penalties for the use and sale of cannabis, it has become the most commonly used substance in the world (Shrivastava et al., 2011). As per the WHO statistics, 2.5 % of Substance addicts reported as cannabis users and youth have been identified as the most vulnerable population to initiate this substance (World Health Organization [WHO], 2024). As previous research findings imply, cannabis directly affects individuals' cognitive development. Thus, if an individual initiates cannabis in adolescence, over a period of time their learning, recall and psychomotor performance will be impaired (Gorey et al., 2019). Compared to late-onset initiation, early-onset initiation has caused more damage to the executive functions according to one of the research findings related to cannabis dependence.

Additionally, it is indicated that the early onset of cannabis use could be a factor in the initiation of other narcotics during later times (Hawke et al., 2020).

Cocaine-related cognitive impairments

Cocaine is also a plant-based addictive stimulant drug (National Institute on Drug Abuse [NIDA], 2022) that can also have a significant impact on cognitive functions (Chao et al., 2019). Researchers found that once an individual uses cocaine, it stimulates the brain pleasure center releasing dopamine neurotransmitters. Along with that chronic usage might increase the tolerance and eventually end up with substance use

disorder with severe cognitive impairments (memory, attention, learning, motor skills, psychomotor speed, and emotions) and withdrawal symptoms (Vonmoos & Quednow, 2017; Moeller et al., 2014). Chao et al. (2019) conducted an experimental study that revealed there is a significant impairment that can appear in attention, processing speed, visual memory, and working memory among young adults who smoke cocaine.

Opioid-related cognitive impairments

Opioids can be considered highly addictive narcotic that is used as a pain medication. As per the strong interaction between brain receptors and opioid-active compounds, tolerance will be rapidly generated within the human body. Hence, within a short period of time they might encounter physical and psychological withdrawal symptoms (Koob, 2020). Apart from that opioids combined with the brain reward system and secret dopamine neurotransmitter continuously reinforcing behaviours associated with pleasure. A cross-sectional study conducted by Moghaddam et al. (2021) indicated that among the individuals diagnosed with opium use disorder, the majority of them present impairments in working memory and speed of information processing. Additionally, individuals can develop psychological dependence involving strong emotional or mental reliance on this drug (Moghaddam et al., 2021).

Amphetamine-related cognitive impairments

Amphetamine is a synthetic stimulant drug that has been made to increase the message traveling speed between the brain and body. Earlier, this drug was designed to treat attention-deficit hyperactivity disorder (Boos et al., 2021). However, drug addicts are habituated to misuse this drug without a prescription due to their addictive properties. Chronic use of amphetamine can lead to memory deficits, including both short-term and long-term memory impairments (Nyberg, 2012). Nevertheless, using a high dose of Amphetamine can impair certain cognitive processes including impulse control, decision-making, and problem-solving (Yechiam & Zeif, 2021). Amphetamines are known for their stimulant effects,

but ironically, chronic use may lead to a reduction in processing speed that delays cognitive tasks to complete (He et al., 2022). Chronic usage of amphetamine may cause psychiatric symptoms including anxiety, hallucination, and paranoia (McKetin et al., 2017).

2. CONCLUSION

This exploration highlights the complex relationship between substance use and cognitive function, emphasizing the profound implications for individual well-being and societal health. Cognition, a pivotal mechanism governing executive functions, is intricately shaped by genetic, biological, and environmental factors from birth. The compelling evidence presented in this review reveals substances as an alarming factor, directly compromising cognitive domains such as memory, decision-making, attention, and reasoning. The comprehensive literature review underscores the vulnerability of emerging adults, with a spotlight on the Sri Lankan context revealing alarming rates of substance-related arrests and use among these demographic areas. The influence of personality traits, media exposure, and peer pressure on substance initiation further complicates this multifaceted issue. The dopaminergic dysregulation induced by substances such as alcohol, nicotine, cannabis, cocaine, opioids, and amphetamines emphasize the neurochemical underpinnings of addictive behaviors, impacting executive functions and cognitive decline. The specific examination of alcohol, nicotine, cannabis, cocaine, opioids, and amphetamines reveals the intricate ways in which each substance uniquely impairs cognitive functions, ranging from memory deficits to impaired attention and psychomotor skills. Understanding these cognitive consequences is imperative for informing preventative strategies, public health initiatives, and targeted interventions aimed at mitigating the profound impact on academic performance, occupational functioning, mental health, and overall quality of life. As we conclude this review, it is evident that a holistic approach is necessary to address the complex interchange between substance use and cognitive function, ultimately adopting healthier outcomes for individuals and society at large.

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A FRAMEWORK TO INTEGRATE BUILDING INFORMATION MODELLING TO THE CURRICULUM OF THE QUANTITY SURVEYING UNDERGRADUATE DEGREE PROGRAMME IN SRI LANKA

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ABSTRACT

One of the primary sectors that contributes to the national economy of the country is the construction industry. The Quantity Surveyors (QS), offer specific expertise in project management and cost estimation. A revolutionary change is occurring in Sri Lanka (SL)'s construction industry due to the increasing demand for innovative technologies such as Building Information Modeling (BIM). But the Sri Lankan construction industry has been remarkably lagging in adopting these cutting-edge techniques. According to past SL research findings, one of the main obstacles in BIM integration among QS professionals is a severe knowledge gap. By involving BIM approaches into QS education this research aims to develop a framework to implement BIM within the curriculum of quantity surveying undergraduates according to the industrial demand in SL. This paper focuses on the potential difficulties of integrating BIM into SL's QS curriculum, where graduates may fulfill industry expectations. This research used questionnaire survey, semi-structured interviews for both academic and industrial QS professionals separately, and conducted existing university QS curriculum review to gather data. Purposive sampling is used as the sampling technique and this study uses a mixed-method approach to research, combining qualitative and quantitative evaluations, and analyzes data using descriptive statistics and content analysis. According to data gathered from industrial professionals, it was proved that SL construction industry does not widely use BIM and have a huge demand on knowledgeable BIM of QS in the current industry. Most of the knowledgeable BIM personnel gain knowledge from self-learning and by following some extra courses. Professionals with an academic background proved, that the current QS curriculums are outdated. As a solution, this research develops the framework to integrate BIM to the QS curriculum of the undergraduate degree programmes in SL. A framework suggestion is to be incorporated into the curriculum was the outcome of the researcher's reflections on the interview results. These results contribute to the growth and development of the Sri Lankan construction industry by knowledgeable QS professionals, thereby fostering the advancement of the Sri Lankan construction industry.

KEYWORDS: *Building Information Modelling, Quantity Surveying (QS), Education System, Sri Lanka.*

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1. INTRODUCTION

Ttechnology is constantly developing and transforming every aspect of life, from the most basic to the most sophisticated activities. Building BIM is one of the most obvious factors of a deep and systemic transformation that is rapidly evolving the worldwide construction sector (Olorunfemi et al., 2021). BIM is a multifunctional model platform that delivers as a project resource center and database, and it is a popular trend in the construction sector. The use of BIM software arrange for several assistances such as digitization, communication, and engagement among project contributors (Ismail et al., 2021). It allows for real-life scenario simulations and discovers potential difficulties such as clashes and errors in a virtual environment before the actual building project is established and which could be mitigated (Ying, Kamal and Esa, 2022).

Quantity surveying is a profession that facilitate the smooth progress and achievement of construction projects. The traditional duties of a quantity surveyor includes creating bills of quantities (BOQ), cost estimates, measuring, and planning, as well as other procurement-related duties including payment and claim handling (Yan and Cheng, 2021). Quantity surveyors or cost engineers in Northern America are recognized as the major individuals conducting high standard QS procedures. Mensuration, accounting, financial side, contracts, law, and information management are all samples of QS techniques. From the feasibility study stage until the delivery stage, QS techniques place strong emphasis on the cost and contract management. QS may work more efficiently, reduce mistakes and provide better results by applying BIM (Nawari and Alsaffar, 2016; Olowa, Witt and Lill, 2019).

The demand for new services from the construction industry has forced quantity surveyors to expand their capabilities. Building information technology and business management are two important competencies that the quantity surveyor might need to have. Software like cost-X, Revit, cube-cost and others may make it easier to develop these skills. The quantity surveyor of today must possess a wide range of

Iinformation Ttechnology (IT) skills (Yan and Cheng, 2021).

However, BIM is not widely used in the local construction industry yet. But in the near future, BIM will overtake the local construction industry expeditiously and some of the Sri Lankan projects are already used in BIM technology. Then in future, it may challenge the traditional quantity surveying practices. Lack of BIM experience, knowledge, expertise and resistant to change are the current challenges of BIM Implementation in Sri Lanka (Perera et al., 2021). The role of quantity surveyor is likely to change considerably in the future due to the constantly evolving demands of the modern construction industry and without updating the knowledge and experience, ? cannot overcome this challengers (Yan and Cheng, 2021).

The best solution to mitigate those problems is to improve the education system in Sri Lanka (SL) and it will be challenging for education to adapt to the complex demand of the construction sector. Further, the degree programs and related expertise offered by educational institutions must regularly recognize new opportunities and upgrade their curriculum to increasing abilities of quantity surveyor. This research is made to seek the way of upgrading undergraduate curriculum regarding the BIM to fulfil the industrial demand and mitigate challengers faced by future Quantity Surveyors, Sri Lanka.

2. LITERATURE SURVEY

BIM in construction industry

Project managers or BIM coordinators in the construction industry are responsible for introducing and putting BIM into practice inside their firms. They create BIM implementation strategies, set BIM standards and protocols, specify project-specific BIM needs, and manage the adoption of BIM tools and processes (Vigneault, Boton and Chong, 2019; Rachid, 2021). BIM is used by construction professionals to improve communication and coordination amongst different project stakeholders. They may discover and resolve clashes or conflicts before construction begins by actively engaging in

multidisciplinary coordination meetings and using BIM coordination tools, which reduces rework and delays (Keung, Yiu and Feng, 2022).

The BIM models are created and managed by construction experts throughout the course of the project. They aid in the creation of intricate building models by including details like phasing, sequencing, and construction techniques. As the project advances, they update the models to reflect alterations and as-built circumstances (Vigneault, Boton and Chong, 2019).

Building specialists can help BIM be used effectively for facility management and maintenance beyond the building phase. They can add asset and maintenance data to the BIM model to produce an extensive digital twin of the structure. Facilities management, space planning, preventative maintenance, and restorations can all benefit from this knowledge (Keung, Yiu and Feng,2022).

Application of BIM in Practice by Quantity Surveyors

A quantity surveyor is a specialist in monitoring and controlling building project costs. They work in the construction company operations (Vigneault, Boton and Chong, 2019). BIM has also had a considerable impact on quantity surveying techniques, resulting in more effective and accurate cost control. The following BIM procedures link to quantity surveying (Jin *et al.*, 2019; Calvin, Wing and Feng, 2022).

a) Quantity takeoff automation: Quantity Surveyors may automate the manual takeoff procedure by extracting quantities straight from the BIM model. (Olsen and Taylor, 2017).

b) Integration of cost estimation: BIM models may be connected to cost databases, giving quantity surveyors access to current cost information. Cost X, Sage Estimating are Software that can be used for cost estimation (Ekanayake *et al.*, 2022).

c) Early Cost Analysis: Quantity surveyors may do early cost analysis responses to BIM. Premavera P6 (Oracle) and e-builder are software that can be used for cost analysis (Sivarajah, 2022).

d) Change Management: The BIM model is updated to reflect design changes, and quantity surveyors may swiftly determine the impact on costs, reporting back to the project team right away. (Tomek and Matějka, 2014).

e) 4D and 5D BIM: The integration of time (4D) and cost (5D) data into the BIM model by quantity surveyors enables a more thorough knowledge of the project's schedule and budget. (Harrison and Thurnell, 2015; Vigneault, Boton and Chong, 2019)

f) Value Engineering: With BIM, value engineering procedures are made possible, allowing the QS to evaluate options and maximize project value without sacrificing quality. (Sivarajah, 2022).

Current Situation of BIM Application in SL's Building Sector

It is a prominent fact that the construction industry in Sri Lanka is turning out to be a blooming industry and QS contribution is a significant factor in project completion successfully, but still, BIM isn't extensively used in Sri Lankan quantity surveying (Epasinghe et al., 2018; Perera et al., 2021).

The implementation of BIM applications for the Quantity Surveying practice is a fear among Quantity Surveyors in Sri Lanka (Nagalingam et al., 2013). This is because the professional's existence is disturbed by the threatening and challenging nature of employing BIM in the practice and lack of knowledge of BIM and lack of professional expertise(Jayasena & Weddikkara, 2013; Perera et al., 2021).

Therefore, the current issues in the Sri Lankan Quantity Surveying are expected to be resolved through the evolvement of Quantity Surveying following the technology trend. For that, mainly forced undergraduate curriculums advance as the first step of the BIM concept. This also helps to implement BIM concept in Sri Lanka by solving lack of knowledge on BIM and lack of expertise (Epasinghe et al., 2018).

Existing curriculum review in Sri Lanka

Identifying technological gap between SL and global QS practices is crucial for industry expectations. Sri Lanka's construction sector is slow to adopt new technologies, and still quantity surveyors prefer paper documents and simple software like MS Word, AutoCAD. Modern software such as Primavera, Revit Architecture, and Cost X, are yet to be implemented (Ekanayake et al., 2022).

Consider about QS curricula of three universities named as "X", "Y" and "Z" in government, semi-government, and privets universities in Sri Lanka considering that the other factors were constant. Table 1 shows subjects related to BIM in existing curriculum in above selected universities.

Table 1: Subjects related to the existing BIM curriculums in three selected universities.

Year	"X" University	"Y" University	"Z" University
1st Year	Information and Communication Technology (ICT). (Credit – 3)	ICT 1 (Credit – 2) ICT 2 (Credit – 2)	IT application for QS. (Credit – 4)
2nd Year	BIM. (Credit -3) Advanced Building Measurement. (Credit – 3)	GIS and Remote Sensing. (Credit – 3) BIM (Credit – 3) Design appreciation. (AutoCAD). (Credit – 2)	Advanced measurement and contract administration. (Credit – 8)
3rd Year	-	Design appreciation. (AutoCAD - MEP). (Credit – 3)	Advanced quantity surveying. (Credit – 5)
4th Year	Automation of Construction. (Credit -3) BIM Management. (Credit -3)	Advanced ICT/ BIM & modeling. (Credit – 3)	-

	15	18	17
Total BIM Mod: Credit			
Total Credit value	148	157	186

"Total Credit Value" – These values obtained by observing the selected university QS curriculums
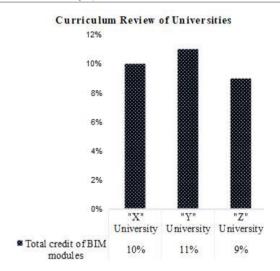
Figure 1: Curriculum review of selected three universities.

Based on the Subjects related on BIM in existing curriculum in three selected universities (Table 1), created *figure 1*. According to *figure 1*, The universities "X" and "Y" offered four-year degree programs, while "Z" offered a three-year degree program. The university "X" covers mainly BIM protocol and Construction Industry Council (CIC) BIM protocol. The "Y" university covers introduction to BIM and advanced BIM and some software like CAD and CostX as main parts around BIM knowledge. The University of "Z" mainly covered advanced measurements. Three universities allocate significant amounts of credits to theoretical BIM subjects, with most covering the theoretical part, while the practical part is less extensive. Considering the BIM modules credit, "Y" university gained the highest amount of credit on BIM modules (Refer Figure 1).

3. METHODOLOGY

Here explains the research methodology in detail, explaining how the study was conducted to meet its goals. This section includes the methodology for the research study and the techniques that analyze the data. This research study aims to develop framework to integrate BIM in undergraduate curriculum in Sri Lanka. The research was carried out using a questionnaire survey, semi-structured interviews and document review under the mixed method research approach.

Data Collection Methods

To carry out this research, two separate questionnaires were made for academic professionals and industrial professionals. The questionnaires survey and semi-structured interviews were conducted for the Data collection. The questionnaire survey was conducted through Google Forms with the quantity surveying professionals in the industry and academic. The questionnaire included two sections, and the questions were open- ended and closed-ended. Table 2 shows data collection methods, sample details and sample size. Sample was obtained through purposive sampling.

Table 2: Population and sample techniques

Data Collection Method	Population	Sample
Questionnaire Survey	QS Professionals in Construction Industry	20
	QS Professionals in Academic	20
Semi-Structured Interviews	QS Professionals in Construction Industry	05
	QS Professionals in Academic	05
Document Review	QS university Curriculums	03

The interviews were conducted with professionals from both physical meeting and online platforms as well. The questionnaire included two sections, and the questions were open- ended and closed-ended. In this study, background information from questionnaires, such as job history, current position, and other aspects were evaluated . The collection of secondary data included the of related materials of different university curriculums.

Data Analysis Methods

The qualitative data were analysed using content analysis and quantitative data were analysed using statistical tools in this study. This type of analysis may be used to examine the data that was acquired through open-ended interview questions. Here, it is important to compare the respondent's total feedback. To upgrade the identified lacking areas in the university curriculum on BIM and software applications, it is required to upgrade the existing BIM modules to suite undergraduate curriculum.

Therefore, this methodology contributes to achieving the objective of the research by providing an overview and analysis of the research findings. The survey was carried out via Google Forms among 40 industry and academic quantity surveying professionals who are working in Sri Lanka. Interviews were carried out among 10 quantity surveying professionals who are working in industry and academic fields in the Sri Lanka. Finally, it is required to collect further information to build the framework on BIM curriculum for QS undergraduates.

4. RESULTS AND DISCUSSION

The purpose of this research is to upgrade content on Building Information Modelling (BIM) in the undergraduate QS curriculum, to fulfill the industrial demand in Sri Lanka.

Analyzing Data on Industry Professional

i.   Details of respondents

The questionnaire survey was carried out among twenty (20) industrial QS professionals and semi

structured interviews were conducted with five industrial QS (5) professionals (Table 2) in the construction industry (Figure 2). Throughout both surveys, most of the responses were senior quantity surveyors and second most resonance were quantity surveyors. When considering about the education qualifications, most of the responses in postgraduate level (Masters, MPhil, PhD) as the highest educational qualification and second most education qualification is the B.Sc. Degree. When analyzing the experience of the respondents, the majority has 0 - 5 years' experience and majority of the professionals work under the contractor. The second highest number of professionals has 10 - 15 years' experience and the second highest majority of the professionals work under the consultant.
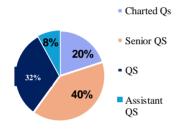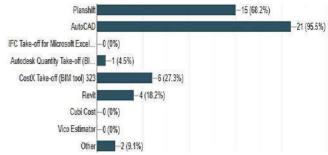
Figure 2: Sample population – Industrial Professionals

When considering the BIM adoption of the organization, only 12.6% already adopt BIM and 50.5% processing of adopting BIM and rest of other percentage of the organizations have not yet adopted this BIM and they will process to adopt BIM in near future.

ii. Current demanding competencies for the QS

When analysing the QS role in the construction industry, it shows QS integrates with all work from initial stage to final stage. In the software usage in the industry practice, quantity surveyors use a variety of specialized technologies to improve and expedite their work. These software programs help with project scheduling, budget management, cost estimate, and the analysis of intricate construction data.

According to the gathered data, Figure 3 shows software usage in local construction practice.

According to the chart AutoCAD, Planshift, CostX and Revit are main software uses in QS field.

Figure 3: Software usage in QS.

iii. BIM education on quantity surveying practice

When considering BIM knowledge in QS professionals, **Figure 4** illustrates the survey results of how industrial QS professionals gather the BIM knowledge. Accordingly, 8% learn BIM at the universities, although the majority (72%) of the industrial professionals gather BIM knowledge through certificate or academic courses. The remaining respondents (20%) learn BIM on self-learning with industrial practice.
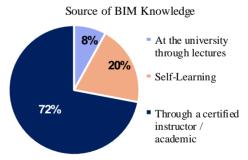
Figure 4: survey results of how industrial QS professionals gather the BIM knowledge

Analyzing Data on Academic Professionals

i. Details of questionnaire respondents

The questionnaire survey was carried out among twenty (20) academic QS professionals and semi structured interviews were conducted with five academic QS (5) professionals (Table 2) in the academic industry. Throughout both surveys, most of

the responses were senior lectures and the second most resonance were lectures. When considering about the education qualifications, most of the responses have Masters as the highest educational qualification and second most education qualification is the B.Sc. Degree. When analysing the experience of the respondents, the majority have 0 - 5 years' experience and the second highest number of professionals have 5 -10 years' experience.
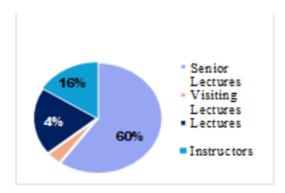
Figure 5: Sample population – Academic Professionals
Strategies for bridging the industry-academia gap

It is essential to implement solutions that effectively bridge the gap between industry and academia in BIM to ensure adequately prepare students for the specific requirements of the real-world construction situation. Teachers can use interactive teaching strategies, such virtual simulations and group projects, to help students grasp BIM better and become more interested in the subject.

To bridge the knowledge gap between academic learning and industry BIM practices, the critical role that a multidisciplinary approach plays should be highlighted. Understanding that hands-on experience is a powerful learning tool, they support incorporating real-world BIM projects and workshops within the academic program. Students may build a broad skill set by connecting theoretical knowledge with real-world applications through this practical method. In addition, the idea of planning site visits and inviting prominent figures from the business to provide guest lectures adds a significant dose of practical experience and gives students a direct understanding of how BIM is actively is used in regular quantity surveying procedures.

On the strength of this foundation, there is an ongoing necessity for curricular growth in order to keep up with changing industry demands. They emphasize the need for flexibility and the need of keeping up with new developments in BIM technology, software, and industry trends. Education institutions may guarantee that their programs stay current and adaptable to the ever-changing construction industry by encouraging a flexible curriculum that changes in accordance with industry innovations. This flexible strategy is strengthened even further by creating a clear link between classroom instruction and real-world BIM needs. Guest lecturing business professionals and implementing industry best practices into the curriculum, guarantees that students will graduate with both the academic understanding and the practical know-how needed to function in the ever-changing BIM environment. These factors were conformed by Ojo & Pye, (2014).

ii. Upgrading content on BIM in QS undergraduate curriculum

When analyzing the results of academic professional on upgrading BIM content of undergraduate curriculum, firstly all were accepted that both software and theoretical knowledge need to integrate into the QS curriculum. In order to improve a Quantity Surveying program using BIM, theoretical understanding and software competency must be included. Most academic professionals accepted that introduction of BIM, BIM software with their usage and advantages, BIM Guidelines and standards and quantity surveyor's workflow with BIM, are included under the theoretical knowledge cover.

As the practical knowledge students want to acquire useful abilities like creating Bills of Quantities (BOQ), taking quantity takeoffs, identifying conflicts, and creating cost reports utilizing BIM tools. These areas must be included into the QS curriculum so that students graduate with the software skills needed for contemporary construction projects as well as a comprehensive grasp of the principles and real-world applications of BIM.
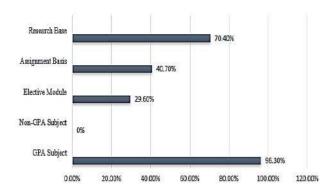
Figure 6: BIM Integration into Curriculum

According to the above figure 6, Many academic professionals (96.3%) have mentioned that more credit should be given to BIM subject. Similarly, it has been responded that this subject will be continued through research (70.4%) and assignment (40.7%) for further study.

5. CONCLUSION AND RECOMMENDATION

Quantity surveyors, also known as construction cost managers, play a crucial role in ensuring the economic feasibility and successful completion of building projects. Their expertise in Building Information Modeling (BIM) is increasingly important, as it allows for accurate data extraction and analysis from digital models. This skill also enhances the effectiveness of cost control procedures and facilitates collaboration among project stakeholders. As the construction industry continues to embrace digital transformation, quantity surveyors are at the forefront of innovation, ensuring smooth communication and effective project completion.

The local education system in Sri Lanka lacks sufficient technological knowledge, with most universities covering only theoretical BIM knowledge. Barriers include lack of expertise, high software costs, and limited resources. Future quantity surveyors can contribute to the modern construction sector by incorporating BIM models and software capabilities into university curricula.

6. RECOMMENDATIONS

For creating this framework (Refer figure 7), used "BIM maturity diagram; 2008/13 Bew – Richards" gave clear understanding of how BIM knowledge can be achieved step by step under QS curriculum. In other words, the intension was to demonstrate the progressive nature of the BIM learning process. This framework (Refer figure 7) provides a roadmap for the quantity surveying related academic professionals to implement BIM into the undergraduate QS curriculums by bridging the gap with construction industrial requirements. By adopting this farmwork, future challenges faced by quantity surveyors in Sri Lanka can be mitigated.

The following is the framework (Refer figure 7) which is prepared, and it clearly shows how BIM knowledge is shared year after year. The created framework, which fills in the gaps and arranges the implementation phases in an adaptable way, is the result of translating all the collected and evaluated data. The framework that was created was organized based on new learning objectives of BIM features and scales. The following is an overview of each section:

a) BIM aspects and scales involve step-by-step development from basic concepts to more complex ones.
b) The first component is the theoretical fundamentals, which will be introduced as a stand-alone module covering the ideas of BIM in the early years of the QS program.
c) Secondly, the practical fundamentals where applying BIM at levels requires applications like taking off quantities, detecting clashes, and preparing cost estimates, among other things.
d) The last component is represented integrated BIM system in the research and case studies and will be represented in the graduating year.

The learning objectives in the curriculum should be reorganized to show that students understand BIM concepts and can apply them. This will be accomplished by upgrading QS curriculums including BIM.

Then incorporate the new BIM planned outputs, the educational approach to BIM necessitates updating the learning objectives. In the undergraduate years, a

module offers learning goals that span Level 0, Level 1, and Level 2. As the example it clearly shows (Refer figure 7) how second, and third year BIM modules overlap Level 1 and Level 2 BIM.
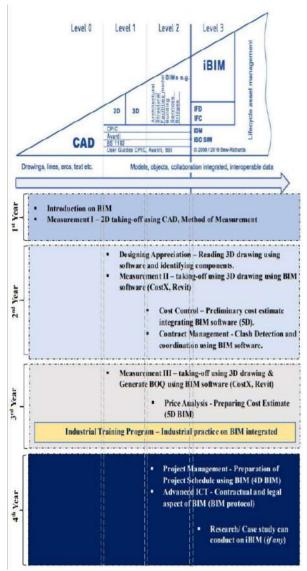
Figure 7: Developed Farmwork for QS undergraduate curriculum.

7. RESEARCH LIMITATIONS AND FUTURE DIRECTIONS

This study limited only for upgrading quantity surveying undergraduate curriculum including BIM and limited to conducted only of Sri Lankan practice. The role of quantity surveying is multidisciplinary, but

this study focused on aspect of BIM challengers to the conventional QS practice.

The research on the topics that are studied can be expanded on a variety of ways. These topics are not included in the study as the scope has not been expanded and has been placed below for as suggestions for future research.

a) Focusing on upgrading postgraduate curriculums in construction related subjects by implementing BIM.
b) Focusing on identifying barriers to integrate BIM into the local undergraduate quantity surveying curriculum.
c) Focusing to identify practical challengers that involved technological based construction industry in Sri Lanka.

Abbreviations

4D – Four Dimensional
5D – Five Dimensional
BIM – Building Information Modeling
BOQ – Bills of Quantities
CIC – Construction Industry Council
ICT – Information and Communication Technology
IT - Information Technology
QS – Quantity Surveying
SL – Sri Lanka

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AN ASSESSMENT OF LAND USE AND LAND COVER CHANGES ON URBAN FLOODING: A CASE STUDY IN SRI JAYEWARDENEPURA KOTTE

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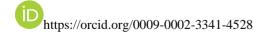
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ABSTRACT

This study investigates the relationship between Land Use and Land Cover (LULC) changes and urban flooding in the Sri Jayewardenepura Kotte Divisional Secretariat Division (DSD). The research objectives include analysing flooding patterns, mapping LULC changes, and assessing the correlation between these changes and flooding occurrences. Additionally, a temporal rainfall variation analysis was conducted to provide further context. The study employed Geographic Information System (GIS) technology, specifically utilising ArcGIS for LULC classification and Inverse Distance Weighting (IDW) interpolation technique for rainfall data. The analysis reveals a clear association between heightened precipitation and major flood events. In 2010, the flood inundation area was 5.762 km² during the major flood in May, despite a monthly rainfall of over 650mm. However, in 2016, with over 700 mm of rainfall in May, the flood-inundated area was reduced to 4.046 km², highlighting the role of other factors such as wetland recovery. Moreover, it identifies significant LULC changes, emphasising rapid urbanisation and wetland decline. From 2009 to 2018, built-up areas increased from 11.49 km² to 14.18 km², while wetlands decreased from 2.29 km² in 2009 to 1.19 km² in 2015, before recovering slightly to 1.58 km² by 2018. The expansion of built-up areas is found to slightly increase flood risks, while wetland recovery acts as a natural flood buffer. This research underscores the importance of targeted interventions for urban flood resilience, such as flood-resistant infrastructure and wetland management. The findings provide critical insights for evidence-based urban planning and flood management strategies, aiming to create more resilient and sustainable urban environments.

KEYWORDS: *Land Use Land Cover, Geographic Information System, Inverse Distance Weighting*

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1. INTRODUCTION

As a small island in the Indian Ocean, Sri Lanka faces a range of natural disasters annually, such as floods, landslides, droughts, cyclones, lightning, coastal erosion, and tsunamis, resulting in widespread destruction and loss of life (Madhubhashini, 2019). One of the tragic natural occurrences that had a significant impact on society, the economy, and the environment is flooding. Due to its distinct topography and geographic location, Sri Lanka is a country that is very susceptible to floods (Dasandara et al., 2022). One of the most common natural hazards that caused property damage and happened in the past few decades was floods and landslides (Hemachandra et al., 2019).

Floods can have a wide variety of appearances because they can cover anything tiny or large. The floods may start slowly or quickly. There are several types of floods such as river floods, flash floods, inland floods, coastal floods, and storm surges (Nied et al., 2014). Urban flooding occurs when rainfall exceeds drainage systems, causing waterlogging in streets, homes, and infrastructure. Impervious surfaces, reduced natural floodplains, and climate change increase risks. Impacts include property damage, daily disruptions, and health and safety challenges (Kui Xu, 2023). River floods transpire when water levels surpass riverbanks, while coastal floods arise from tidal surges, high wind, and barometric pressure. Urban floods, occurring in cities due to heavy and prolonged or sudden intense rainfall, pose intricate challenges with diverse land uses, concentrated constructions, and numerous projects (Plate, 2002).

A flash flood is a sudden, intense inundation occurring within a few hours, resulting from heavy rainfall, rapid snowmelt, or the release of impounded water. Flash flood inundation involves rapidly covering usually dry areas, particularly in low-elevation zones near rivers or water bodies, leading to significant harm to infrastructure, buildings, and roads (Montz & Gruntfest, 2002). Flash floods are common in the southwest region of Sri Lanka, particularly during the monsoon season from May to September. They can

cause significant damage on property and infrastructure, and they can also result in loss of life.

Land use refers to how a piece of land is used or intended to be used. The way that land is used can greatly affect the environment, the economy, and the community. It is also determined by many factors such as population growth, urbanization, landowner's wishes, public policy, and zoning rules. Land Use and Land Cover (LULC) planning is the process of making decisions about how land should be used (Foley et al., 2005).

Sri Lanka is mainly affected by the southwest and northeast monsoon rains due to its location and topography. Sri Jayewardenepura Kotte (SJK) Divisional Secretary's Division (DSD) in the Western Province is annually affected by floods. Furthermore in 2010, 2016, and 2017 major flood events were recorded in the SJK area. Those flood occurrences caused significant property losses, impacted on transportation, and communication disruptions, and posed a threat to human safety.

The study includes identifying the relationship between LULC changes and urban flooding, analysing temporal flooding trends, mapping changing LULC, and looking into the relationship between LULC alterations and flooding. Also, it investigates the rainfall patterns of the study area to identify the relationship of rainfall patterns with flood occurrences in the study area.

SJK is an area that is frequently affected by floods during the monsoon periods in Sri Lanka. This city is a rapidly developing area. In addition to floods caused by monsoon rains, flash floods and urban floods also occur suddenly because of the heavy rainfall in short durations. LULC changes also may be the cause of urban flooding. By having proper LULC management, the city can achieve sustainable development goals and mitigate flood occurrences.

The study can be defined by its objectives, which include identifying the relation between LULC changes and urban flooding, analysing temporal flooding trends and mapping changing LULC. Also, this investigates the rainfall patterns of the study area to identify the

relationship of rainfall patterns with flood occurrences in the study area. Collectively, the research deepens our understanding of the dynamics of urban flooding and provides insights essential for well-informed urban planning, resilient strategies, and efficient flood management, within and across broader urban contexts.

2. METHODOLOGY

1. *Study Area*
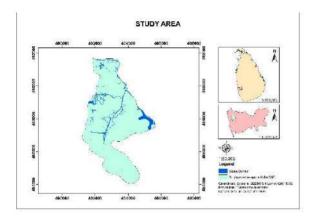
Figure 1. Study area map

SJK is the capital of Sri Lanka. This area is the DSD of the Colombo district in the Western Province. SJK has a hot, oppressive, windy, and overcast tropical climate. The average annual temperature is 26.5 °C around this area. The average annual rainfall is 2668 mm.

Sri Lanka has experienced several major floods over the years that have caused significant damage to public and private property and resulted in the loss of many lives. Colombo has been particularly affected by severe floods in 2010, 2016, and 2017, with one event causing one-eighth of the city's yearly rainfall in just 12 hours. SJK is also at risk of urban flooding due to its rapid population growth and land use changes.

2. *Workflow*

The workflow of the study unfolds through a systematic and comprehensive process. The general objective is to identify a relationship between the LULC changes and urban flooding in the study area. Initial data collection involves obtaining Landsat satellite images spanning

from 2009 to 2018 for LULC analysis, monthly and annual rainfall data from the Meteorological Department, and flood inundation maps for significant events from Land Reclamation and Development Corporation.
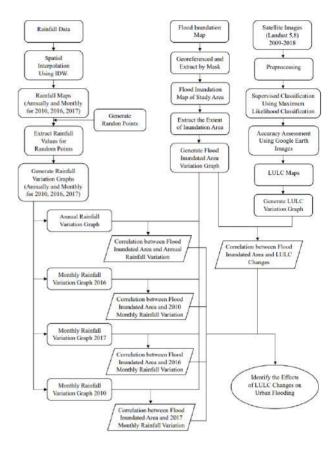
Figure 2. Workflow of the study

The methodology employs GIS and remote sensing techniques, including preprocessing steps like atmospheric correction and image classification for LULC analysis. Accuracy assessment is conducted using ArcGIS tools and Google Earth images. Rainfall analysis utilises IDW interpolation to analyse patterns, and flood inundation area analysis simulates the impact of LULC changes on floods. Correlation analysis explores the relationship between vulnerable flood areas and LULC changes. The complete process is outlined above in Figure 2 for clarity, ensuring a comprehensive investigation into how changes in LULC influence flooding in the study area.

Initial data collection involves obtaining Landsat satellite images spanning from 2009 to 2018 for LULC analysis, monthly and annual rainfall data from the Meteorological Department, and flood inundation maps for significant events from the Land Reclamation and Development Corporation.

Using Landsat satellite images from the years 2009 to 2018, the methodology of this research involved analysing LULC changes. To ensure complete temporal coverage, Landsat 5 and 8 images were acquired for the study area. The images were sent through pre-processing procedures such as atmospheric correction, radiometric calibration, and geometric correction before analysis to improve their quality and consistency. Then, using representative training samples from various land cover classes, supervised image classification was applied to the stacked images. Following that, the detected changes in land cover were interpreted within the context of the study area while considering both socio-economic and environmental factors. The accuracy assessment process of a LULC map involves evaluating the reliability and correctness of the map's classifications and spatial representations. This process is typically conducted by comparing the LULC map with reference data, which have been collected through satellite imagery. The accuracy assessment process for a LULC map using satellite images involved ArcGIS tools and Google Earth images.

Rainfall information for each year during the study period was gathered from five rainfall stations located throughout the study area for the rainfall analysis. The IDW method was then used to spatially interpolate these data points to create rainfall estimates for areas without weather stations. The IDW method gives nearby data point weights based on proximity, with closer points receiving higher weights. This enables the creation of continuous surfaces that depict annual rainfall distribution across the study area.

Monthly rainfall information for the years were collected when a significant flood occurred. To create monthly rainfall maps for those particular periods, IDW interpolation was applied to these data points. This

method made it possible to comprehend the rainfall patterns both before and during flood occurrences in detail.

The identification of spatial and temporal variations was made possible by the IDW interpolation technique, which provided an extensive representation of rainfall patterns in both annual and monthly contexts. The resulting rainfall maps and interpolated surfaces were useful tools for examining rainfall distribution and amount, assisting in the evaluation of flood risk, and advancing knowledge of the connection between rainfall patterns and flooding events in the study area.
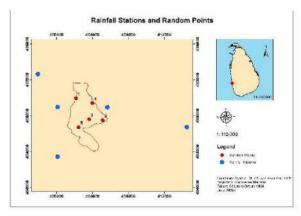
Figure 3: Rainfall Stations and Random Points

Five randomly chosen points were chosen from the study area for the analysis of the rainfall data. Data were extracted for each of these points from 2008 to 2022 for the analysis of annual rainfall. At each location, the monthly rainfall data was also gathered, specifically for the months that experienced significant flooding. The extracted rainfall values were tabulated to generate the relevant graphs. Figure 3 above shows the map that illustrates the used Rainfall Stations and generated random points.

To simulate the impact of LULC changes on flood occurrences in Sri Jayewardenepura Kotte area, the flood inundation maps of the relevant flood occurrences in 2010/05, 2010/11, 2016/05, 2017/05 were used from the Land Reclamation and Development Corporation. The first step was to obtain a flood inundation map showing the flooded areas during the flood event of interest to calculate the flood inundated extent using the

map and produce a bar graph. The total area covered by the flooded regions on the map was then measured to determine the inundated area. This required measuring the size of the flooded polygons using ArcGIS software. The inundated areas were depicted on a bar graph. This bar graph made it possible to compare the areas that various significant flood occurrences had inundated visually.

3. RESULTS AND DISCUSSION

A. *LULC Change Analysis*

The study encompassed the creation of LULC maps spanning the years 2009 to 2018, as illustrated in Figures 4 to 13. These maps offer a comprehensive overview of the evolving land use patterns over time. The data for generating these maps were extracted from satellite imagery, specifically Landsat 5 and Landsat 8 images. The employed methodology involved a process of supervised classification using the ArcGIS software.

To ensure the accuracy and reliability of the obtained LULC maps, an accuracy assessment was conducted. ArcGIS tools and Google Earth imageries and available LULC maps were employed in this assessment, validating the classification results. This validation process ensured that the generated maps accurately represented the true land cover in the study area. The temporal coverage of these maps facilitated a comprehensive analysis of the dynamic land cover patterns and transitions over the specified ten-year period.

By examining the LULC maps, the study aimed to determine the distribution and composition of various land cover classes within the study area. This analytical approach enabled the obtaining of spatial extent and change trends associated with different land use types. The findings derived from these LULC maps serve as a fundamental basis for ensuing in-depth analysis and interpretation.
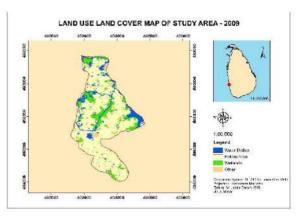
Figure 4: Land Use Land Cover map of the study area in 2009
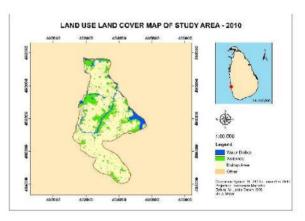
Figure 5: Land Use Land Cover map of the study area in 2010
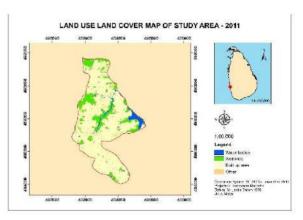
Figure 6: Land Use Land Cover map of the study area in 2011
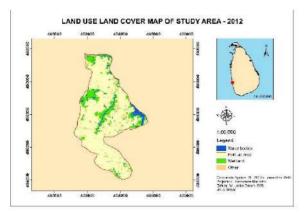
Figure 7: Land Use Land Cover map of the study area in 2012
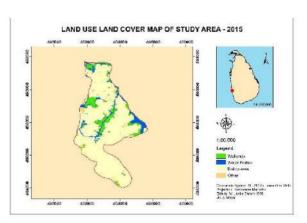
Figure 10: Land Use Land Cover map of the study area in 2015
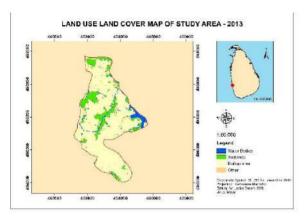
Figure 8: Land Use Land Cover map of the study area in 2013
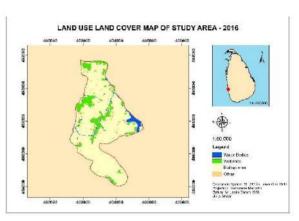
Figure 11: Land Use Land Cover map of the study area in 2016
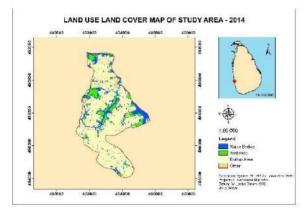
Figure 9: Land Use Land Cover map of the study area in 2014
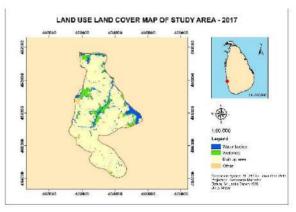
Figure 12: Land Use Land Cover map of the study area in 2017
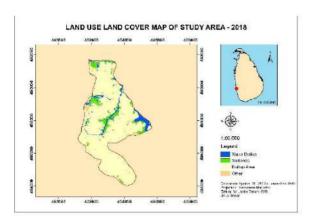
Figure 13: Land Use Land Cover map of the study area in 2018

Created LULC maps from 2009 to 2018 for the study area are shown in the above maps from Figure 4 to Figure 13. Based on the LULC maps and the data presented in Figure 14, covering the years 2009 to 2018, there has been a noticeable increase in the built-up areas and a decline in wetlands from 2009 - 2015. In 2009, 2.29 km^2 was covered by wetlands and in 2015 it decreased to 1.19 km^2. In contrast, the built-up area increased from 11.49 km^2 to 14.18 km^2 between the 2009-2018 period. From 2015 to 2018, there was a slight increase in wetlands from 1.19 km^2 to 1.58 km^2.
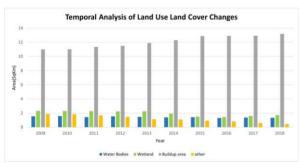
Figure 14:Temporal Analysis of LULC Changes

B. Rainfall Analysis

Annual rainfall maps spanning from 2008 to 2022 were meticulously generated for the study area, capturing a 15-year overview of rainfall patterns. Metrological Department data facilitated the geospatial analysis, incorporating IDW interpolation to create continuous rainfall distribution surfaces. These maps offer a comprehensive depiction of spatial and temporal rainfall variations, aiding in identifying regions with varying rainfall levels.
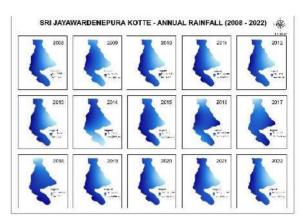
Figure 15: Annual Rainfall map of the study area from 2008 to 2022

The annual rainfall trends and their correlation with flood occurrences are visible through these maps shown in Figure 15 and the annual rainfall variation graph shown in Figure 16.
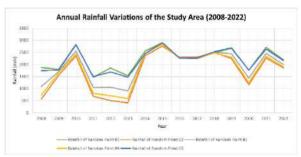
Figure 16: Annual Rainfall Variation of Study Area

Monthly rainfall maps were specifically generated for years with major floods in the study area in 2010, 2016 and 2017, offering a detailed analysis of rainfall patterns during critical periods. Figures 17, 18 and 19 show the monthly rainfall maps of 2010, 2016 and 2017 respectively. The methodology involves analysing monthly rainfall data and employing geospatial techniques to create spatially explicit maps, depicting rainfall distribution and amount. These maps provide a comprehensive understanding of monthly rainfall leading to major floods.

The graphs were generated by plotting the monthly rainfall values in millimetres on the y-axis against the corresponding months on the x-axis, specifically for the years when significant floods were recorded in the study area.
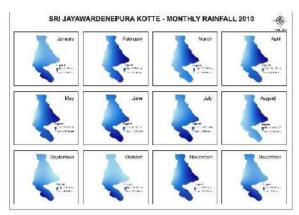
Figure 17: Monthly Rainfall map of the study area in 2010
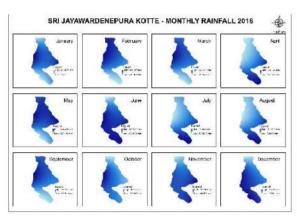
Figure 18: Monthly Rainfall map of the study area in 2016
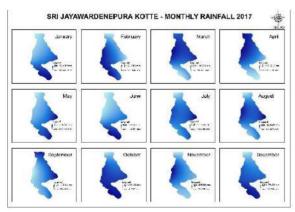
Figure 19: Monthly Rainfall map of the study area in 2017

Derived from reliable meteorological records, the graph illustrates how monthly rainfall fluctuated during flood periods, identifying months with significant rainfall contributing to the events. This visual aid enhances understanding of meteorological factors influencing floods, serving as a valuable tool for interpreting

research findings and communicating rainfall patterns during flood events.
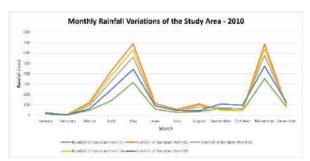
Figure 20: Monthly Rainfall map of the study area in 2010
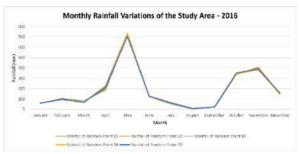
Figure 21: Monthly Rainfall map of the study area in 2016
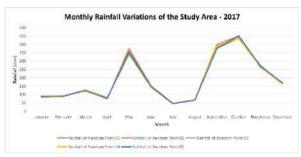
Figure 22: Monthly Rainfall map of the study area in 2017

Figures 20, 21, and 22 illustrate monthly rainfall variations during major flood events in 2010, 2016, and 2017, offering insights into rainfall patterns in the study area. These figures also reveal a bi-modal rainfall variation, typically occurring in the months of May and October, highlighting the seasonal distribution of precipitation in the region.

C. Flood Inundated Area Analysis
The flood inundation maps were specifically generated for major flood events in the study area in 2010 May 2010 November 2016 May and 2017 May. Sourced from the Land Reclamation Department, these maps in

figures 23, 24, 25 and 26 offer essential insights into the extent and spatial distribution of floods during significant occurrences.
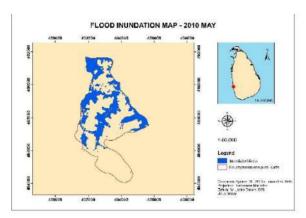
Figure 23: Flood Inundated Area of the Study Area - 2010 May
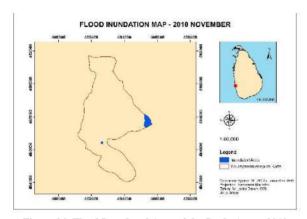
Figure 24: Flood Inundated Area of the Study Area - 2010 November
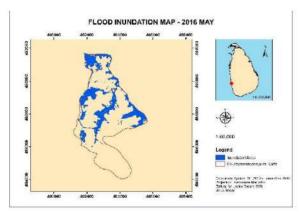
Figure 25: Flood Inundated Area of the Study Area - 2016 May
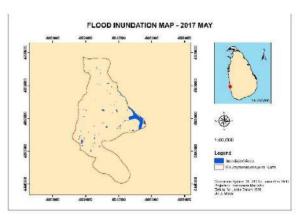
Figure 26: Flood Inundated Area of the Study Area - 2017 May

The methodology involved processing and analysing flood extents, providing valuable tools for understanding spatial flooding patterns and identifying vulnerable areas.

Figure 27 illustrates a graph depicting variations in flood inundation areas during major flood events in the study area, offering a comprehensive visualization of flooding extent over time. Derived from data in flood inundation maps, the graph illustrates temporal fluctuations in inundation areas, highlighting differences between flood events.
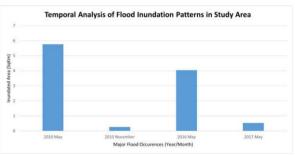
Figure 27: Temporal Analysis of Flood-Inundation Patterns

D. Correlation Analysis of the Study
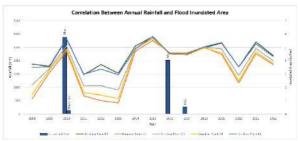
Figure 28: Correlation between annual rainfall and

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In 2010, there was an identifiable increase in flood inundated areas and also in annual rainfall. In the same way, in 2016 and 2017, floods occurred with an increase in rainfall. However, in 2014, 2015, 2019, and 2021, there were major increases in the rainfall pattern, but there were no recorded major flood occurrences in those years. In 2016 and 2017, the rainfall increase was the same, but the flood extent was different. The flood extent in 2016 was greater than that in 2017, but the rainfall appeared similar according to Figure 28.
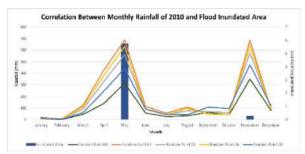
Figure 29: Correlation between monthly rainfall in 2010 and flood-inundated area

Based on the findings presented in Figure 29, it is observed that there is an increase in rainfall during May and November. In November, the rainfall is slightly higher than in May. However, it is interesting to note that despite the higher rainfall levels in November, the flood-inundated area in May is considerably more extensive.
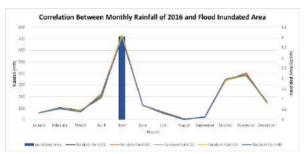
Figure 30: Correlation between monthly rainfall in 2016 and flood-inundated area

In May, there is a major incensement in rainfall than in the other months according to Figure 30. Also, a major flood happened in May 2016 in the study area. The months of October and November also have higher rainfall values than the other months but there were no flood occurrences in these months in the year 2016.

According to Figure 31, May, September, and October had higher rainfalls than in the other months in 2017. But only in May, there was a flood occurrence in the study area. According to the figure, September and October months had higher rainfall than May in 2017 but the flood occurred only in May.
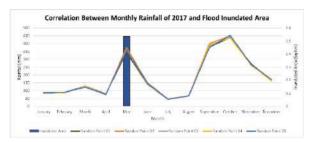
Figure 31: Correlation between monthly rainfall in 2017 and flood-inundated area
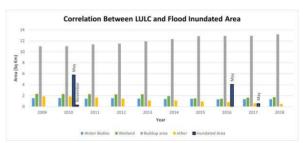
Figure 32: Correlation between LULC changes and flood-inundated area

The correlation between the variations in LULC over time and the areas affected by flood inundation is depicted in Figure 32.

The buildup area has increased steadily over time, while a slight decrease in the wetland area can be observed. But again from 2016, the wetlands have experienced a slight increase according to this graph. Additionally, the extent of waterbodies and other land use areas also changes over time. This figure offers an approximate representation of the changes in LULC categories including water bodies, wetlands, buildup areas, and other land uses.

4. CONCLUSION

The study aimed to identify a correlation between LULC changes and urban flooding in the SJK DSD. The objectives included analysing flooding patterns, mapping LULC changes, and assessing the correlation

between LULC changes and flooding. Employing ArcGIS and IDW interpolation, rainfall distribution was analysed annually and monthly for 2010, 2016, and 2017.

The analysis revealed a link between heightened rainfall and major flood events. Notably, in 2010, 2016, and 2017, periods of elevated rainfall correlated with significant flood events. Examining monthly rainfall variations highlighted May as critical, indicating a strong association between intense rainfall and flooding. The accuracy of LULC classification using Landsat satellite images ranged between 74% and 92%.

LULC changes over the study period demonstrated a rise in built-up areas and a decline in wetlands, signifying rapid urbanisation. Noteworthy was the recovery of wetlands after 2016, suggesting potential shifts in environmental policies. The study indicates a relation between urban land use changes and flood inundation areas, highlighting how even minor urbanisation and wetland coverage can impact flood risks. Additionally, variations in rainfall patterns, particularly during peak months, were identified as significant contributors to flood occurrences, compounding the effects of LULC changes.

The expansion of built-up areas poses a heightened risk of flooding by contributing to the creation of impervious surfaces, restricting natural drainage, and intensifying surface runoff. On the contrary, the restoration and recovery of wetlands serve as a natural buffer against floods. Wetlands, with their absorbent nature, play a crucial role in slowing down and absorbing excess water, thereby helping to mitigate the impact of floods.

It is noteworthy that after 2016, there have been ongoing mitigation projects. These projects, including projects like the "Beddagana" and "Diyasaru" Wetland Management projects, are focused on implementing measures to manage and preserve wetland areas. Such efforts are essential for sustainable flood risk management, emphasising the importance of balancing urban development with the

conservation and restoration of natural flood-mitigating ecosystems like wetlands.

The study provided insights into the relationship between LULC changes, rainfall patterns, and flood occurrences. The findings underscored the need for targeted interventions, emphasising the preservation and restoration of wetlands and stringent regulations for sustainable urban development. This research contributes to evidence-based decision-making in urban planning and flood management, aiming to create resilient and sustainable urban environments.

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GREEN SYNTHESIS OF MAGNETITE NANOPARTICLES USING *Syzygium aromaticum* FOR THE REMOVAL OF METHYLENE ORANGE

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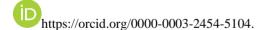
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ABSTRACT

Water contamination by textile dyes is a significant environmental issue, as these dyes are resistant to degradation and can have harmful ecological impacts. The present study focuses on using green synthesized magnetite nanoparticles using a sustainable method involving Syzygium aromaticum extract. These green-synthesized iron oxide nanoparticles (GMNPs) were tested for their ability to degrade methyl orange (MO) and compared to chemically synthesized zero-valent iron particles (CnZVIs). The study records that GMNPs were successfully synthesized, with particle sizes ranging from nano to micro scales. Within 20 minutes, 100 ppm of MO was reduced to 43 ppm and reached equilibrium at 120 minutes, with GMNPs removing up to 40 ppm of the dye. At equilibrium, approximately 59% of MO was removed using ~20 ± 1 mg of GMNPs, indicating they were more effective than CnZVIs. Kinetic studies indicated that the pseudo-second-order adsorption model (R^2 = 0.9993) was a better fit, while isotherm studies favored the Langmuir isotherm (R^2 = 0.9992) and Freundlich isotherm (R^2 = 0.9997). This suggests that the adsorption process was favorable for MO removal using GMNPs. Importantly, this research not only provides a promising solution to the problem of water contamination by textile dyes but also underscores the significant potential of GMNPs for environmental remediation, offering hope for a cleaner future.

KEYWORDS: *Green synthesis, Magnetite, S. aromaticum, Methyl orange, Cost-effective*

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1. INTRODUCTION

Azo dyes, widely used across several industries worldwide, cause significant environmental harm due to improper disposal. It has been found that approximately 20% of these dyes used in dyeing processes end up in wastewater, posing a grave threat to the environment (Basturk and Karatas, 2015). The azo bond, also known as N=N, is the chromophore responsible for the dazzling colors of these dyes (Phukan, 2015). Over the years, a plethora of azo dyes have been developed (Rahman, Abedin and Hossain, 2014) since Sir William Henry Perkin's (Perkin, 1856) discovery of the first synthetic dye in 1856 (Rahman, Abedin and Hossain, 2014). However, the rising demand for different dyes has significantly increased the percentage of azo dyes in wastewater. These harmful dyes are widely present in effluent sources such as textile, dyeing and printing, paper and ink manufacturing industries, and cosmetics. The release of azo dyes into the environment can cause severe damage to the ecosystem and living organisms.

Azo dyes are widely used in various industries, including cosmetics, textiles, and printing. However, they are known to be hazardous to human health and the environment. Azo dyes can cause skin cancers and other health problems, thus posing an occupational hazard for people working in dye-related industries. Therefore, researchers have developed effective methods for cleaning dye-contaminated wastewater for decades. Strategies such as ozonation, UV degradation, nanofiltration, membrane filtration, oxidation, adsorption, and electrocoagulation have been employed in the past (Dutta *et al.*, 2016). However, these methods have limitations in degrading azo dyes due to their resistivity. Biological treatment using microorganisms was also ineffective due to the low degradation activity. Therefore, researchers have turned to novel strategies to treat azo dye contaminations (Kobya *et al.*, 2014; Gao *et al.*, 2019). One promising method is the use of zero-valent iron nanoparticles (ZVINPs). ZVINPs have been recognized as a potential remediation to treat azo dye contamination (Iravani, 2011). Scientists discovered that zero-valent iron could reduce the azo bond (N=N) of the azo dye, causing discoloration (He

et al., 2012). Different strategies were developed to synthesize ZVINPs, including chemical and physical approaches. However, the utilization of these methods to synthesize ZVINPs is limited due to the cost and toxicity of the chemicals. Therefore, green synthesis emerged as an alternative approach to synthesizing ZVINPs due to its cost-effectiveness, eco-friendliness, non-toxicity, and utilization of bio-renewable natural sources (Huang *et al.*, 2014; Wang *et al.*, 2014; Abbasi Kajani and Bordbar, 2019; Gaminda *et al.*, 2023).

Recently, several research groups revealed the utilization of green synthesized nanomaterials to effectively remove azo dye (Beheshtkhoo *et al.*, 2018; Abbasi Kajani and Bordbar, 2019; Lohrasbi *et al.*, 2019; Khashij *et al.*, 2020; Yuan *et al.*, 2020; Khunjan and Kasikamphaiboon, 2021). Khunjan et al 2021 reported the synthesis of a novel Kaolin-supported nanoscale zero-valent iron (K-NZVI) using *Ruellia tuberosa* leaf extract to decolorize reactive black 5 (RB5) dye. The data showed that K-NZVI can decolorize the RB-5 with 92.1 – 99.8% efficiency. Bashir, et al. 2020 reported the development of iron nanoparticles using *Dimocarpus longan* extract to remove methyl orange (MO). The study revealed that green synthesized particles (DL-FeNPs) has achieved a 98.1% MO removal efficiency within 30 minutes. Beheshtkhoo group (Beheshtkhoo *et al.*, 2018) utilized the green synthesized iron oxide nanomaterials using leaf extract of *Daphne mezereum* to remove methyl orange. The decoloration efficiency was reported as 81.0% after 6 hours of incubation, the iron oxide nanoparticles with hydrogen peroxide (H_2O_2) treated MO. In green synthesis, various parts of the plant such as leaves, seeds, flowers, roots, etc., are used to prepare the green extract. The polyphenolic compounds in the green extract could act as a reducing agent to reduce metal ions and minimize the aggregation of the nanomaterials by acting as a capping/stabilizing agent. Various green extracts have been utilized to develop novel nanomaterials for multiple applications over time, and the functional properties of the green synthesized nanomaterials depend on the compounds available in the green extract. Furthermore, the size of the green

synthesized nanomaterials significantly depends on the capping/stabilizing agents in the green extract (Chen *et al.*, 2011). Over the years, different strategies have been developed to synthesize magnetite nanoparticles. However, to date, the synthesis of magnetite particles using a green approach, which indicates a comparison of chemical constituents, has not been reported.

Hence, our primary objectives are to synthesize novel iron oxide nanoparticles (GMNPs) using *Syzygium aromaticum* (clove) buds extract (water extract) and characterize the GMNPs using SEM, XRD, and FT-IR analysis. Lastly, we evaluated and compared the methyl orange degradation efficiency of GMNPs and chemically synthesized zero-valent iron particles (CnZVIs).

2. METHODOLOGY

A. Materials

Ferric chloride hexahydrate (with a purity of at least 99%, $FeCl_3 \cdot 6H_2O$), Sodium borohydride ($NaBH_4$), and Methyl orange (with an 85% purity, $C_{14}H_{14}N_3NaO_3S$) were acquired from Sigma Aldrich. Clove buds were sourced from local farms. All solvents essential for the experiments were prepared using distilled water.

B. Chemical synthesis of zero-valent iron particles and green synthesis of GMNPs

Zero-valent iron particles (CnZVIs) were chemically synthesized using a method reported by Rahman et al., 2014, using $FeCl_3.6H_2O$ and $NaBH_4$.

In this experiment, GMNPs were synthesized using the method reported by Gaminda et al 2024, using *Syzygium aromaticum* (clove) extract, $FeCl_3.6H_2O$, and NH_4OH. A precise amount of 1.0 grams of purified clove buds was carefully weighed and added to a flask containing 300.0 mL of distilled water. The mixture was heated to a temperature of 80°C and stirred continuously until the volume of the solution was reduced to 100.0 mL. The solution was then filtered using a gravity filtration process to remove any impurities and allowed to cool down to room temperature. Next, a 0.1 mol dm^{-3} $FeCl_3.6H_2O$ solution was prepared and mixed with the clove bud

extract in a ratio of 1:2. The mixture was then stirred for 30 minutes at a controlled temperature of 60°C. During this process, the yellow color of the solution changed instantly to black, indicating the formation of iron oxide particles. In the next step, a 50 mL portion of 0.1 $moldm^{-3}$ $FeCl_3$ solution was mixed with 25.0 mL of the black color solution. The pH of the mixture was adjusted to 10 using NH_4OH, and the solution was continuously stirred for another 30 minutes at 60°C. This step facilitated the formation of iron oxide particles with improved purity and stability. Finally, the black color iron oxide particles were collected by gravity filtration and thoroughly washed with absolute ethanol and distilled water to remove any residual compounds of the extract. The particles were then dried using a vacuum oven for 12 hours at a temperature of 50°C.

C. Characterization

A range of characterization techniques were employed to analyze the properties of the synthesized nanomaterials, including a UV-visible spectrophotometer (UV-Vis), Fourier transform infrared spectroscopy (FT-IR), Scanning electron microscopy (SEM), and X-ray diffraction (XRD).

1. *UV-Vis spectroscopy*

The UV-visible spectrophotometer (ChromTech, CT-2600, Taiwan) was employed to analyze the absorption spectra of solutions treated with GMNPs and CnZVIs at 464 nm.

2. *Fourier transform infrared spectroscopy (FT-IR) analysis*

Fourier Transform Infrared Spectroscopy (FT-IR) was utilized to investigate the fabrication of GMNPs by the clove extract and CnZVIs, with measurements taken over the 4000 - 400 cm^{-1} range. The analysis was carried out using Bruker Vertex80 FT-IR spectrometer, Germany.

3. *Scanning electron microscopy (SEM) analysis*

The microstructure and size of the GMNPs were analyzed using scanning electron microscopy at different magnifications with an operating voltage of 20 kV (Carl Zeiss Evo 18 Research, Germany).

4. *X-ray diffraction (XRD) analysis*

X-ray diffraction (XRD) pattern was used to analyze the crystallinity state of GMNPs and CnZVIs with a Cu-K$_\beta$ radiation source at room temperature, operating at 40Kv/30mA over a 2θ range of 5 to 80⁰, with a scanning speed maintained at 10 min^{-1}.

D. Batch experiment - Methyl orange (MO) degradation efficiency

A 100 parts per million (ppm) standard methyl orange (MO) solution was prepared by dissolving 25 mg MO in 250.0 mL of deionized water. A calibration plot was then developed using 5, 25, 50, 75, and 100 ppm concentrations. The unknown concentration was determined using the plot. According to the UV-Vis spectroscopy, the maximum wavelength (λ$_{max}$) for the MO was identified as 464 nm. Hence, the absorbance of the degraded MO solution was measured using a UV-spectrophotometer at 464 nm. The batch experiments were conducted using GMNPs and CnZVIs nanoparticles. A 25.0 mL of MO solution (100 ppm) was incubated with 20 ± 1 mg of GMNPs separately in 50 mL polypropylene plastic vials fitted with plastic caps. The solution was mixed using a thermo incubator at a speed of 150 rpm at a temperature of 25°C. One of the vials was withdrawn at a specific time interval (0, 20, 40, 60, 100, and 120 minutes), and the solution was filtered through Whatman filter papers (Grade 1) to remove the particles and measure the residual concentration of MO in the solution. The same procedure was followed using CnZVIs to evaluate the MO degradation efficiency.

The removal efficiency (η) and the amount of absorbed dye per unit mass of sorbent at a given time (q$_t$, mg/g) and equilibrium (q$_e$, mg/g) using GMNPs and CnZVIs were calculated by using the following equations (Wang and Li, 2013; Katata-Seru *et al.*, 2018; Gao *et al.*, 2019):

$$\eta = \frac{c_o - c_t}{c_o} \times 100\ \% \qquad (2)$$

$$q_t = (C_o - C_t)V/W \qquad (3)$$

$$q_e = (C_o - C_e)V/W \qquad (4)$$

Where η = the MO removal efficiency, C_o = the initial MO concentration in the solution (ppm), C_t = the MO concentration at a time (ppm), and C_e = the MO concentration at the equilibrium (ppm). All experiments were undertaken in triplicate, and the error values are less significant.

3. RESULTS AND DISCUSSION

A. UV-Vis spectroscopic analysis
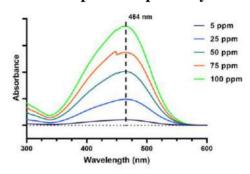
Figure 1. UV-Vis spectrum of the MO at different concentration

The UV-Visible spectroscopic analysis was performed to find the maximum wavelength (λ$_{max}$) of the MO solution. The UV-Vis spectrum indicated that 464 nm was the λ$_{max}$ for the MO solution. The absorbance of the degraded MO solution in the presence of magnetite particles was then measured at a wavelength of 464 nm.

B. FT-IR analysis
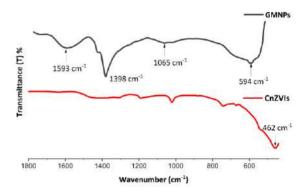
Figure 2. FT-IR spectrums of the GMNPs and CnZVIs

FT-IR analysis was conducted to assess the functional characteristics of iron nanoparticles. As illustrated in Figure 2, the peak observed at 594 cm^{-1} signifies the Fe-O stretching vibrations, affirming the GMNPs' formation through the constituents found in clove extract, supporting the idea that clove extract serves as both a reducing agent and a capping/stabilizing agent. The distinct peaks at 1065 cm^{-1} and another at 1593 cm^{-1} are associated with the C-N stretching vibrations of aliphatic amines and the C=C aromatic stretching vibration of GMNPs, respectively. The sharp peak at 1398 cm^{-1} corresponds to the -CH$_2$ groups (T. *et al.*, 2020; Parthipan *et al.*, 2021).

C. XRD analysis
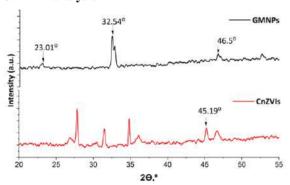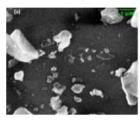
Figure 3. XRD pattern of the GMNPs and CnZVIs

These findings collectively validate the creation of GMNPs facilitated by the polyphenolic compounds in clove extract. Furthermore, in Figure 2, the peak at 462 cm^{-1} indicates the Fe-O stretching vibration of CnZVIs.

The X-ray diffraction (XRD) pattern, illustrated in Figure 3, of the green-synthesized iron nanoparticles (GMNPs) reveals a distinctive peak at 2Θ = 23.01º, corresponding to the characteristic absorption peak for polyphenols present in clove extract. This value aligns with previously reported data (Njagi *et al.*, 2011; Cao *et al.*, 2016). Additionally, the XRD pattern of the GMNPs displays a peak at 32.54º, corresponding to magnetite (Fe$_3$O$_4$). The peak at 32.54º corresponds to the Miller indices (hkl) values of 220, which denotes the crystalline phase of Fe$_3$O$_4$ (JCPDS/ICDD card No. 00-003-0862). The XRD

pattern of the chemically synthesized iron nanoparticles (CnZVIs) exhibits a peak at 45.19º attributed to Fe^0 (Huang *et al.*, 2014). The peak at 45.19º corresponds to the hkl value of 110, which denotes the crystalline phase of Fe (JCPDS/ICDD card No. 00-001-1262). Consequently, both XRD and FT-IR data affirm the functionalization of GMNPs by the polyphenolic compounds in clove extract.

D. SEM analysis
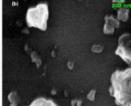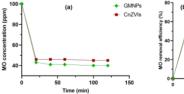
Figure 4. SEM images of GMNPs (a) 10 KX, and (b) 25 KX magnification

SEM images of GMNPs (Figure 4(a) and 4(b)) reveal irregularly shaped particles with a size distribution ranging from the nano to micro-scale, attributed to aggregation (Smuleac *et al.*, 2011). Furthermore, the broad size distribution of GMNPs from 70 nm to the micro-region may be attributed to the lower concentration of capping agents in the clove extract. The results confirm the successful synthesis of GMNPs utilizing clove extract, with SEM images supporting FT-IR analysis data.

E. Batch experiment - Methyl orange (MO) removal and kinetic studies

1. *Methyl orange (MO) removal*
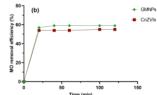
Figure 5. (a) MO concentration in the presence of GMNPs and CnZVIs with time and (b) MO removal efficiency of the GMNPs and CnZVIs

The removal of MO by GMNPs can be divided into two stages - an initial rapid removal stage followed

by a slower stage until the system reaches equilibrium over time. Figure 5(a) indicates that the concentration of MO declines with time and stabilizes at 120 minutes. After a 20-minute incubation period with GMNPs, the initial concentration of MO in solution was reduced to 43 ppm, ultimately reaching 40 ppm at equilibrium. Similarly, with CnZVIs, the initial concentration of MO in solution was 46 ppm, reaching 45 ppm at 120 minutes. In addition, as shown in Figure 5(b), MO removal efficiency by GMNPs and CnZVIs reached 57 % and 54 % at the 20-minute interval, respectively. At the equilibrium stage, MO removal efficiency reached 59 % and 55 %, respectively.

2. *Kinetic Studies*

The adsorption kinetics of MO onto the adsorbents (GMNPs and CnZVIs) were explored by applying pseudo-first-order and pseudo-second-order equations. These models rely heavily on the physical and chemical attributes of the adsorbent material. The pseudo-first-order model is particularly applicable at lower solution concentrations. The corresponding rate equation for the pseudo-first-order kinetics can be expressed as follows: (Wang *et al.*, 2014; Gao *et al.*, 2019):

$$\ln(q_e - q_t) = \ln q_e - k_1 t \qquad (5)$$

Where q_e and q_t (mg/g) are the amounts of MG molecules adsorbed on the GMNPs and CnZVIs at equilibrium and at different times t (min) and k_1 is the rate constant of the pseudo-first-order model for the adsorption process (min^{-1}). The linear plot of ln $(q_e - q_t)$ against time, as shown in Figure 6, was used to calculate the rate constant k_1. The slope of the linear plot gives the value for the k_1.
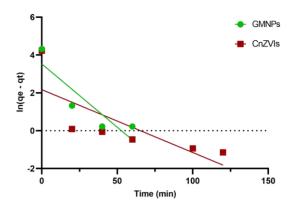
Figure 6. Pseudo-first order kinetics of the GMNPs and CnZVIs in the MO removal process

The pseudo-second-order kinetic model equation is expressed as follows (Bhattacharyya and Gupta, 2008; Gao *et al.*, 2019):

$$\frac{dq_t}{dt} = k_2 (q_e - q_t)^2 \qquad (6)$$

Integrating Eq. (6) by applying the boundary conditions t = 0 to t and q_t = 0 to t, gives:

$$\frac{1}{(q_e - q_t)} = \frac{1}{q_e} + kt \qquad (7)$$

When Eq. (7) linearized, it expressed as follows:

$$\frac{t}{q_t} = \frac{1}{k_2 q_e^2} + \left(\frac{1}{q_e}\right) t \qquad (8)$$

Where, q_e and q_t (mg/g) are the amounts of MG molecules adsorbed on the GMNPs and CnZVIs at equilibrium and at different times t (min) and k_2 (g mg^{-1}min^{-1}) is the rate constant of the pseudo-second-order model for the adsorption process. Values of the k_2 and q_e can be determined from the plot of t/qt against t, as shown in Figure 7.
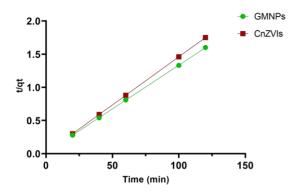
Figure 7. Pseudo-second-order kinetics of the GMNPs and CnZVIs in the MO removal process

Table1. **The kinetic parameters of MO removal by GMNPs and CnZVIs**

	Pseudo Order	First	Pseudo Order	Second
	K_{obs} (min^{-1})	R_1^2	K_2 (g mg^1 min^{-1})	R_2^2
GMNPs	0.0276	0.5706	0.0188	0.9993
CnZVIs	0.0315	0.5979	0.0688	0.9999

The correlation coefficients (R^2) show that MO adsorption onto the GMNPs and CnZVIs was better fitted for the pseudo-second-order model ($R^2 = 0.9993$ and 0.9999, respectively) compared to the pseudo-first-order model, according to Table 1. Therefore, the adsorption of MO onto GMNPs did not follow the pseudo-first-order model but well-fitted the pseudo-second-order model.

3. *Adsorption model isotherms*

Adsorption isotherms are crucial for understanding the interaction between adsorbates and adsorbents, correlating parameters like adsorbate uptake (q_e) and equilibrium concentration (C_e), while keeping temperature and pH constant. They offer insights into adsorbent capacities, behaviors, and optimization of adsorption mechanisms. Various models, such as Langmuir and Freundlich, are commonly used in scientific literature to compare outcomes and understand sorption mechanisms due to their versatility. (Gao *et al.*, 2019; Sahoo and Prelot, 2020)

a) *Langmuir model*

The Langmuir model (Langmuir, 1916, 1917), initially designed for gas-to-solid adsorption, has been adapted for solid-liquid interfaces, especially for monolayer adsorption scenarios. This model quantifies the equilibrium between adsorbate and adsorbent by assessing surface coverage, dependent on adsorbate concentration. It assumes surface homogeneity, monolayer adsorption, and reversibility, neglecting lateral interactions among adsorbed molecules. Despite these simplifications, the Langmuir model is widely used and appreciated for effectively fitting various experimental datasets (Piccin, Dotto and Pinto, 2011; Gao *et al.*, 2019; Sahoo and Prelot, 2020). The following equation represents the expression for the Langmuir isotherm:

$$q_e = \frac{K_L Q_m C_e}{1 + K_L C_e}$$

where Q_m (mg/g or mol/g) and C_e (mol/L) are the maximum adsorption capacity and the concentration at equilibrium, respectively, and K_L is the Langmuir constant, which represents the energy of adsorption or the equilibrium constant of adsorbate-absorbent equilibrium (L/g or L/mol depending on the unit of Q_m and C_e).

This equation can be easily converted to linear forms:

$$\frac{1}{q_e} = \frac{1}{K_L Q_m C_e} + \frac{1}{Q_m}$$

The plot (Figure 8) of $1/q_e$ as a function of $1/C_e$ allows the determination of the Langmuir constants.

The adsorption characteristics of the Langmuir isotherm can be explained in terms of a dimensionless constant R_L. R_L or separation factor is defined as follows:

$$R_L = \frac{1}{1 + K_L C_e}$$

The R_L factor indicates if the adsorption process is favored or not. If $0 < R_L < 1$, adsorption is considered as favorable. It is irreversible for $R_L = 0$, unfavorable for $R_L > 1$, and linear adsorption when $R_L = 1$ (Piccin, Dotto and Pinto, 2011; Gao *et al.*, 2019; Sahoo and Prelot, 2020).
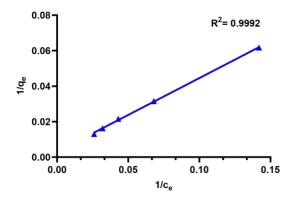
Figure 8. Langmuir isotherms for MO adsorption onto GMNPs, experimental conditions: T = 298 K, pH ~ 7.0

b) Freundlich model

The Freundlich isotherm elucidates reversible adsorption on surfaces with multiple layers under non-ideal conditions. It posits that each adsorption site exhibits a distinct binding energy, departing from a uniform distribution. This model reflects the heterogeneous nature of binding energies through an exponential function, mirroring real-world complexities (Piccin, Dotto and Pinto, 2011; Gao *et al.*, 2019; Sahoo and Prelot, 2020).

The following empirical equation represents the Freundlich isotherm:

$$q_e = K_F C_e^{-1/n}$$

where C_e is the equilibrium concentration of the adsorbate (mol/L). K_F and $1/n$ are the Freundlich constants representing the adsorption capacity and intensity, respectively.

The equation can be linearized by taking logarithms and is expressed as follows:

$$log(q_e) = log K_F + \left(\frac{1}{n}\right).log C_e$$

The representation of $log(q_e)$ as a function of C_e (Figure 9) gives access to the K_F and n parameters. The value of $1/n$ gives characteristic information regarding the adsorption process. The $1/n$ value of less than 1 implies chemisorption or ordinary Langmuir isotherm, whereas $1/n$ above 1 indicates cooperative adsorption.
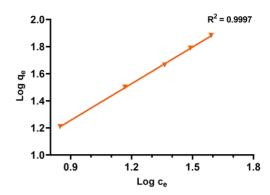
Figure 9. Freundlich isotherms for MO adsorption onto GMNPs, experimental conditions: T = 298 K, pH ~ 7.0

c) The Temkin isotherm model

The Temkin isotherm model suggests that the adsorption heat of all molecules decreases linearly as the adsorbent surface coverage increases. The model also assumes that the adsorption process is regulated by a uniform distribution of binding energies with a maximum binding energy (Piccin, Dotto and Pinto, 2011; Gao *et al.*, 2019; Sahoo and Prelot, 2020). The mathematical representation of the Temkin isotherm is shown in Figure 10:

$$q_e = \frac{RT}{b} ln K_T + \frac{RT}{b} ln C_e$$

where K_T is the equilibrium binding constant (L mol^{-1}) corresponding to the maximum binding energy, b is related to the adsorption heat, R is the universal gas constant (8.314 J K^{-1} mol^{-1}), and T is the temperature (K). Plotting q_e versus $ln(C_e)$ results in a straight line of slope RT/b and intercept (RT ln KT)/b.
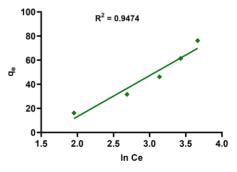
Figure 10. Temkin isotherms for MO adsorption onto GMNPs, experimental

Table 2. Langmuir, Freundlich, and Temkin parameters for the adsorption of MO by GMNPs

Isotherm model	Isotherm parameters	GMNPs
Langmuir	Q_m (mg/g)	327.33
	K_L (L/mg)	0.0074
	R_L	0.5761
	R^2	0.9992
Freundlich	K_F (mg/g)	2.7861
	n	1.1096
	R^2	0.9997
Temkin	K_T (L/mg)	5.0134
	b	35.03
	R^2	0.9474

Based on the isotherm data (Table 2), the Langmuir isotherm has a strong linear correlation for the adsorption of MO by GMNPs, with an R^2 value of 0.9992. The R_L value is approximately 0.57, which indicates that the adsorption process by the GMNPs is favorable. This observation suggests that the adsorption is homogeneous for MO in the solution. Furthermore, the 1/n values calculated from the Freundlich isotherm indicate that the removal of MO by the GMNPs follows the Langmuir isotherm/chemisorption, as the 1/n value is less than 1. Additionally, the heat sorption value 35.03 J/mol (0.0083 kcal/mol) calculated from the Temkin isotherm also suggests the physical adsorption of MO onto GMNPs. The positive value proposed by the heat sorption value of the Temkin isotherm suggests an exothermic process.

4. *Synthesis mechanism of GMNPs, and proposed adsorption mechanism for MO removal*

Based on the characterization data and the analysis data, a possible mechanism for the synthesis of GMNPs is proposed based on the published literature (Li, Elliott and Zhang, 2006; Wang *et al.*, 2014; Bashir, Ali and Farrukh, 2020; Gaminda *et al.*, 2024). Further, the kinetic data shows that the removal of MO follows the adsorption by the GMNPs and CnZVIs. Also, according to the reported studies, zero-valent iron particles can degrade the MO. The proposed mechanisms are described below, where the Ar stands for the phenyl group of the polyphenols.

Synthesis of GMNPs;

$$nFe^{3+} + Ar - (OH)_n \rightarrow nFe^{2+} + n (Ar = O) + nH^+$$

As previously mentioned, the synthesis of GMNPs is influenced by redox processes within the reaction, which hinge on the chemical species' standard reduction potentials (E^0). The standard reduction potential for Fe^{3+} is 0.77 V ($Fe^{3+} + e^- \rightarrow Fe^{2+}$). However, according to reported studies, the polyphenol-assisted reduction of Fe^{3+} to Fe^{2+} has been demonstrated (Eslami, Ebrahimzadeh and Biparva, 2018), and serves as evidence for the generation of Fe^{2+} through the reduction of Fe^{3+}, subsequently utilized as a precursor in the synthesis of magnetite via the co-precipitation method.

$$Fe^{2+} + 2Fe^{3+} + Ar - (OH)_n \rightarrow Fe_3O_4 - Ar = O(pH = 10)$$

(I) Adsorption of MO onto GMNPs,

$$Fe_3O_4 - Ar = O + MO \rightarrow Fe_3O_4 - Ar - O - MO$$

Recent studies (Li, Elliott and Zhang, 2006; Wang *et al.*, 2014; Bashir, Ali and Farrukh, 2020; Gaminda *et al.*, 2024) suggested that the zero-valent iron nanoparticles consist of the core-shell model. The core consists of zero-valent iron, and the shell is formed by the iron oxides/hydroxides formed due to the oxidation of the zero-valent iron.

In the first stage, Fe^{2+} is formed on the CnZVIs surface,

$$2Fe^0 + O_2 + 2H_2O \rightarrow 2Fe^{2+} + 4OH^-$$

$$Fe^0 + H_2O \rightarrow Fe^{2+} + H_2 + 2OH^-$$

In the second stage, Fe^{2+} oxidized to Fe^{3+},

$$4Fe^{2+} + 4H^+ + O_2 \rightarrow 4Fe^{3+} + H_2 + 2H_2O$$

In the third stage, Fe^{3+} reacts with OH^- and H_2O to form various hydroxides,

$$Fe^{3+} + 3OH^- \rightarrow Fe(OH)_3$$
$$Fe^{3+} + 2H_2O \rightarrow FeOOH + 3H^+$$
$$Fe(OH)_3 + 3H^+ \rightarrow FeOOH + H_2O$$

(II) Adsorption of MO onto CnZVIs particles,

$$Fe^0 - FeOOH + MO \rightarrow Fe^0 - FeOOH - MO$$

(III) Also, the partial reduction of the azo bond of the MO is possible due to the oxidation of the

CnZVIs (Beheshtkhoo *et al.*, 2018; Khashij *et al.*, 2020; Khunjan and Kasikamphaiboon, 2021),

$$Fe^0 \rightarrow Fe^{2+} + 2e$$

(IV) The degradation of the MO by the potent oxidant radicals is more likely as Fe^0 is a mild reductant, and iron corrosion promotes the generation of hydrogen peroxide in the presence of dissolved oxygen.

$$Fe^0 + O_2 + 2H^+ \rightarrow H_2O_2 + Fe^{2+}$$

$$2Fe^{2+} + O_2 + 2H^+ \rightarrow Fe^{3+} + H_2O_2$$

After, hydrogen peroxide and ferrous iron in the medium act as a Fenton catalyst system (Yuan *et al.*, 2020) and generate a strong oxidant of hydroxyl radical ($OH^{\cdot}$), which attacks the azo chromophore, causing decolorization.

$$Fe^{2+} + H_2O_2 \rightarrow Fe^{3+} + OH^{\cdot} + OH^-$$

$$MO + OH^{\cdot} \rightarrow OH^{\cdot} + CO_2 + H_2O +$$
mineralized products

Further investigations are required to understand the mechanisms associated with the complete removal of the MO using green synthesized magnetite particles.

4. CONCLUSION

The current study demonstrates a successful method for synthesizing iron oxide nanoparticles (magnetite) utilizing *Syzygium aromaticum* extract. The clove extract's polyphenols significantly contributed to the reduction and capping of the nanoparticles during the synthesis process. FT-IR analysis confirmed the presence of various functional groups (polyphenols) from the clove extract on the nanoparticle surface. SEM images indicated that the nanoparticles exhibited irregular shapes and a range of sizes from approximately 70 nm to a micro-region, attributed to aggregation. XRD analysis further confirmed the identification of magnetite nanoparticles encapsulated by the polyphenols in the clove extract,

as evidenced by the peak at 32.54°, characteristic of magnetite (Fe_3O_4).

Furthermore, batch experimental data revealed that the synthesized nanoparticles efficiently removed 100 ppm methyl orange (MO) from an aqueous solution using a 100 µL suspension (~20 ± 1 mg) of nanoparticles. This performance surpassed previously reported nanomaterials synthesized from other plant extracts. The MO removal efficiency by the nanoparticles reached 40 ppm (59% degradation efficiency), with an equilibrium time of approximately 120 minutes. Kinetic studies of the MO degradation indicated that the adsorption followed the pseudo-second-order model with an R^2 value of 0.9993. Isotherm studies revealed the superiority of the Langmuir isotherm in fitting the data (R^2= 0.9992) and the favorable R_L value (~0.57), along with the Freundlich isotherm with an R^2 value of 0.9997. These results signify the favorability of the adsorption process in MO removal using the synthesized iron oxide nanoparticles. The synthesized nanoparticles show great potential for removing methyl orange dye and improving water quality. Further research is required to optimize the reaction conditions and understand the nanoparticles' reactivity for removing various pollutants from wastewater.

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SRI LANKA'S INTERNATIONAL SECURITY LANDSCAPE: THE WAY FORWARD AFTER COVID-19 PANDEMIC
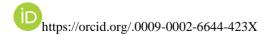
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ABSTRACT

The ripple effects of the COVID-19 pandemic had reshaped the three-way nexus between the pandemics, national and international security, and international relations. When the public health issues strain international security and international relations at the same time, states are compelled to take different approaches to mitigate the effects on national integrity or sovereignty. However, in the Sri Lankan context, the possible long-term consequences of the COVID-19 pandemic are particularly disturbing. According to Peiris (2021), "pandemics go far beyond mere public health crises, leaving an indelible mark on the contemporary social fabric." In that sense, a deep analysis is required to identify the tangible as well as intangible factors that resulted from such a catastrophe. Initially, COVID-19 impacted the social, economic, and political pillars of the~~ the~~ Sri Lankan society and secondary effects were more in global context. In this context, this paper aims on identifying significant traditional and non-traditional security threats faced by Sri Lanka in the context of international security since due to the COVID -19 pandemic. This study is qualitative in nature. In that, in-depth interviews were conducted with a cross section of professionals involving major disciplines that have bearing on the traditional and non-traditional national security concerns. The NVivo was used in analysing the data gathered through in-depth interviews. This paper analyses the present applicability of Regional Security Complex Theory (RSCT), which is one of the most comprehensive frameworks that outline distinct variables necessary for regional security analysis. However, the paper proposes changes to RSCT from ~~a~~ 2023 and beyond ~~context~~ after analysing the international security landscape since the COVID-19 pandemic. It is concluded that Sri Lanka should establish durable political stability as the essential component in reaching its economic goals. Civil society cultivation and engagement are two key areas in which Sri Lanka should focus more in the present context. It is imperative that Sri Lanka preserve and augment its domestic / national defence / regional security freedom of manoeuvre among large states such as China, India, th U.S.A and Russia using th correct blend of foreign policy whilst upholding national interests.

KEYWORDS: *COVID-19 Pandemic, National security, international security, Traditional and non-traditional security threats.*

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1. INTRODUCTION

As emphasized by Buzan (2009), security is a relational phenomenon. Therefore, it is paramount to understand the international pattern of security interdependence in order to determine the national security of a state. In those regions they play a mediating role between the states and the international systems. In security terms, *region* means that a distinct and significant subsystem of security relations which exist among a set of states whose fate is that they have been locked into geographical proximity with each other (Buzan, 2009). The overarching concept in determining the power relations therein is the amity/enmity pattern among states. Buzan and Waver (2003: 45–51) describe patterns of amity/enmity as 'taking the form of sub global, geographically coherent patterns of security interdependence'. Simply amity defines the possible protection whereas enmity speaks on suspicion and fear involved in such a relationship among states. The historical relations between India and Sri Lanka over centuries are a typical example of the principal elements of amity and enmity. This position leads to the concept of *security complex* in the international security landscape coined by Buzan. A security complex means a set of states whose national security concerns are linked together, resulting in their individual security concerns ~~could~~ not being considered separately. Besides, the anarchic international system acts as the main cause in developing such security complexes.

In this context, an extreme level of threat and fear that is felt mutually between two or more major states is a defining factor in determining a security complexes. The Indo Pakistan rivalry is a typical example in this respect. However, geography plays a vital role in the phenomenon of security complex. Although countries such as Bangladesh, Nepal, and Sri Lanka are minor geographical entities in the South Asia security complex, their alliances with major powers may impact and become a threat to a larger power. Another interesting factor that disturbs the security complex is identified as the condition of *overlay.* The involvement or intervening of armed forces of a great power in an overlain area in such a manner which

suppresses normal operations of security dynamics is termed an overlay. The colonial dynamics of European powers is the best example of this condition. This condition creates a situation where it is difficult to determine the local security dynamics due to the presence of the great power.

In this context, having identified the overarching security dimensions through RSCT, it could frame a comprehensive analytical framework to determine the complexities of national and international security dimensions. The domestic security environment of individual states is the first line or the bottom line in this framework. Next come the local security complexes, followed by great power complexes. In analyzing through this framework, it is imperative to identify the distinguishing security dynamics at each level. There may be certain interplay as well as the interferences mainly by great power complexes towards other two complexes.

As per the Director of National Intelligence (DNI) USA, the COVID-19 pandemic has killed millions of people and disrupted life worldwide, with far-reaching effects extending well beyond global health to the economic, political, security and societal spheres. In this context, the COVID-19 pandemic has resulted in shifts in security priorities and perceptions around the globe. The subsequent budgetary reductions have paved the way for gaps in military training and preparedness, counterterrorism operations, and arms control monitoring, verification, and compliance. The definition of national security thus has faced further revisions and debates due to the advent of the pandemic. In the global context, research relating to the COVID-19 pandemic and how it has shaped the security landscape has been widely spoken of. Yet, such research work relating specifically to Sri Lanka or small state scenarios is limited in the public domain. Accordingly, this paper addresses this specific research gap.

2. METHODOLOGY

This study was qualitative in nature. In that, in-depth interviews were conducted with a cross section of professionals involving major disciplines that have

bearing on the traditional and non-traditional national security concerns. Thirty-three (33) experts in the fields of security, international relations, medical and health, science and technology, geography, economy, rehabilitation and reconciliation, energy, crime prevention, and human security were consulted. The questionnaire had four clusters ,namely human security, civil society, social cohesion, transnational – domestic linkages of concern, and emerging international security issues. The secondary data ,including authentic books, journal articles, conference proceedings, and other on-line sources ,were also used. The NVivo was used in analyzing the data gathered through in-depth interviews.

3. RESULTS

According to Kevany et.al. (2021), diplomacy and integrated international collaborations have played a vital role in effectively controlling the Ebola outbreak in the West African region during 2014, along with the decisive role of the military.

Table 1: Pandemic issues as they relate to international relations and security
Source: Security Nexus 2021

International Relations	International Security
Secure essential resources and supply chains (e.g. pandemic supplies)	Telework and exposure to cyber vulnerabilities
Border closures	Tighter border management
Travel restrictions to and from affected countries	Managing travel quarantine
Citizen evacuation and airlift	Monitoring foreign travel
Expulsion of foreign workers	International contact-tracing
Cancellation of migration programs	National hoarding and price hiking
Suspension of visas	Lack of transparency and denial
Banning international travel from certain countries	Geopolitical maneuvering through opportunity exploitation
	Blame gaming
	Disinformation in an uncertain environment
	Disease migration

However, it seems a difficult proposition to expect similar results in the current international environment. The soft power and international relations have been more effective in such circumstances, as per Kevany et.al. The military has been tasked with a more logistical role when it comes to addressing health security issues. The study of Kevany et.al. (2021) shows that "thus, while pandemics may contain regional expansionism, generate new military roles, or force countries to turn inward, they also have dramatic impacts on other aspects of international relations and security" (Table 1).

According to Fonseka and Ranasinghe (2022), "the health and other challenges spawned by COVID-19 have engulfed Sri Lanka since 2020." The areas such as social fabric, reconciliation, and governance have faced multiple challenges during the process.The initial response of the Government of Sri Lanka (GOSL) in this regard was to appoint a few Presidential commissions to tackle the issues at hand. As per Fonseka and Ranasinghe (2022), these commissions were established in line with Article 33 of the Constitution, which has vested such powers under the President. The establishment of the National Operations Centre for Prevention of COVID-19 Outbreak (NOCPCO) under the Commander of the Army was considered a major action plan of the government to curb the pandemic. Subsequent appointment of a Presidential Task Force with greater powers to coordinate government machinery in a number of districts supplemented the NOCPCO. However, a major criticism levelled against these authorities was the neglect of civilian administration during the process. It was highlighted that the expertise and mandate of the public officials are undermined through the process (Fonseka and Ranasinghe, 2022). Critics of the government response to the pandemic viewed the process as militarization and securitization. According to Satkunanathan (2021), the unofficial structures created through these processes acted as a shadow state further to the already existing mechanisms. It was further emphasized that the democratic processes of the country are being eroded through the government's intentional activation of a parallel mechanism through the military.

The important aspect in this context is whether the pandemic disruptions are temporary in nature or whether they have shaped the fundamental future scenarios. More importantly, the non-traditional security threats have taken center stage more than the traditional ones. In the Sri Lankan context, straining governance is a major consequence of the pandemic. The capacity of government mechanisms under difficult conditions went down further along with the public confidence. The entire government mechanism reached a standstill with the state losing its control over the people. Sri Lanka not being an economically resilient country had to face major issues with regard to its sovereignty. In historical terms, the plague that devastated the city state of Athens during the Peloponnesian War with Sparta is an interesting phenomenon. Therein the unbearable losses of lives and economic conditions affected the Athenians as a major factor in their subsequent defeat at the hands of Spartans. In that sense, the pandemics could be termed a major non-traditional security aspect that needs the highest level of preparations to counter effectively.

4. DISCUSSION

The concept of globalization and the emergence of economic power has brought new insights to the security discourse. Ernst Hirsch Ballin, Huub Dijstelbloem, and Peter de Goede (2020) contended that security encompasses more than protecting the state's territory against military aggression by another state. The non-state actors have also played a prominent role in this regard. These authors have mentioned the role of geographical, danger, substantive, and reference dimensions as the four main pillars or dimensions of security. According to Niruthan (2023), terrorists, pirates, organized crime rings (including drug trafficking, human trafficking, and routine crimes), activist disruptors, and hackers could be considered as the main non–state actors who pose severe threats. As per Niruthan, the worldwide debate on political rights and law and order is due to the major activist disruptions that have crippled the nation states since of late. Initially, those who protest may have legitimate reasons for their course of action. However, these protests blew out of proportion thus becoming severe threats to national security. The

Black Lives Matter Movement in the USA, Mahsa Amini protests in Iran in 2022, and Nahel Merzouk riots during June 2023 in France, along with Sri Lankan Aragalaya in 2022, are examples of such activist disruptions with major consequences. Further, as per Niruthan, most of these non–state actors are international in nature yet have to be dealt with nationally. Besides, mostly they are unconventional in nature.
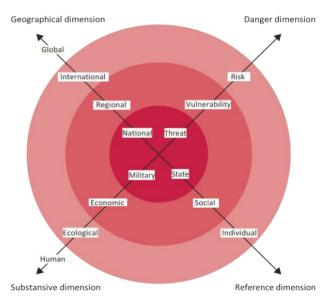
**Figure 1: Four pillars or dimensions of security
Source: Ballin et.al (2020)**

Besides, traditional security threats sphere headed by terrorism continue to pose severe danger to the globe while countries constantly determine on the counter measures to be effected. In that, the Four Waves Theory of Modern Terrorism is still very much applicable to the present context. David C. Rapoport in the 1970s came out with this approach for terrorism, highlighting implications of religiously driven activities. As per Kaplan (2021) wave theory relates strongly with Arthur Schlesinger's theory of political generations which posited 40-year generational cycles. According to Kaplan, "each has a precipitating event, signature tactics and weapons, and an inevitable gradual decline that culminates in the birth of another wave". The four waves according to Rapoport are: the Anarchist wave (1878–1919), the Anti-Colonial wave (1920s–early 1960s), the New Left wave (mid-1960s–1990s), and the Religious wave (1979–onwards).
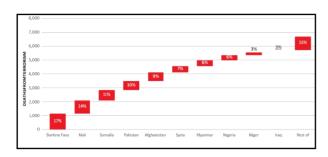
**Figure 2: Deaths from terrorism by country, 2022
Source: Dragonfly Terrorism Tracker**

According to the Global Terrorism Index (GTI), Afghanistan continues to be the country impacted mostly by terrorism. Besides, violent conflict has been the decisive course behind terrorism. Countries in conflict had suffered over 88 percent of attacks and 98 percent of terrorism deaths in 2022.

Another interesting development reflected through this study is the relationship between armed conflict and terrorism. All ten countries most impacted by terrorism in 2022 were also involved in an armed conflict. Attacks in countries involved in conflict are seven times deadlier than attacks in peaceful countries. As per the GTI, Burkina Faso has recorded the highest number of deaths due to terrorism in 2022. Besides, suicide bombing has been the deadliest form of attack by the terrorists. The study has further confirmed that the IS and its affiliates continue to be the deadliest terror group in the global arena, as per the statistics. Al-Shabaab, the Balochistan Liberation Army (BLA), and Jamaat Nusrat Al-Islam wal Muslimeen (JNIM) have been identified as other prominent terrorist groups in the global context.

In relation to the COVID-19 pandemic, Sri Lanka can derive valuable lessons with regard to the impact of health security challenges on national security and regional security. It is evident that the major impact of the pandemic was reflected towards human security.

Human security is a multi-sectoral approach to security that identifies and addresses widespread and cross-cutting challenges to the survival, livelihood, and dignity of the people.
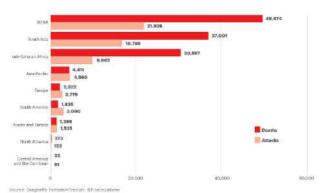
Figure 3: Attacks and deaths from terrorism by region, 2007–2022 (Source: Dragonfly Terrorism Tracker)

Human security integrates three freedoms: freedom from fear, freedom from want, and freedom from indignity. In that, economic security is a key component of human security. However, with Sri Lanka in dire straits with regard to economic security, the country faces numerous vulnerabilities in the coming years as far as national security is concerned. Energy security has become one of the biggest geopolitical factors in the present context. Sri Lanka at present struggles to find long term solutions in this respect. Besides, food/calories/human energy is a totally neglected phenomenon in Sri Lanka over the years. Civil society cultivation and engagement are two key areas in which Sri Lanka has failed to achieve the desired long term objectives. Further, Sri Lanka's diaspora relations is another vital area that needs course correction. Identification and analyzing possible transnational categories of criminal activities that could endanger the national security of Sri Lanka is paramount. Another important factor is how Sri Lanka can preserve and augment its domestic / national defence / regional security freedom of maneuver among large states such as China, India, th U.S.A,and Russia. It is imperative that Sri Lanka perform a comprehensive threat assessment to identify the possibilities of rivals or adversaries of the state using a larger category of technology or non-lethal technology against her.

Another important factor that came to light during the study was the fierce geopolitical competition surrounding Sri Lanka. Especially the Indo Pacific strategy (IPS) of the USA and the Belt and Road

Initiative (BRI) of China have created much tension in the region. The Indian sphere of influence is another vital factor that has created geopolitical challenges to Sri Lanka. With the country's economy in dire straits, Sri Lanka has little choice in various fronts. Alliance competition or alliance neutrality is a decision that has to be made by the country considering its domestic and foreign policy formulations. Accordingly, it is envisaged that the country needs to corporate with these global powers in line with a robust foreign policy and a geo strategy.

Analysis

It is evident according to the study that Sri Lanka faces critical traditional, non-traditional, and hybrid security challenges at this juncture. From all these factors, the geopolitical issues could be termed as the most vital in relation to Sri Lanka. The containment strategies of the USA led alliances towards China have affected Sri Lanka geopolitically. As such, it has to use statecraft to good effect and navigate in a sound geo-strategy focusing prosperity in line with its national interests. Moreover, a foreign policy that ensures 'alliance neutrality but not alliance partnership is the way forward for Sri Lanka. However, terrorism, cyber security, energy security, environment security, and health security issues such as pandemics are also of vital importance. The threat of transnational crimes is another factor to be noted.

5. CONCLUSION

The study identifies two ways that COVID -19 pandemic and RSCT complement each other. Firstly, the pandemic was treated as a threat and in many ways securitized by all countries. The discourse was often framed as a war/competition/rivalry, both between humanity and the pathogen, but also between states. COVID-19 did not recognize borders, natural obstacles, religion, culture, gender ,etc. This suggests that in such an interconnected, globalized world, 'regionalization' of contemporary security threats can be overplayed. On the other hand, the very fact that different states dealt with the pandemic differently shows RSCT at play. For example, vaccine diplomacy fused with other regional security issues in the case of

Chinese gifting vaccines to Sri Lanka and the desire by some in the UK to see Oxford-AstraZeneca produce a vaccine before Pfizer-BioNTech in order to vindicate Brexit. It is also the case that in different countries the populations securitize Covid to different levels. Climate change is securitized to greater levels in Europe, whereas Pacific countries consider infectious diseases/pandemics a greater threat. This again reinforces RSCT at play. The study emphasizes that Sri Lanka needs to navigate its geopolitical setting in a professional manner through a solid foreign policy. With the global powers engaged in a fierce competition to wrest control of the global balance of power, Sri Lanka should navigate its future in line with non-alignment policies.

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APPLICABILITY OF HEALTH, SAFETY, AND WELFARE LAW RELATING TO THE CONSTRUCTION INDUSTRY IN SRI LANKA

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ABSTRACT

Construction is particularly a high-risk industry, with a higher rate of accidents compared to other sectors. In Sri Lanka specifically, numerous construction accidents result from neglecting safety protocols stipulated by relevant authorities. Despite the presence of various Health, Safety, and Welfare (HSW) legislations in Sri Lanka, the incidence of accidents has been steadily increasing. Hence, this research aims to examine the Health, Safety, and Welfare Law pertinent to the Construction Industry, proposing strategies to improve the effectiveness of the current laws. It includes a review of primary legislation governing HSW aspects in Sri Lanka's Construction Industry, such as the Factories Ordinance No. 45 of 1942, Workmen's Compensation Ordinance of 1934, Shops and Office Employees Act No.19 of 1954, Wages Boards Ordinance No.27 of 1941, Employees Provident Fund (EPF) Act No. 15 of 1958, and Employees Trust Fund (ETF) Act No.46 of 1980. Additionally, the research addresses the significant challenges and issues encountered by stakeholders in the Construction Industry when adhering to these laws. This study utilized a mixed-method approach, incorporating both qualitative and quantitative data collection methods. The analysis utilized the RII method, mean and standard deviation assessments, and content analysis. Results revealed a lower average awareness level among respondents concerning these legislations, and significant variability in their understanding. Notably, despite previous suggestions to update existing legislation, this study highlighted that while the laws have been amended, stakeholders remain unaware of these amendments.

1. INTRODUCTION

The construction industry is among the most hazardous and dangerous in the world, as well as in Sri Lanka (Wijewantha, 2018) considering the number of accidents and injuries they cause (Abeynayake, 2010). As per the Health and Safety Executive (2003), an accident is defined as an unplanned event leading to property damage, human injury or illness, environmental harm or loss, or a missed opportunity for commercial gain. The majority of these accidents lead to tragic outcomes, including human injuries or fatalities, environmental and property damage, and the associated direct and indirect costs and efforts (Pathirana & Abeynayake, 2018).

The increase in construction activity, combined with insufficient occupational health and safety measures, puts construction workers at greater risk . According to the Department of Labour, the construction industry has the highest number of fatal accidents. (Melagoda & Rowlinson, 2022). Workplace health and safety stand is one of the most critical concerns that every organization must give due attention to (Abeynayake, 2010). The term "safety" pertains to safeguarding individuals from physical harm, while "health" relates to protecting people's physical and mental well-being from illnesses that may arise due to materials, procedures, or practices employed in the workplace (Darshana, 2017). It is challenging to standardize safety procedures across all construction operations since construction produces unique and immobile products. (Koskela, 2000).

Compared to other industries, the construction sector in Sri Lanka experiences a disproportionately high number of accidents due to the negligence of workers (Fernando, 2016). Insufficient attention has been paid to the subject of occupational health and safety in the construction industry in Sri Lanka (Wijewantha, 2018). A significant portion of construction accidents in Sri Lanka can be attributed to the failure to adhere to the safety precautions recommended by the relevant authorities (Siriwardana & Wickramasinghe, 2018), poor knowledge, attention and attitudes over safety measures (Abeynayake, 2010).

The development of the construction sector is mostly determined by the impact of the country's legal framework (Rathnasinghe et al., 2020). In reality, Sri Lanka's construction industry has inadequate health and safety regulations. This might be the result of lack of resources, lack of commitment among stakeholders, lack of education, or negligence (Siriwardana & Wickramasinghe, 2018).

Labour law, which focuses on the health, safety, and welfare of workers, regulates the rights and responsibilities of employers and employees. In Sri Lanka, this area of law is governed by both legislation and common law principles, (Abeynayake, 2010) and the departments of Labour and Workmen's Compensation are principally responsible for its enforcement.

Numerous labour laws and regulations have been put into place by the Sri Lankan government to solve labour issues, and they are crucial for both compensating workers and lowering the frequency of workplace fatalities and injuries (Rajapakshe, 2019). The Mines and Machinery Protection Ordinance, which was passed in 1896, is credited with establishing the beginning of industrial health and safety in Sri Lanka (Melagoda & Rowlinson, 2022). A number of Acts and Ordinances related to the well-being and safety of workers in the construction industry have been enacted over the past few decades (Kariyawasam, 2003).

Factories Ordinance No. 45 of 1942.

The Factories Ordinance No. 45 of 1942, Chapter 128 of Sri Lanka's Legislative Enactments, is an Act that establishes rules for the HSW of workers in factories (Melagoda & Rowlinson, 2022). It is the primary law governing HSW in Sri Lanka (Siriwardana & Wickramasinghe, 2018). It was enacted with 131 sections that address each situation (Rajapakshe, 2019) and is enforced by the Department of Labour's Industrial Safety division (Melagoda & Rowlinson, 2022). Subsequently, this Ordinance was amended by several Acts in 1961, 1976, 1984, 1998, 2000, and 2002 (Melagoda & Rowlinson, 2022). It primarily offers its laws and regulations, as well as quality of the premises; cleanliness; overcrowding; maintaining a reasonable temperature; ventilation; lighting; drainage

of floors and sanitary facilities (Pathirana & Abeynayake, 2018).

Construction is not a specific focus of the Factory Ordinance, which was created for all industries (Siriwardana & Wickramasinghe, 2018). But, Section 84 of Factories Amendment Law No. 12 of 1976's Provision 37 mentions the construction industry in the Factories Ordinance (Melagoda & Rowlinson, 2022).

Workmen's Compensation Ordinance of 1934

The Workmen's Compensation Ordinance of 1934 and its Subsequent Amendments provide details of how compensation is paid to employees who get injured while on the job due to an accident that results from their specific field of work (Abeynayake, 2010; Pathirana & Abeynayake, 2018). It is the primary law that protects employees from all types of injuries incurred while working (Fernando , 2016). This ordinance is governed by the Commissioner for Workmen's Compensation and was finally amended in 2005 (Melagoda & Rowlinson, 2022). By the Workmen's Compensation Ordinance, employers are responsible for compensating employees for injuries, accidents, occupational diseases, and fatalities if they occur while they are on the job at one of the different rates provided in the Ordinance (Abeynayake, 2010; Fernando , 2016; Pathirana & Abeynayake, 2018).

Shops and Office Employees Act No.19 of 1954

The Shop and Office Employees Act pertains to the terms and conditions that are relevant to office and shop workers. This Act defines office as encompassing all corporate administrative offices, including construction offices (Abeynayake, 2010). According to this regulation, every employee is provided with an appointment letter that outlines their employment terms. Records of salaries, attendance, and employment history are kept for all employees, regardless of their employment type, be it casual or permanent (Rajapakshe, 2019).

Wages Boards Ordinance No.27 of 1941

The Wages Boards Ordinance regulates the terms and conditions of employment for workers in a variety of trades and professions, including construction, about the number of hours worked, weekly and annual holidays, minimum salaries, and other factors (Abeynayake, 2010). The Wages Board decides what the industry's minimum salary should be for each category. Employees may be eligible for wage increases via national policy choices that are announced in gazette notifications (Rajapakshe, 2019).

Employees Provident Fund (EPF) Act No. 15 of 1958

The Employees Provident Fund (EPF) Act No. 15 of 1958 requires all employers to ensure that all of their subordinates make contributions to the Fund. A minimum of 12% of the employee's gross income must be contributed to the pension fund by the employer, and a minimum of 8% must be contributed by the employee (Abeynayake, 2010). According to the Employees Provident Fund (EPF) Act No.15 of 1958, all employees who fall into the categories of permanent, apprentice, non-permanent, temporary, casual, part-time, piece rate contract basis, and commission basis are eligible to become members (Rajapakshe, 2019). The Central Bank is entrusted with the handling of the fund, which is administered by the Labour Department. These interest-bearing deposits are withdrawable (Abeynayake, 2010).

Employees Trust Fund (ETF) Act No.46 of 1980

The Employees Trust Fund (ETF) Act No.46 of 1980 established a non-contributory fund to which only the employer is obligated to contribute (Abeynayake, 2010). In accordance with this law, the employer is required to provide a financial contribution equal to 3% of an employee's annual salary. This is advantageous for employees. Payment is given to the worker when they leave their job (Rajapakshe, 2019). Employees can withdraw this money once every five years upon leaving any workplace, regardless of their age, under the administration of a special board known as the Trust Fund Board (Abeynayake, 2010).

To address health and safety protocols across all workplaces, the Department of Labour has developed a new Act known as the Occupational HSW Act, which is currently awaiting cabinet approval. This Act draws inspiration from the United Kingdom's Health and Safety at Work Act (Melagoda & Rowlinson, 2022). Nonetheless, according to Halwatura & Jayathunga (2011), the existing safety and health

regulations within the Sri Lankan construction sector remain insufficient. Moreover, in the local context, there is a notable absence of specific laws concerning the safety and well-being of employees at construction sites (Siriwardana & Wickramasinghe, 2018).

To determine whether the current regulations are sufficient and to identify whether Sri Lanka's construction industry is aware of and effective at applying the country's health, safety, and welfare legislation to reduce accidents, this research aims to explore health, safety and welfare law in line with the Construction Industry and propose strategies that can enhance the effectiveness of the current health, safety, and welfare law in Sri Lanka. Accordingly, this research seeks to contribute to the improvement of safety standards and overall well-being in the construction industry in Sri Lanka.

Accordingly, the following objectives were established for this research:

1. To review the key legislation relating to health, safety, and welfare in the construction Industry in Sri Lanka.

2. To investigate the awareness and effectiveness of health, safety, and welfare law on construction industry stakeholders in Sri Lanka.

3. To determine the major challenges and issues faced by construction industry stakeholders in adhering to the existing health, safety, and welfare law in Sri Lanka.

4. To propose recommendations to overcome these challenges and enhance the effectiveness of the health, safety, and welfare law in the construction industry in Sri Lanka.

2. METHODOLOGY

This research employed a mixed-method approach, integrating qualitative and quantitative data collection methods. It enables a thorough understanding of how health, safety, and welfare laws affect Sri Lanka's construction industry and helps in gathering both quantitative data through questionnaires for statistical analysis and contextual information for qualitative

analysis through interviews, giving the research topic a more comprehensive perspective.

This study is focused on the Health Safety and Welfare legislation of the construction industry, with data collected directly from professionals and stakeholders working on construction sites, including quantity surveyors, project managers, human resource managers, site engineers, health and safety officers and other specialists in the industry. The choice of this sample was deliberate, aiming to optimize both efficiency and effectiveness in the research process while minimizing time constraints.

To collect data, a combination of random and purposive sampling methods was employed. Qualitative information was obtained via an extensive review of the literature and five semi-structured interviews conducted with professionals in the construction industry who were selected through the purposive sampling method. Quantitative data, on the other hand, was acquired through a questionnaire survey involving 67 respondents selected through simple random sampling. Analysis of the data employed the Relative Importance Index (RII) method as well as content analysis.

3. RESULTS AND DISCUSSION

Major Challenges and Issues Faced by Construction Industry Stakeholders in Adhering to Existing Health, Safety, and Welfare Law in Sri Lanka

Pathirana & Abeynayake (2018) state that the Factories Ordinance and all other laws are now out-of-date. They avoided discussing current topics like the hazards of construction. The Factories (Amendment) Act No.19 of 2002 served as its most recent modification. It has not been updated in more than ten years (Siriwardana & Wickramasinghe, 2018). Only a few small amendments have been made to it since it was first established more than seven decades ago (Melagoda & Rowlinson, 2022). Therefore, it is presumed that current developments in construction technologies and standards may not be covered by the requirements (Siriwardana & Wickramasinghe, 2018; Melagoda & Rowlinson, 2022).

The Factories Ordinance targets the safe operation of mechanical equipment, cleanliness of the factory and its surroundings, and employee welfare across all industries, rather than addressing issues specific to the construction industry (Melagoda & Rowlinson, 2022). However, this is very different from the reality in other countries that are primarily developed countries (Fernando , 2016). In almost every country, legal authorities enforce occupational safety laws about construction. Unlike Sri Lanka, which lacks dedicated safety regulations for the construction sector, countries like the United Kingdom (Construction, Design and Management Regulations 2015), the United States of America (PART 1926 OSHA regulations), China (Construction Law of the People's Republic of China), the United Arab Emirates, and India (Building & Other Construction Workers Act, 1996) have established specific safety regulations for this industry (Siriwardana & Wickramasinghe, 2018). As an example, the CDM (Construction, Design, and Management) Regulations in the UK brought about a new paradigm for construction health and safety in the UK by transferring safety management responsibility across all project phases and introducing new health and safety roles such as clients, designers, and the planning supervisor (Howarth et al., 2000).

Tragically, there is no reliable method of gathering information on all accidents on construction sites in Sri Lanka. The authorities are not informed of these accidents (Darshana, 2017; Pallewaththa et al., 2018). Practically, new laws are not implemented, and there is no independent, assigned office for inquiries (Abeynayake, 2010). According to the Factories Ordinance, there is a minor fee in the existing system for accidents that are not reported (De Silva et al., 2018). The government is encouraged to enact a higher fine that will correspond to failure to follow H&S laws (Othman, 2012). For instance, in the Workplace Safety and Health Act (WSHA) of Singapore, the key principles that serve as the primary law governing workplace safety and health in Singapore, encompass: reducing risks at the source, cultivating a safety culture, and penalties for prevention.

A significant number of construction accidents in Sri Lanka are attributed to activities conducted at heights.

However, the Factories Ordinance does not adequately address the essential safety measures for accidents arising from work at heights. Furthermore, the maximum compensation of Rs. 515,000.00 for a fatal accident in Sri Lanka is deemed unreasonable, and there is a need for an increase in this amount to better address the needs of affected parties (Pathirana & Abeynayake, 2018). Moreover, the Factories Ordinance has shortcomings such as incomplete coverage of building activity, subjective claims, a lack of descriptions, a lack of applicability, a lack of numerical expressions, and a disorganized presentation (Siriwardana & Wickramasinghe, 2018).

Construction experts' knowledge of the Factories Ordinance (1942) is relatively limited and unsatisfactory. There is a lack of skilled officers in the areas of HSW. Several other specialists are somewhat knowledgeable about HSW (Pathirana & Abeynayake, 2018). Moreover, the lack of necessary resources contributes to the insufficient and ineffective implementation of safety laws by government institutions in developing countries. Although law enforcement organizations and prevention programs in developing countries have few resources, the safety laws themselves can be very loose and vague (Kheni et al., 2008).

Workers lack enough awareness of HSW, and many of them choose not to wear their safety helmets' chin guards. They are therefore adjacent to the hazards. Additionally, employees have a negative mindset about safety; it is an additional load for them (Pathirana & Abeynayake, 2018). However, workers in the construction sector have consistently disregarded those provisions of legislation (Abeynayake, 2010). Particularly, workers are unclear of their rights, the benefits they are entitled to from management, and the procedures for obtaining those advantages. The morning awareness programs have very low labour attendance (Pathirana & Abeynayake, 2018).

The RII was computed for the data obtained from the 67 responses in the questionnaire survey regarding the above-stated challenges and issues with the use of MS Excel. This calculation was aimed at ranking these challenges in order, signifying their respective levels

of importance, and highlighting which factors had the most substantial impact. A greater RII value signifies challenges of greater importance or increased significance.

Table 1. RII of challenges

Challenge/Issue	RII Value	Rank
The outdated features of current legislation	0.770149254	6
Current developments in construction technologies and standards have not been covered	0.862686567	2
The construction industry has not been specifically focused	0.710447761	8
Lack of a dependable way to track accidents	0.797014925	5
Incomplete coverage of building activity (For example - working at height and fall protection are not addressed)	0.731343284	7
The maximum amount of compensation for a fatal accident (Rs. 515,000.00) is unreasonable.	0.841791045	3
Lack of descriptions and numerical expressions	0.710447761	8
Prejudice due to confusion between legislations	0.680597015	10
Lack of expertise, knowledge and resources	0.802985075	4
Poor knowledge and negative attitude of workers	0.946268657	1

Although several past studies have highlighted that there have been only a few minor amendments to this legislation, it was found through the interviews that the Factories ordinance was amended in 2019 as Factories Regulations No. 2 of 2019, and additionally in 2021 as Factories (Amendment) Act, No. 4 of 2021.

Moreover, the Employees' Provident Fund (Amendment) Act, No. 23 of 2021, and the Wages Boards (Amendment) Act, No. 14 of 2019, stand as notable recent amendments within the Health, Safety, and Welfare legislation pertinent to the construction industry.

When considering lack of a dependable way to track accidents, which is the 5th ranked factor and RII value is 0.797, the opinions of the interviewees are contradictory. Interviewees 2 and 5 indicated that *"internal organizational concerns and fears about job security might result in underreporting of accidents, particularly for minor injuries or near-misses."* Interviewee 4 highlighted that workers might not have a complete understanding of the reporting procedures. However, Interviewee 1 stated that *"all accidents (permanent or not) are mandated to be reported to the Department of Labour, and failure to do so can lead to legal actions by the department. Additionally, they mentioned that a summary of accidents documented in the General Register should be submitted to the labour department twice a year."* Despite Interviewee 1 emphasizing the necessity of reporting all accidents, there appears to be an issue regarding effectively tracking accidents.

The data analyzed revealed that the most influential challenge confronted by stakeholders in the construction industry concerning adherence to these laws was the poor knowledge and negative attitude of workers. Notably, despite suggestions in several studies advocating for updating existing legislation, this research highlighted that the laws have been updated; however, stakeholders continue to be unaware of these changes.

Recommendations to Enhance the Effectiveness of the Health, Safety, and Welfare Law

To decrease accidents and maintain up-to-date health and safety regulations in Sri Lanka, it is crucial to consider establishing an organization or a ministry dedicated to gathering data related to accidents on construction sites. This data collection and analysis can provide valuable insights for crafting and implementing effective safety measures (Darshana, 2017). It must also be developed to provide socially conscious clients with a higher grade regarding their

safety and health (Siriwardana & Wickramasinghe, 2018).

Management is legally obligated to uphold health and safety standards to prevent workplace accidents. A risk assessment must be conducted to identify any hazards on the premises, and the results must then be incorporated into the H&S plan that will be put into action (Othman, 2012).

To defend workers' rights, Parliament should also update the labour law's provisions relating to health and safety. Moreover, to ensure the appropriate administration of justice in the nation, the Ministry of Justice should set up new employment courts for the industrial sector (Abeynayake, 2010). Therefore, it is crucial to tighten the existing laws and regulations to safeguard our essential human resources and reduce economic losses (Pathirana & Abeynayake, 2018). As a result, the Sri Lankan construction industry needs thorough and updated health and safety standards since implementing a safe working environment in the construction industry requires suitable legislation. The government should create and strongly implement comprehensive safety laws that apply directly to construction (Siriwardana & Wickramasinghe, 2018).

It is suggested that workers raise their awareness of the OHS in Factories Ordinance (No. 45 of 1942). On the other hand, in order to ensure that general and specific OHS regulations in the Factories' Ordinance are implemented and that employees receive the greatest possible benefits, employees should be given the authority to interact with management (Pallewaththa et al., 2018). Universities and technical institutions should emphasize the value of safety in their training for engineers and technical officers to encourage employee ideas (Siriwardana & Wickramasinghe, 2018).

The Relative Importance Index (RII) was calculated using the data gathered from 67 responses in the questionnaire survey concerning the recommendations for the identified challenges associated with the utilization of MS Excel, as previously mentioned.

It is crucial to note that all the proposed recommendations derived from the questionnaire

survey are ranked with high importance, considering their RII values, which are above 0.8.

Table 2. RII of recommendations

Recommendation	RII Value	Rank
Establishing an organization to gather data related to accidents on construction sites	0.847761194	4
Maintain Health and Safety standards at site	0.904477612	2
Update current Health Safety and Welfare legislation	0.87761194	3
Raise awareness of legislation among stakeholders	0.943283582	1

Therefore, increasing awareness among stakeholders regarding the legislation can be achieved through improving education, training, and public awareness regarding health, safety, and welfare legislation, along with guidelines for post-accident legal procedures, should occur through consistent updates and reminders. It is essential for stakeholders to comprehend their legal responsibilities following an accident, facilitating compliance with investigation, documentation, and reporting protocols. Increasing awareness is pivotal, as laws alone cannot shift people's attitudes. Moreover, stakeholders must be aware of the accident reporting procedure in order to monitor them properly.

Moreover, increasing the amount of penalties for non-compliance with the law is of utmost importance. Given the prevailing negative attitudes among labourers towards health, safety, and welfare (HSW), There is a suggestion to prioritize HSW, mandating its implementation, and imposing penalties for non-compliance with these laws. Implementing penalties for non-compliance acts as a deterrent, motivating stakeholders to prioritize Health, Safety, and Welfare (HSW) to be clear of legal consequences.

Due to the diverse educational backgrounds and language barriers within the construction industry stakeholders, there is a potential variation in

understanding and implementing safety protocols. Encouraging compliance through incentives like rewards or licensing could effectively motivate adherence to safety legislation, presenting a universally understandable approach. Therefore it is suggested to implement a rating system for safety standards.

Furthermore, legal action cannot proceed without the requisite terms outlined in the law. The challenge arises when modern developments lack coverage within legislation due to missing terms. Hence, when amending legislation, it is suggested to consider these modern developments and incorporate the necessary terms accordingly.

Further Research Potential and Limitations

During the research process, there was a noticeable scarcity of published articles addressing this topic. Hence, exploring these research avenues further could significantly enhance comprehension of challenges associated with health, safety, and welfare (HSW) legislation in the construction industry. Additionally, these avenues could provide valuable insights into strategies aimed at improving compliance and raising awareness.

Conducting in-depth case studies within the construction industry, particularly in organizations that have effectively enhanced compliance with HSW legislation, would significantly contribute to a more comprehensive analysis. This approach would involve analyzing their strategies and best practices, aiming for broader applicability in the industry. Additionally, while this study compared legislation solely from the UK and Singapore, expanding the comparison to encompass a wider range of countries or regions would offer a more global perspective, allowing for a better understanding of global best practices and variations in HSW regulations across diverse geographical areas.

Furthermore, examining the economic ramifications resulting from non-compliance or insufficient awareness of legislation within the construction industry, encompassing expenses related to accidents, legal penalties, and the adoption of proper HSW

practices to mitigate cost overruns, stands as a crucial area for further investigation.

The study's potential limitations, such as a restricted sample size or inadequate representation of the diverse stakeholder spectrum within the construction sector, especially considering the scarcity of professionals knowledgeable about HSW legislation, might impact the generalizability of findings. Addressing these constraints in future research endeavors could significantly contribute to a more comprehensive and resilient understanding of challenges and solutions concerning HSW legislation in the construction industry.

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A CRITICAL OVERVIEW OF THE IMPLEMENTATION OF RIGHT TO INFORMATION IN SRI LANKA

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ABSTRACT

The Right to Information (RTI) is integral to the concept of democracy today, as it embodies key democratic principles including good governance, transparency, and accountability of public authorities. In Sri Lanka, the Right to Information Act No. 12 of 2016, introduced through the 19th Amendment to the Constitution in 2015, stands as a significant initiative within the country's legal framework. Despite being ranked as the world's 4th best mechanism, the practical implementation of Sri Lanka's RTI regime faces several shortcomings even nearly after a decade. Hence, the objective of this research is to critically evaluate the practical application of the Black Letter Law related to the right to information in Sri Lanka. This literature-based qualitative research is a comparative study of jurisdictions. Right to information laws, conventions, legislation, case law, and scholarly publications were used to analyse and identify gaps and propose recommendations based on global best practices to create a robust implementation mechanism for RTI. The study reveals that language barriers, rejection of information on unreasonable grounds, lack of knowledge and awareness, exclusion of NGOs and private organizations from RTI coverage, inadequate media intervention, and misuse of legal provisions are key barriers for coherently executing the right to information in Sri Lanka. Adhering to the principle of maximum disclosure, establishing strong oversight mechanisms, implementing effective records management, fostering supportive political and civil society cultures, and providing training for information officers are recommendations for building a robust RTI mechanism in Sri Lanka. Sri Lanka can also gain insights from India to follow innovative approaches for public awareness at grassroots levels. Thus, it can be concluded that despite a strong legal framework, overcoming implementation barriers requires coordinated efforts and close monitoring.

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1. INTRODUCTION

The concept of human rights has evolved from the past to present with the addition of various new dimensions to the law. Even though information was considered as a wealth, limited to the ruling class in early kingdoms, today along with the advancement of technology and media, people are interested in receiving information. Especially, due to globalization, today the channels of information have widened their parameters by extending to the international level. Currently, we are discussing the right to information while internet users are facing a potential risk of leaking sensitive personal information (Masur et al, 2023).

In 1946, during the inaugural session of the UN General Assembly, Resolution 59(1) acknowledged the significance of the freedom of information on a global level. This recognition laid the groundwork for the right to information, which is considered foundational and essential for upholding various other freedoms. The Universal Declaration of Human Rights, specifically Article 19, identifies the Freedom of Information as a subset of the broader freedom of expression.

The possibility of incorporating the right to information as a fundamental right is a controversial issue. In the present context, bribery, corruption and lack of transparency have become huge barriers in exercising the virtues of democracy. However, when the citizens are equipped with the right to information, it helps to maintain good governance, transparency and accountability since the government is answerable to the public (Right to information Act No 12 of 2016). Also, the right to information ensures better record keeping and proper decision making in the institutions. Moreover, the right to information encourages the proactive citizen participation and oversight. Through exercising the right to information, the public has the opportunity to get to know about their personal grievances, delays and reasons for delays in administrative procedure (Roberts, 2001). This inclusiveness of citizens in the governance will provide a strong support for the upliftment of democracy within the country. Currently, the right to

information has been utilized for revealing necessary information in several sectors such as public service delivery, issues related to governance process and accountability, missing cases during the civil war, corruption scandals and mishandling public money (Pinto-Jayawardena, 2019). Hence, in the present context, the right to information (RTI) is considered as a very significant right of a citizen in a democratic country. At present many countries have included the right to information as a fundamental right recognized by their constitution, and it plays a major role in creating the checks and balances of the power. This right also helps to maintain the true essence of sovereignty vested on the citizens.

Although Sri Lanka has recognized the right to information, there is still a dilemma as to whether the citizens are properly benefiting from the practical application of this right. Mainly as a developing country, many procedural barriers, bottlenecks and technical obstacles can adversely affect exercising the right to information. Although there are many past research about the application of right to information in Sri Lanka, some gaps in the literature can be identified. Specially there is a lacuna in the literature that connects the best practices of the international level, to fix the issues connected to right to information in Sri Lanka.

Hence, this research intends to assess the practical application of the right to information in Sri Lanka while drawing best practices from other jurisdictions in order to establish a robust mechanism for ensuring the Black Letter Law related to right to information. This research is significant in addressing the practical barriers to the application of right to information in Sri Lanka and helps to explore the relevant innovative ideas in legal, policy and administrative structures. It is intended to identify a strong legal and regulatory mechanism which uplifts the right to information of the Sri Lankan citizens, from rural and marginalized communities as well.

2. METHODOLOGY

This research is conducted according to the qualitative approach. A literature-based comparative study was conducted by comparing the legal and regulatory frameworks of similar jurisdictions, that have

incorporated the right to information. Conventions, domestic and international legislation, case law, journal articles, research papers and other scholarly publications were included in the analysis. The researcher analyzed the current literature on the right to information in Sri Lanka to identify the existing gap in the literature. Furthermore, the researcher analyzed the regulatory frameworks of other countries to identify the best practices related to the right to information. A literature-based comparative study was suitable to achieve the research objective since it helps to identify the loopholes in the existing structure while finding recommendations from global best practices.

3. RESULTS AND DISCUSSION

Legal Framework for Right to Information in Sri Lanka

Following the example set by neighboring countries like India, Sri Lanka has also successfully initiated to draft the relevant legal provisions for safeguarding the right to information. As per the 19th Amendment to the Constitution of the Democratic, Socialist Republic of Sri Lanka, right to information was recognized as a fundamental right (Constitution of Democratic Socialist Republic of Sri Lanka ,1978). The Article 14(2) of the Constitution clearly states the right to access to information.

The Right to Information Act No 12 of 2016 was enacted as a supportive legislation for protecting the right to information and through section 41(2) this right was highlighted. Accordingly, the Gazette No 2004/66 of 03.02.2017 of the Democratic Socialist Republic of Sri Lanka was issued to affirm the above-mentioned legislation. According to the preamble of the Act it is clearly indicated that the Act intends to promote the right to access to information with an effective citizen participation while ensuring the good governance. With all the implications related to the right to information, Sri Lankan legal framework is among the top ten countries due to the supportiveness of the legal structure. It is commendable that Sri Lanka has gained 131 marks out of 150 in the Global Right to Information Rating, 2023.

Implementation of the Right to information

In terms of the supportive legislations, a strong institutional architecture is essential for effective implementation of the right to information. This may comprise of a collaborative approach maintained by oversight and capacity-building agencies such as training institutions and RTI commissions. There should also be implementing agencies such as ministries, departments and enforcement agencies such as judiciary. All these institutions should play their role homogenously in order to enhance the implementation of the laws on right to information. For an example, in the United Kingdom, the Department of Justice acts as an executive oversight body while the Information Commission has the mandate as an independent oversight body. A key feature is that the U.K Information Commission has the power vested in it to initiate its own motions (Roberts, 2001). Similarly, it is important that the oversight of the right to information should be carried out without a fall continuously. However, the global as well as Sri Lankan experiences depict that maintaining sustainability in the oversight procedure has been challenging.

Recent Landmark Decisions

There have been many landmark decisions regarding the right to information in Sri Lanka. In *Gamini Karunaratne Vs. Information & Communication Technology Agency of Sri Lanka (ICTA)* the appellant requested a full disclosure of the staff member information of ICTA. However, the information officer and the designated officer failed to respond to this request and only a website link was provided, without any formal release of information. Hence it was decided that the public authority should release the aforementioned information requested by the appellant before 24.05.2023 and the failure to comply with that will cause the information officer and the public authority to be prosecuted according to the section 39 of the Right to Information Act No 12 of 2016.

According to *Center for Environmental Justice V. Ministry of Investment Promotion,* the appellant requested for a copy of the tripartite agreement related to Port City Project. However, it was rejected relying

on Section 5(1)(b)(ii), Section 5(1)(c)(v), Section 5 (1) (i) and Section 5(1)(d) mentioning the confidentiality clause in the Tripartite Agreement. The public authority mentioned that there can be a potential breach of confidentiality as certain aspects of this agreement are still 'ongoing' even if the Agreement itself is signed and finalized. However, when this was appealed it was declared that the information requested by the Appellants does not fall within the exempted categories in Section 5(1)(b)(ii) as the relevant Agreement is not encompassed within its ambit. It was held that Section 5(1) (c) (v) is inapplicable as no 'premature' disclosure of an overseas trade agreement is evidenced on the facts.

In *Sajeewa Wijeweera V. Sri Lanka Telecom PLC,* some website domain information from Sri Lanka Telecom was requested. However, it was argued that Sri Lanka Telecom is not a public authority. However, it was pointed out that since Sri Lanka Mobitel is an affiliated institute under Sri Lanka Telecom, it is a public authority falling under the purview of the Act No. 12 of 2016. Also, it was held that the connection between Sri Lanka Telecom and Sri Lanka Mobitel is irrelevant in fulfilling this request. Likewise, when considering the above cases, it is evident that there have been many progressive decisions related to the right to information in Sri Lanka.

Challenges in Implementing the Right to Information in Sri Lanka

Since there is a favorable legal background in the country, it cannot be concluded that there are no barriers for implementing the right to information. Most probably the issues arise in the implementation level of the right and those cannot be traced at the initial stage of legal drafting.

Language Barriers

The basic problem faced in the right to information practice in Sri Lanka is the language barrier. As per the National Language Policy, the government institutes are bound to adhere to the requirement of using both Sinhala and Tamil Languages as the national languages. It is mandatory for the public officers in Sri Lanka to achieve the national language proficiency. It is expected that the officers have a

capacity to address the concerns they receive from the language other than their language of recruitment. Also, when considering the supreme law of the country, Article 12(i) of The Constitution of Democratic, Socialist Republic of Sri Lanka also highlights the right to equality by stating that all citizens are equal before the law and are entitled to get the equal protection of the law.

Given the fact that these requirements are laid out one may argue that the citizens are capable of requesting the information from the national language they are comfortable with. However, in practice it is observed that the government institutions do not always address the RTI requests in the language requested by the applicant (Gunatilleke, 2014).

Due to this reason, the minor communities will experience several communication problems and hardships in this process. Furthermore, the aggrieved citizens cannot get a binding decree through the Right to Information Commission since it can only give recommendations for adhering to the national language policy when working on the requests for right to information.

Rejection of Information on Unreasonable Grounds

One main issue faced when submitting the RTI applications is that officers are discouraging the practice of forwarding the requested information. Although the Act affirms that the RTI requests should not be rejected, if there is no reasonable ground, in the practical sense this is not implemented as suggested by the Act (Annual reports, Right to Information Commission, 2021). Moreover, the ancient roots of state bureaucracy in the Colonial Period are followed even today in some of the government entities. Due to this mindset, the public officers may see the right to information as a threat for the authority executed by them. Hence it is essential to educate the public officers about the grounds on which the applications for the right to information can be rejected.

Also, in many occasions the requested information will not be available, because the authorities have discarded those documents or because they have been ruined by the cause of time or due to adverse weather

or flood conditions. This affirms the fact that the right to information should go in line with a proper archive maintenance in the public offices.

Lack of Knowledge and Awareness

When following the law on the right to information another major challenge is the lack of knowledge and awareness among the citizens regarding the parameters of this right. Basically, both the public masses and the public officials lack this awareness and knowledge on the right to information. In relation to the government institutions, it is essential to give a proper training to the information officers about their duty and responsibility in safeguarding the right to information (Centre of Policy Alternatives, 2018).

Similarly, while taking examples from India, it will be very useful to create the citizen awareness even in the grassroot level in order to get the maximum usage of the legal provisions. The pathetic situation is that the majority of the rural community in Sri Lanka are also not familiar of right to information (Singh, 2016). As a result, they may be going through many discriminations and difficulties and still they are helpless without a remedy. Information literacy and the ability to achieve the right to information are two concepts which have a very close relationship (Eltemasi,2024). Thus, in the Sri Lankan context it can be observed that more than the public, media and civil society organizations are interested in gaining the maximum benefit of the right to information.

RTI which does not cover the NGOs and Private Organizations

Sri Lanka, as a developing country faces severe threats of corruption; hence, it is important to have a proper oversight of government and non-government sectors as well. However, as per the legal capacity of the Right to Information Act of Sri Lanka, the citizens are not entitled to request information of the NGOs and other private entities (Gunatilleke, 2014). Therefore, this may create malpractices in the public and private partnerships in Sri Lanka. However, the Act also mentions that the 'institutions whose shares are held at least 25% or more by the government or controlled by a government-owned companies should comply with the provisions of the Right to Information Act'.

However, in practice it is observed that these private organizations in Sri Lanka which fall into the purview of this legal provision have not followed this by appointing the information officers to disseminate the requested information.

Inadequate Intervention by Media

Right to information has been a newly introduced segment to the classical fundamental rights in Sri Lanka and due to this reason, it is very important to create awareness and knowledge about the parameters of this Law. In this process the mass-media can play a vital role. Unfortunately, this media responsibility is not properly fulfilled by the public and private media organizations. Mainly the television and radio channels can organize special programmes to make officers and citizens aware about the right to information. However, it is the high time to think creatively and establish a platform to create awareness even by using social media. Through these initiatives, a positive change in the attitude regarding the right to information can be made among the younger generation.

Misuse of the Section 05

Interpretation of legal phrases is an issue encountered when exercising the right to information. Misuse of the Section 05 of the Act to reject the information is a common example.

Section 5 (1) of the Right to Information Act clearly defines the grounds for the denial of access to the information. As per the provisions of Section 05 of the Right to information Act, a request for information can be rejected based on the ground that the relevant information amounts to personal information.

It is fair that the information cannot be revealed when the opinion of the Attorney General is sought regarding a matter of an ongoing court case. However, the public authorities cannot misuse the section 5(1) which states that where the public interest in disclosing the information outweighs the harm, that would result from its disclosure, such information should be provided according to section 5(4).

However, if this provision is misused in a broader sense as an excuse to refrain from revealing the

requested information, then the objectives of this law will not be properly achieved. Also, when rejecting such requests, it should be clearly indicated that which subsection of the Section 05 has been taken into account. Although, the law also provides that even the personal information can be revealed for the sake of the common welfare of public it is questionable whether the authorities are making use of this provision to facilitate the requests of the public. Therefore, the public authorities should always be mindful of the fact that the rule is to disclose, while exclusion from disclosure is the exception according to Section 51 (a).

Misuse of the Section 09

RTI Act of Sri Lanka intends to promote the citizen participation in public life and for this purpose the Section 09 of the Sri Lankan RTI Act states that the relevant minister has a duty to inform the public about the initiation of the development projects above the given value, at least three months prior to its commencement. However, the Section also enables to disclose the information about urgent projects, a week prior to its commencement. This legal provision can be misused when the politicians want to cover up some scandalous projects from the public and the expected outcome will not be reaped. Therefore, when exercising the right to information in the practical sense, there are several barriers faced by the citizens as well as administrators.

Best Practices around the Globe

Even though the right to information has become a controversial in Sri Lanka recently, there have been best practices around the world over a long period of time. For an example in 1766 Sweden enacted its 'Freedom of the Press Act' from which the right to information was recognized as a fundamental right (Dokeniya,2013). In the year of 1966, Mexico launched its legislative framework enshrining the right to information (Dokeniya, 2013). When compared to the other developing regions in the world, SAARC has been keen on protecting the right to information. Countries such as Maldives, Bangladesh, Nepal and India have successfully enacted required legislation incorporating the right to information (Ackerman & Sandoval,2006). By 2024 all the South Asian

countries except Bhutan were among the top 40 according to the Global Right to Information ranking map (Kundu, 2023).

Even it is commendable that Afghanistan while going through harsh political turmoil was able to embrace the right to information through the legal provisions (Ackerman & Sandoval,2006). However, in 1990 only 13 countries had recognized right to information, yet by 2012 this escalated to 90 countries including Asian, African and Latin American regions reflecting the global revival on right to information (Freedominfo.org, 2024). In 2005 Uganda being a lower income country, enacted the Access to Information Act and the lower middle-income countries like Albania and Moldova progressed with right to information in the years of 1999 and 2000 respectively (Freedominfo.org, 2024). India has gone one step further from classical legal implications for ensuring the right to information. Specially, when addressing the citizens of grassroot level, the Black Letter Law will not suffice, and there should be a proper implementation mechanism. In the Indian context the call for right to information revolved around the slogans 'We will know, we will live' and 'Our money our account'. India has introduced Dial.gov web portal to easily access common government information (Singh, 2016).

Most interestingly through the 'RTI on Wheels' project India has been able to disseminate the knowledge on right to information (Jenkins & Goetz, 1999). Through this mobile vehicle operated by solar, battery or generator power, 3-4 volunteers can help the public for filing RTI applications, providing awareness and legal help (Dokeniya, ,2013). Through this innovative approach India has been capable of creating an educated citizen forum even in the rural areas. Also, with the collaboration of Commonwealth Human Rights Initiative, the Right to Information awareness is created by writings on the walls of public places to provide the necessary guidance to citizens as well as administrators.

Recommendations for a Strong Practice of Right to Information in Sri Lanka

Currently Sri Lanka has legally recognized the right to information through Constitution and the relevant act.

However, for its effective implementation and practice special measures are to be taken.

Adhering to the Principle of Maximum Disclosure

According to the set of global standards laid out regarding the maximum disclosure, it is expected that the right to information should be interpreted in a broader sense. By the end of 2021 the Commission had received 202 complaints on non-compliance of RTI (Annual Report, Right to information Commission, 2021). Also, according to the statistics of the Annual Report of the Right to Information Commission, 46.7% of the public authorities were at the moderately unsatisfactory level in terms of adhering to proactive disclosure of information. Therefore, if Sri Lanka also follows this maximum disclosure principle, then the right to information can be enhanced while minimizing the unreasonable denials of information.

Establishing a Strong Oversight Mechanism

For the smooth operation of the right to information, it is required to have both executive oversight bodies and independent oversight bodies. In the Sri Lankan context the essential need is an executive oversight wing and an independent oversight wing to operate in a good co-operation.

Raising Awareness in the Implementation Process

As per the Section 02 of the Right to information Act, Minister of the Ministry of the subject of mass media is responsible for the effective implementation of the Act. Therefore, the Ministry can take proactive decisions to establish public awareness by using the mass media to disseminate this message about the right to information. Currently, guidelines on Proactive Disclosures for Public Authorities have been compiled and the officers should be educated enough to follow these guidelines when answering the requests (Jayawardena, 2019).

Following Effective Records Management Techniques

Although the Act supports a strong legal backing for the right to information, the administrative structure and the officers in different levels of the government should follow an effective records management system in order to get the real use of these legal provisions. Mainly, if the records are maintained in a systematic manner, it helps to fulfill the requests of the citizens within the given timeframe. Therefore, as the Section 07 of the Act highlights, it is the duty of the public authorities to maintain and preserve their records. However, the Commission has not chosen to go for legal action under Section 39 against the non-compliance of the provisions in the Act. If sanctions are granted against the officers who have violated the Act, it will create a culture which recognizes a systematic archive and records management.

Creating a Supportive Culture from Politicians and Civil Society

It is praiseworthy that the RTI Commission has prepared a three-year strategic implementation plan with the assistance of UNDP (Jayawardena, 2019). However, for the practice of the right to information in Sri Lanka, the legal framework and the administrative support will not be sufficient. The country should embrace the right to information and create a supportive culture for safeguarding the right to information.

In Japan the legal system addresses the issues related to personal autonomy and right to information (Murata & Orito, 2008). This will be a useful practice for Sri Lanka to facilitate a robust disclosure principle without undermining citizens' other rights. Moreover, the politicians should support to uplift this right by maintaining transparency and accountability. It is important to raise Sri Lankan's awareness through the involvement of the civil organizations as well.

Training the Information Officers

According to section 24(2) of the RTI Act the information officer should assist the citizens to make an information request in compliance with the provisions of the Act. Therefore, as the law provides the information officer is expected to render a proactive role in safeguarding the right to information (Gunatilleke, 2014). Hence, the information officers and designated officers should be given an extensive training for ensuring this right (Gunatilleke, 2014). Through this Sri Lanka can combat the lack of awareness among the officers regarding RTI.

Due to the bottlenecks which provide required information, sometimes the citizens may try to deal with their requirements informally through personal contacts. This will adversely affect the equal protection of the right to information. Through training and awareness, the bureaucratic mindset of the authorities can be changed and the information requests can be accommodated without a delay.

4. CONCLUSION

When considering all the above facts it can be concluded that although there is a strong legal framework in Sri Lanka to support the right to information, still there are some barriers at the implementation level. Hence by close supervision, by oversight and harmonized approach, the institutions and public could be monitored in order to establish these legal wordings as a reality.

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IMPACT OF STEM EDUCATION IN OVERCOMING POVERTY

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ABSTRACT

Poverty in general is a state in which one lacks financial resources and essentials. Modern-day poverty is understood as a complex, multi-dimensional set of issues, introducing it in a relative manner rather than a single idea. Intellectual and ethical poverty are the two main types of poverty that are related to education, and both could be overcome by education. Mainly, intellectual poverty could be overcome by providing access to knowledge, critical thinking skills, information, and technology, while ethical poverty could be overcome mainly by social development and commitment of individuals. STEM is a teaching and learning process that combines Science, Technology, Engineering, and Mathematics and STEAM is the recent inclusion of Arts. STEM education provides opportunities for students to enhance problem-solving skills, and to become innovators, critical thinkers, and technologically literate. This study identified the definition of poverty in general and the definition of STEM education. It also identified the STEM education systems in the world and in Sri Lanka, and the methods involved in overcoming poverty through STEM education in Sri Lanka, by investigating and reviewing literature, acquiring information from specialists in the field. In Sri Lanka, industries, Research and Development (R&D), farmers, and Small and Medium Enterprises (SMEs) could be empowered with STEM education. As a result, Sri Lanka will be able to come out of the poverty cycle by increasing its purchasing power. This will lead to the socio-economic stability of the country making it move forward as a nation with sustained health, wealth, and happiness among Sri Lankans.

1. INTRODUCTION

Poverty could be generally introduced as a state in which one lacks financial resources and essentials (Goulden and D'Arcy, 2014). Nonetheless, modern-day poverty is understood as a complex, multi-dimensional set of issues (Gweshengwe and Hassan, 2020), introducing it in a relative manner rather than a single idea (Spicker, 2020). Intellectual and ethical poverty are the two main types of poverty that are related to education. Intellectual poverty is a state in which one lacks access to education, critical thinking skills, knowledge, and intellectual resources (Finger et al., 2003; Ivan, 2019). Ethical poverty refers to a state in which one lacks a strong moral compass, principles, and ethical values which are required to live in dignity, respect, and harmony with each other in a society (Barrientos et al., 2016; Schweiger, 2019).

Both intellectual and ethical poverty could be overcome by education. Mainly, intellectual poverty could be overcome by providing access to knowledge, quality education, critical thinking skills, information, and technology. However, ethical poverty could be overcome mainly by social development and commitment. Increasing the income of a person will increase his purchasing power and that will result in reducing poverty. In contrast, the ethical mindset of a person comes from the background and friends who are closely associated. Positive role models, mainly parents and teachers should become ethical in order to develop the ethical behaviors of the children. Those parents and teachers who are ethical will lead the socio-economic stability of a country. Hence, to overcome ethical poverty, the commitment of individuals, communities, and policymakers is crucial (Barrientos et al., 2016; Schweiger, 2019).

STEM is a teaching and learning process that combines Science, Technology, Engineering, and Mathematics and was an initiative by the United States National Science Foundation (NSF) in 1990 (Sanders, 2009). STEAM is the recent improvement of this aspect by adding arts to reduce the limitations of the STEM approach (Perales and Aróstegui, 2021). STEM education provides opportunities for students to enhance problem-solving skills, and to become innovators, critical thinkers, and technologically literate (Morrison, 2006; Stohlmann et al., 2011). STEM education helps to come out of the poverty cycle by working in higher-paying jobs. It also helps to reduce the gap in gender inequality by providing STEM education, especially for girls. Income, race, and gender are not considered limiting factors when it comes to STEM education. Furthermore, STEM education is more efficient when started at the early stages of education. Taking the initiative for STEM education at present itself will guarantee the building of more qualified people for the future job market and for the development of the nation (O'Rourke, 2021; Malan, 2023).

As the world is becoming more automated, most of the existing jobs are expected to be lost in near future. Hence, there is a high demand for STEM-educated people when recruiting for jobs (O'Rourke, 2021; Malan, 2023). Thus, it is important to be aware of the concepts of poverty and especially STEM/STEAM education as Sri Lankans.

This study expects to address the definition of poverty in general and the definition of STEM education. It is also expected to study the STEM education systems in the world and in Sri Lanka. Finally, it is aimed to propose the methods involved in overcoming poverty through STEM education in Sri Lanka.

2. METHODOLOGY

This study was carried out mainly through a literature survey and via personal communication. The publications used in this study were accessed via web search engines such as Google Scholar and ResearchGate. Furthermore, the Taylor and Francis Online database and abstracts and publications with open access in Springer and Science Direct were used. Keywords used in this study were "Poverty," "Intellectual poverty", "Ethical poverty", "STEM education," "STEAM education", "UNESCO and STEM", "STEM in the world", "STEM in Finland", "STEM in South Korea", and "STEM in Sri Lanka". Furthermore, the literature survey was conducted with the help of books, official websites on the internet, published newspaper articles online, and reports issued by government sectors (i.e. MoE, NSF, NIE, MoSTR, SLIC). The Ministry of Education, Sri

Lanka, provided detailed information on the current situation of STEM education in Sri Lanka. Also, the information on the impact of STEM education in overcoming poverty in rural farming communities in Sri Lanka was gathered from professionals at the Institute for Agro-technology and Rural Sciences, University of Colombo, Sri Lanka (UCIARS). In addition to this, various other data sources such as annual reports of the World Bank, OECD, and WIPO were also used.

The search was limited to English-language articles published between 2003-2023. All studies discovered throughout the search were evaluated independently for competency and inclusion. Following compliance with inclusion criteria, experimental research and data sources addressing the contribution of STEM education to poverty alleviation were integrated into the current study to provide strategies for overcoming poverty in Sri Lanka through STEM education.

Poverty

The general idea of poverty is a state in which one lacks financial resources such as socially acceptable amount of money and essentials including food, clothing, and shelter for a certain standard of living (Goulden and D'Arcy, 2014). Rather than this conventional representation of poverty, modern-day poverty is understood as a complex, multi-dimensional set of issues (Gweshengwe and Hassan, 2020). Hence, it has been introduced in a relative manner rather than a single idea (Spicker, 2020).

Several types of poverty can be identified, and intellectual poverty and ethical poverty play a major role with respect to education. Intellectual poverty is a state in which one lacks access to education, critical thinking skills, knowledge, and intellectual resources. The reasons for intellectual poverty may be the difficulty of accessing educational opportunities or may be the hindering by social and economic barriers that prevent them from gaining knowledge and skills. Limited access to education and knowledge results in individuals who lack critical thinking skills, curiosity, and creativity. This will result in difficulty in understanding and directing the complexities of society and will limit the ability of an individual to

actively participate in the development of society (Finger et al., 2003; Ivan, 2019).

Ethical poverty refers to a state in which one lacks a strong moral compass, principles, and ethical values which are required to live in dignity, respect, and harmony with each other in a society. Ethical poverty will result in a lack of honesty, respect, and fairness towards others. Unwillingness or inability to understand others' perspectives, needs, and well-being will create problems like corruption, injustice, discrimination, unethical judgments, exploitation, and environmental degradation (Barrientos et al., 2016; Schweiger, 2019).

Both the above-mentioned intellectual and ethical poverty could be overcome by education. Especially, intellectual poverty could be overcome by providing access to knowledge, quality education, critical thinking skills, information, and technology.

Besides, increasing the income of a person will increase his purchasing power and that will result in reducing his poverty. However, ethical poverty could be overcome mainly by social development and commitment. The ethical mindset of a person comes from the background and friends who are closely associated. Positive role models, mainly parents and teachers should become ethical in order to develop the ethical behaviors of the children. Those parents and teachers who are ethical will lead the socio-economic stability of a country because socio-economic stability would not take place without ethics. Hence, to overcome ethical poverty, the commitment of individuals, communities, and policymakers is crucial (Barrientos et al., 2016; Schweiger, 2019).

It is also important to consider the correlation between intellectual and ethical poverty where the occurrence of ethical poverty may be due to the result of intellectual poverty. For example, poor access to education may result in a lack of ethical behaviors of a person (Schweiger, 2019).

STEM Education

STEM education was initially called Science, Mathematics, Engineering, and Technology (SMET) and was an initiative as STEM by the United States National Science Foundation (NSF) in 1990 (Sanders,

2009). STEAM is the recent improvement of this aspect by adding arts to reduce the limitations of the STEM approach (Perales and Aróstegui, 2021). Besides, STEM is a teaching and learning process that combines Science, Technology, Engineering, and Mathematics. Rather than teaching the above subjects separately, STEM education focuses more on an integrated teaching of those subjects by interacting with the real world.

In general, STEM education provides opportunities for students to enhance problem-solving skills, and to become innovators, critical thinkers, and technologically literate (Morrison, 2006; Stohlmann et al., 2011). It was mainly established due to growing concerns that many students would fall behind or be unable to keep up in the highly competitive global economy driven by the growing need for STEM-related skills and abilities (Vasquez, 2015).

The integrated approach of STEM education could be achieved by several methods. They are multidisciplinary, interdisciplinary, transdisciplinary, and neo-disciplinary approaches. The multidisciplinary approach uses a common theme, and the subjects may be taught separately. The interdisciplinary approach uses a shared concept making the disciplines blur, while the transdisciplinary approach seeks to fully dissolve the boundaries between the conventional disciplines. The neo-disciplinary approach creates new categories of skills and knowledge networks disregarding the traditional subject boundaries (Boon Ng, 2019).

The integration of Artificial Intelligence (AI) into STEM education enhances the teaching and learning process. Due to the rapid advancement of STEM education, the integration of AI methods into STEM has been considered. AI-related subject streams such as Data Analytics, Decision trees, Machine Learning, and Neural Networks have been used to prepare high school teachers in the United States for the integration of AI methods into the STEM classroom (Lee and Perret, 2022).

Moreover, STEM education focuses on every individual relating it to the students' learning style, interests, and preferences. It emphasizes collaboration, communication, research, problem-solving, critical

thinking, and creativity. Those factors are becoming essential in the future job market. Since the world is becoming more automated, most of the existing jobs are expected to be lost. Hence, there is a high demand for STEM-educated people when recruiting for jobs (O'Rourke, 2021; Malan, 2023).

STEM in the World

STEM policies and programmes differ from country to country. Some are intended to promote a positive image of science while others aim to increase public engagement with the knowledge of science. For example, national STEM policies addressing unmet labor market demand for STEM skills (e.g., United Kingdom), national science and technology policies and plans (e.g., Japan), and national policies focused on quality education and emerging industry development (e.g., Brazil) (Freeman et al., 2019).

Freeman et al. (2019) describe the participation of students in STEM disciplines also varies by country. For the period of 2011 to 2015, the participation was highest in countries such as Finland, Germany, United Kingdom, South Korea, China, as well as Singapore. Comparatively, it was low in United States and Australia (Table 1).

Table 1: Percentage of Students Enrolled in STEM Tertiary Education Programs According to UNESCO, 2018 and OECD, 2017 (both sexes, 2011-2015). [Source: Freeman et al. (2019)]

Country	2011 (%)	2012 (%)	2013 (%)	2014 (%)		2015 (%)
Finland	53	53	52	53		54
South Korea	47	47	48	48		47
Singapore	49	47	-	-		-
Germany	-	-	46	46		46
United Kingdom	41	41	45	46		44
France	-	42	38	38		42
India	-	43	37	38		38
Australia	-	-	-	-		37
Japan	-	-	-	-		37
United States	32	32	36	36		36

According to the above data, Finland and South Korea rank first and second. In general, both countries are well-known for their education systems. Program for International Student Assessment (PISA) is an important tool for measuring education systems worldwide. Both countries obtain higher ranks in this assessment frequently. Hence, it is important to look at them in a descriptive way.

Finland is a country which has reformed their education system successfully in 1970. This system is mainly composed of equity, equal education and resources, effective evaluation, and trained teachers. Collaboration and communication are highly valued, and educators use different methods to create a collaborative environment for the students. They use methods such as blogs, social media, group work, and learning café. Personal blogs have been considered useful in getting to know the personality of each student and the educators use that information to equitably group the students in their classes (Su et al., 2017). This education system rejects any educational curriculum that includes standardized tests and educators design each school's curriculum as a group (Dickinson, 2019).

In the case of South Korea, the Korea Foundation for the Advancement of Science and Creativity (KOFAC) helps to establish STEAM education in the country. Those include reinforcing the capabilities of teachers, promoting interactive and exploratory activities for students, developing and distributing content, and institutionalizing and building infrastructure. According to a study conducted by KOFAC, the preference for science among the students who participated in STEAM classes was higher than the students who did not participate. Those activities help to increase curiosity, interest, and belief in science, and students show their willingness to perform science-related tasks, embrace the values of science, and wish to pursue a career in science (Hong, 2017; Hong, 2021).

According to the latest data, most likely to graduate in a STEM field are Malaysia and Tunisia (Figure 1) (UNESCO Institute for Statistics). Other countries with STEM graduates are United Arab Emirates, Germany, Belarus, India, and South Korea. However,

U.S. and Brazil have a fewer number of STEM graduates (Buchholz, 2023).
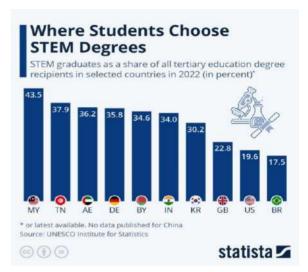
Figure 1: **STEM graduates as a share of all tertiary education degree recipients in selected countries in 2022. [Source: UNESCO Institute for Statistics]**

The United Nations Educational, Scientific and Cultural Organization (UNESCO) has identified that building capacity in STEM especially in Africa and from a gender perspective, is crucial to transform knowledge into resilience ownership to promote sustainable development. They have initiated mentorship programmes in STEM through scientific camps of excellence for secondary school girls since 2014 (UNESCO - STEM in Kenya). The UNESCO offices in Harare and Brazzaville have been equipped with 3D printers and have the facilities needed to conduct workshops utilizing online resources (UNESCO - The UNESCO Section for Innovation). Micro science experiment projects have been conducted for primary and secondary school students, and university students in countries like South Africa, Cameroon, and Norway (UNESCO - Global Micro science Experiments).

STEM in Sri Lanka

The Sri Lankan education system is well-known for its high literacy rate and provides free education for every citizen up to the university level. The conventional teacher-centered and exam-based educational model is the foundation of the current Sri Lankan educational system. However, there were problems regarding whether this system is capable of producing the

expected requirements for the future (The Sunday Times, 2021). Even more of a concern is many young people are studying for jobs that will not exist or will be gradually affected by automation in upcoming years. According to the data in 2019, the number of undergraduates enrolled in STEM and non-STEM courses varied among state universities, indicating 49% of students enrolled in STEM courses, while 51% enrolled in non-STEM courses. It was also obvious that the number of STEM graduates was less than non-STEM graduates in the years 2011-21 (Figure 2) (Subasinghe et al., 2023).
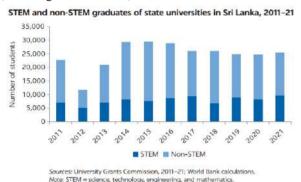
Figure 2: STEM and non-STEM graduates of state universities in Sri Lanka, 2011-21. (According to University Grants Commission, 2011-21; World Bank calculations) [Source: Subasinghe et al., 2023]

At present, STEM education in Sri Lanka has been shifted to the STEAM education system as in other countries (The Sunday Times, 2023). The "Arts" in STEAM introduces empathy, ethical values, social sciences, culture, and soft skills, and gives an added value to a human being. Since STEM disciplines all consist of logical thinking, the "A" in STEAM produces more ethical and humanistic people (Aktürk and Demircan, 2017; Başaran and Erol, 2023). The launching of the STEAM education system to the schools was officially done on 31st of March 2023, and it has been done through the cooperative effort of the Ministry of Education (MoE), National Science Foundation (NSF), and National Institute of Education (NIE), Sri Lanka (MoE, 2023; NSF, 2023).

In Sri Lanka, STEM education plays a beneficial role in enhancing teacher support for technological innovation, integrating technology into the teaching of science and mathematics, and strengthening school science and mathematics laboratories. Likewise, science clubs encourage students to publish science-related articles for local media outlets, drawing from their own observations, experiences, and analyses. Professional development programs such as the "Vidunetha" program guide school children in conducting research projects following scientific methodology and encourage them to conduct research projects (MoSTR, 2023). The Department of Science in NIE is also working on strengthening the STEM initiatives in Sri Lanka (NIE, 2023).

The National Invention and Innovation Competition which is called "Sahasak Nimavum" is held annually by the Sri Lankan Inventors Commission (SLIC) to encourage the creation of inventions in Sri Lankan citizens. Young inventor clubs, incubation centers, and patent support are also among the services of this commission. Young inventor clubs are extremely helpful for the introduction of an innovative culture among students and to popularize it among Sri Lankans. Moreover, SLIC has established two incubators at the National Engineering Research and Development Center (NERDC) and the University of Jaffna (SLIC, 2023).

Overcoming Poverty through STEM Education

Development of Industries through STEM Education

STEM-related industries have ongoing advancements and result in higher profits. Many industries which are based on science and technology are highly advantageous for people who have a STEM background. Some industries related to STEM are manufacturing, biotechnology, software development companies, and food and beverages. Hence, STEM education provides massive opportunities for starting industries (Henry, 2022).

In addition, more industries such as consulting firms, robotics, and online education platforms, green energy development companies, big data analytics companies, AI research labs, and clean energy production plants can also be started with the knowledge of STEM education. Robotics is a popular industry nowadays due to its automated solutions to common problems.

These industries develop and launch robotic products, services, and applications. Similarly, AI research labs explore and develop new technologies related to AI. They create new products and services with the help of AI (Nick, 2023).

In Sri Lanka, the University of Colombo started an Institute for Agro-technology and Rural Sciences (UCIARS) at Weligatta, Hambantota. Subjects such as Biotechnology were introduced to the rural farming community successfully through a Bachelor of Agro-tech degree. With science and technology knowledge, farmers were able to increase their income by improving their cultivations, resulting in a higher social status in the community (Vidanapathirana et al., 2012; Vidanapathirana et al., 2015). Similar efforts could be made in other industries by providing STEM education to people who are passionate about learning new technologies. That would be helpful for the development of skills, knowledge on equipment usage, and technology usage. As a result, people would be able to build new industries, increase income, and come out of the poverty cycle.

Research and Development through STEM Education

Research and development (R&D) are among the main objectives of STEM education. It connects students, teachers, universities, non-profit organizations, and private sector companies to participate in high-quality, student-driven research and development programmes. The lack of research collaboration in STEM fields was a barrier to STEM education (Ejiwale, 2013; Haruna, 2015). Hence, the recent development of this aspect is the introduction of incubators/cells.

The initiation for this programme was taken mainly by universities around the world and those university incubators help to build university entrepreneurs by providing mentorship, funding, resources, and assistance. Those university incubators are able to reduce the gap between academia and the business world by facilitating university students to start up their own small businesses through R&D (Hassan, 2020). In other words, this "cell" concept is to work with companies to develop a product that could provide more benefits to the people. Hence, R&D

should develop into a technology or release a product in order to benefit society.

In Sri Lanka, the University of Colombo also has a cell called "Colombo Science and Technology Cell". The main objective of this cell is to encourage and support Sri Lanka's manufacturing, service, and agricultural sectors through knowledge and technology transfer, scientific services, innovation, and research and development. It has developed many commercial products in Sri Lanka such as Bioclean and Mosguard (Colombo Science and Technology Cell).

According to the Intellectual Property Statistical Country Profile published by the World Intellectual Property Organization (WIPO) in 2022, Sri Lanka ranks 23rd in Asia and there were only 260 patent applications (WIPO, 2022). Hence, there is an urgent need to increase the number of innovations produced within the country. STEAM education is a great solution for that which has integrated solutions to produce an innovation culture within the country. Then, that innovation-oriented line will go up to patent levels making the country move forward.

Farmers through STEM Education

There are a number of modern technologies available in the agriculture sector to increase crop productivity and food security. Technologies such as AI and robotics play a major role in agriculture as well as in other fields. Hence, the current-day farmer is a person who is well-equipped with those new technologies. They are more like agribusinessmen who use agri-tech to enhance product quality, increase yields, and optimize production. Thus, farming has become more related to agribusiness at present (Meers, 2021).

Sri Lanka is an agricultural country, blessed with nourishing good soil, rain, and sunlight. Especially, the rural farming community has played an important role in the national economy. However, Sri Lankan farmers do not maximize their profits from agricultural products, owing to a lack of up-to-date knowledge and information. Therefore, the introduction of a new education method would be a great solution in this regard. This will result in effective knowledge, information, and technology

transfer to the farmers (Vidanapathirana et al., 2012; Vidanapathirana et al., 2015).

UCIARS at Waligatta, Hambantota has become a major institute that provides massive benefits for people who are seeking to develop their agriculture-related skills. By learning different aspects like tissue culture, biotechnology, and agriculture, young people in the farming community can build their own small businesses and become small entrepreneurs. Three programmes were introduced while promoting STEM education for the rural farming community and those include the e-Degree program with ICT, University-Farmers collaborative New Tec Transfer, and Rural Entrepreneur Development (RED) for SMEs.

There are many opportunities in the agriculture field in Sri Lanka such as compost, agricultural products (e.g., spices, fruits – banana, mangos), coconut products, and other value-added products. Developing those fields will require the import of only a few products and the majority could be produced within the country. Hence, the existing human and natural resources, blended with new technology will be helpful to alleviate the poverty in Sri Lanka.

SME Entrepreneurs through STEM Education

Small and Medium Enterprises (SMEs) play a crucial role in economies, especially in developing countries (Pandya, 2012). The development of SMEs helps to overcome poverty mainly by excluding the dependent mentality. In a country like Sri Lanka, most people have dependent-mentality-related issues. Rather than depending on loans, it is important to build their own SMEs using their skills. To overcome poverty, people in a country need to have purchasing power. That will enable them to develop their own SMEs. Since Sri Lanka have less purchasing power, this development could not be seen at present. With the help of the government in agriculture, the purchasing power of the farmers will increase and SME entrepreneurs in the farming community will arise. For example, those who have graduated with BTech degree have their own companies that could employ several people in those companies.

Sri Lankan SMEs account for over 75% of the total enterprises in the country, offering 45% of employment and contributing to 52% of the country's Gross Domestic Product (GDP). Hence, Sri Lankan SMEs play an important role in the development in the national economy. However, there are challenges in this regard in Sri Lanka such as a reduced level of science-based technological innovation, limited skills of human resources with less commitment, lack of broad-based scientific knowledge, poor implementation of policies, etc. (Piyumal et al., 2021). Hence, by overcoming those challenges, most of the problems at present SME entrepreneurs will be reduced.

3. COMPREHENSIVE EVALUATION

The first industrial revolution of the 18th century introduced the steam engine, while the second in the 19th century introduced electricity and mass production. The third in the 20th century introduced semiconductors, computing, and the use of the internet. Likewise, the current 21st century has already introduced massive, sophisticated technologies making this century move towards a digital revolution and fusion of technologies. The physical, digital, and biological subject matter has become blurred making the lines between them disappear. More unthinkable innovations in the fields of robotics, AI, 3D printers, autonomous vehicles, quantum computing, and nanotechnology are making rapid progress at present. This has made the importance of STEM education rise to meet future demands (Boon Ng, 2019).

When looking at the world, the quality as well as the student participation in STEM education varies from country to country. Countries like Finland, South Korea, and Malaysia have successfully implemented STEM education systems with different policies relevant to each country. In Sri Lanka also the launching of the STEAM education system to schools was officially done in 2023. As a result, students would be able to choose their preferred STEM field in the university and would be able to find their preferred career in the future. STEM graduates will engage in STEM careers which they have studied for a long period of time in their education. This will also prevent graduates from engaging in other fields when it comes to career choices. Besides, there is also a need to increase the awareness of the concepts of

poverty and STEM/STEAM education among Sri Lankans. With the awareness and knowledge of new technologies, the involvement of the younger generation in the agricultural and industrial sectors will increase. That would be more beneficial to the socio-economic development of the nation.

At present, there is very little involvement of the younger generation in the agricultural industry. Due to their low socio-economic level, they lack self-confidence as farmers. Changes in attitude toward the agriculture sector are therefore desperately needed, as it is a very economically viable, entrepreneurial-oriented, and high social status-gaining industry. Hence, the introduction of a new education system for farmers where they can enroll while engaging in cultivation is required (Vidanapathirana et al., 2012). STEM education would be a great solution in this regard.

With STEM education, creators and entrepreneurial youth could be developed. They would be able to work hard while taking risks and earn a significant amount of money. This will bring them out of the poverty cycle by increasing their purchasing power. It is important to produce ethical, compassionate, sympathetic, and positive-attitude people through STEM education. That is why it has changed from STEM to STEAM. The "Art" factor will be responsible in this case reducing the limitations arising from the logical thinking in STEM factors (Aktürk and Demircan, 2017; Başaran and Erol, 2023). Hence, the people stepping into society with a STEAM background would be more responsible, knowledgeable, and ethical. They would gain the respect that they need and will lead to the socio-economic stability of the country.

Our country, Sri Lanka, has many resources including human resources that could be utilized for socio-economic development. Industries developed through science and technology provide employment at all levels. When industries are developed, many sectors such as medicine, engineering, IT, legal, management, and even labor force will benefit. There is also the possibility to increase the export market, adding value to socio-economic development. Having experience in other countries, this is how a country could develop. It is a win-win situation for the country.

4. CONCLUSION

This study has examined and reviewed literature, research, and other supportive reports, and personal communication regarding the impact of STEM education in overcoming poverty. As Sri Lankans, it is necessary to be aware of the concepts of poverty and especially STEM/STEAM education because those are becoming more important in socio-economic development at present as well as in the future. The review indicates that the definition of poverty is a state in which one lacks financial resources and essentials; however, modern-day poverty is understood as a complex, multi-dimensional set of issues, introducing it in a relative manner rather than a single idea. The definition of STEM education is a teaching and learning process that combines Science, Technology, Engineering, and Mathematics and STEAM is the recent inclusion of Arts.

Countries like Finland, South Korea, and Malaysia have successfully implemented STEM education systems and the launching of the STEAM education system to the schools of Sri Lanka has been done in 2023. Empowering industries, Research and Development (R&D), farmers, and Small and Medium Enterprises (SMEs) with STEM education would be helpful in overcoming poverty in Sri Lanka.

The key outcomes of the study are:

1. Understand the definition of poverty in general.
2. Understand the definition of STEM education.
3. Study the STEM education systems in the world and Sri Lanka.
4. Identify the methods involved in overcoming poverty through STEM education in Sri Lanka.
   a. Application of STEM knowledge in skills development
   b. Knowledge on equipment usage for skills development
   c. Application of technology in SME development
   d. Removal of ethical poverty for socio-economic development
   e. Increased purchasing power

f. Establishment of a society for development of health, wealth, and happiness

5. ACKNOWLEDGMENT

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CROSS-SECTIONAL STUDY ON HEMATOLOGICAL VARIATION ASSOCIATED WITH ADVANCE CHRONIC KIDNEY DISEASE (CKD) IN A CKDu ENDEMIC AREA IN SRI LANKA

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ABSTRACT

A cross-sectional study was undertaken to investigate the etiology and disease progression in terms of CKD (chronic kidney disease)-initiation risk factors (IRF) and hematology in Nachchaduwa, a CKDu (CKD of unknown etiology)-endemic area in North Central Province of Sri Lanka. Whole blood, spot urine and risk factor history were obtained following informed consent from all medically confirmed CKD/CKDu cases in the area. CKDu was substantiated when medically accepted IRFs did not exist prior to CKD diagnosis. The disease progression stage (G1-G5) was established by kidney dysfunction markers, eGFR (MDRD, and CKD-EPI-sCr) and UACR using serum creatinine (sCr), urine creatinine (uCr) and urine (uAlb) measured in the study. Hematology variables were compared between early (G2-G3b) and advance (G4-G5) stages to reveal changes over disease progression and assessed for linear associations to disease progression in terms of kidney dysfunction markers and renal outcomes. Multivariate dendrogram and principal component analyses were utilized to study inter-variable relations. The results showed that advance disease (G4-G5) in Nachchaduwa had significantly declined RBC counts and RDW-CV, amid unchanged MCV, MCH, MCHC, hematocrit and total hemoglobin suggesting predominantly normocytic anemia. RBC depletion was further evident in its positive associations to eGFRs, and negative association to sCr ($p<0.05$, rho stronger than ±0.45). Multivariate analyses revealed that RDW-CV was following the decreasing eGFRs and uCr over disease progression. Results showed the potential utility of erythrocyte count and RDW-CV as markers of advance disease in CKDu endemic areas of Sri Lanka. IRF distribution in Nachchaduwa pointed to a minor fraction of unknown etiology among total CKD, and the major IRFs that led to chronic renal failure did not include Diabetes Mellitus.

KEYWORDS: *Red Blood Cells, Red Cell Distribution Width, Estimated Glomerular Filtration Rate, Chronic Kidney Disease, Initiation Risk Factors*

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1. INTRODUCTION

The chronic kidney disease of unknown etiology (CKDu) of Sri Lanka was first reported by Abesekara et al, (1996) in late 1990s. The disease is prevalent in a distinct climatic area of the island, known as the dry zone. CKDu is often described as epidemic since a high prevalence exceeding 30,000 reported cases were in the north central province of the dry zone alone (Ranasinghe et al, 2019). With vague distinction in practice, non-endemic CKD and CKDu coexist in the area and share the same pathology, symptoms and medical management. The difference is that etiology of CKDu cannot be described by medically accepted CKD initiation risk factors (IRFs). CKDu is presumed to be causally linked to a hitherto unidentified IRF restricted to the dry zone. Such notion may explain the geographical distribution of the high prevalence disease which is often described as endemic to the region. In this context, further characterization of the development of the dry zone disease and its risk factor history deserve attention.

Hematology variations symptomatic to the chronic renal failure in the CKDu endemic area may provide benchmarks of the disease progression. In peripheral blood of the CKD/CKDu affected in the area, significant decreases reported in total red cell, lymphocyte, platelet, and monocyte counts and increases red cell indices and basophils over disease progression (Gunawickrama et al, 2022). The knowledge gap remains notable with scarcity of further data on hematology trends in the endemic disease. The authors attempted to characterize the disease in the area by following blood cell counts and indices over the entire length of the disease progression, in concert with initiation risk factor history. Nachchaduwa is a typical area of CKDu endemicity in the North Central Province, and it shared the same climate, demography and socioeconomics with the rest of the CKDu endemic area of the island. The study involved all CKD/ CKDu affected people in the village. The participants were field farmers or their family members who relied on irrigated water from a nearby reservoir, for vocational rice cultivation.

2. METHODOLOGY

The households of individuals who had already been medically diagnosed with chronic kidney disease were visited in Nachchaduwa area (8°14'38.0"N+80°27'37.0"E) of the North Central Province in Sri Lanka. The chronic renal failure was verified from the medical records in possession of the affected as the village community provided locations of such households. Following informed consent and on volunteer basis, each subject answered a questionnaire on their own history of CKD initiation risk factors (IRF) and demography. Subsequently at a center, the same participants provided a whole blood (3-4mL), and spot urine samples.

Subject Interview

IRF were followed as put forward by the National Kidney Foundation of USA (Levey et al, 2005). IRF existed prior to initial diagnosis with CKD was gathered individually by interview and from medical records where available. Data were collected by a medical practitioner.

Samples, Initial Processing and Analyses

Blood cell counts and RBC-indices including total RBC, hematocrit, total hemoglobin, MCV, MCH, MCHC, red cell distribution width-coefficient of variation (RDW-CV) total WBC, and the counts of lymphocytes, platelets, neutrophils, eosinophils, basophils, and monocytes were obtained from EDTA-whole blood with an automated hematology analyzer (HumaCount 5 L, Wiesbaden) on the same day. Samples were transported on ice to a commercial medical laboratory for the purpose. At the center, fraction of whole blood was allowed to clot before serum was separated by centrifugation (room temperature, 3000 *g* for 10 min) for determination of serum creatinine (sCr; mg/dL) by colorimetry. Urine albumin (uAb; mg/L) and urine creatinine (uCR; mg/dL) were determined by immunoturbidometry (Bakker, 1988) and Jaffe method (Jaffe, 1886) respectively. Serum and urine samples were delivered on dry-ice and biochemical determinations were made with a Mindray BS-200 clinical chemistry analyzer (Shenzhen) at a commercial laboratory in compliance with the QC guidelines and using reagents of the manufacturer.

The kidney dysfunction markers, estimated glomerular filtration rate (eGFR in mL/min/1.73 m^2) using sCr by the equations, chronic kidney disease epidemiology collaboration (CKD-EPI), and by abbreviated modification of diet in renal disease (MDRD) (Inker et al, 2012; Levey et al, 2003) were calculated. Urine albumin to creatinine ratio (UACR, mg/g) was determined using urine albumin (mg/L) and urine creatinine (mg/dL). All counts and determinations were made for each subject of the study.

Subject Sorting

Individual eGFR< 60 in the study (CKD-EPI; sCr equation) and prior medical diagnosis were considered confirmatory of CKD/CKDu. Participants with higher eGFR were considered to be CKD/CKDu when medical diagnosis was available. This was followed by sorting into CKD stages from G1 to G5 as outlined elsewhere (National Kidney Foundation, 2002). Stages G4 and G5 (ESRD) were considered to be the advance disease. CKDu was presumed when CKD initiation risk factors were absent in own medical history prior to the chronic renal failure (Levey et al, 2005). G1 subjects were not identified in the study. Notably, recruited participants (n=23) were vocational paddy farmers or their family members in total.

Statistical Analyses

The erythropoietin administered and the dialyzed were not recruited. Univariate analyses were performed following log$_{10}$ transformation of data for approximation of normality. Variables were compared between early (G2-G3b) and advance disease (G4-G5) stages by student's t-test to reveal differences (p<0.05) over disease development. Pearson's correlation analysis was conducted to identify linear associations of blood cell counts and indices with kidney dysfunction markers (eGFRs, and UACR) and other renal outcomes of the study (sCr, uCr, and uAlb). An association was considered when correlation coefficient (*r*) was stronger than ±0.4 and at p<0.05. Multivariate cluster dendrogram involving complete linkage and correlation coefficient distance was developed, and principal component analysis (PCA) by correlation-based matrix was performed to visualize nonlinear relations among selected variables. Hematology variables measured in the study, which showed a Pearson's *r* stronger than ±0.2 with any of eGFRs, UACR, sCr, uCr, or uAlb were selected for

multivariate analyses. Weight and body mass index (BMI) were included as well on their symptomatic relation to CKD progression. All analyses were conducted in Minitab 17 software program. The study was conducted under ethical approval (RP/2017/03) from the ethical review committee at Faculty of Medicine, General Sir John Kotelawala Defence University.

3. RESULTS

CKD progression in to advance stages (G4-G5) significantly decreased (p<0.05) red blood cell count (RBC; 10^6/µL) and red cell distribution width-coefficient of variation (RDW-CV; %) as compared to initial G2-G3b stages of the disease (**Figure 1**). Linear correlation analyses showed that total RBC counts from stages G2 to G5 were in a positive association with eGFR by both CKD-EPI; sCr and MDRD (r=0.5, p<0.05), and in a negative association (r= -0.4, p<0.05) with sCr (**Figure 2**). Results collectively suggest anemic tendency towards advance stages. However, total hemoglobin and RBC-indices such as MCV, MCH, MCHC were not associated (p>0.05) to progressive kidney dysfunction. Disease progression over stages G2-G5 resulted in increasing total WBC and lymphocyte counts (**Figure 3**).
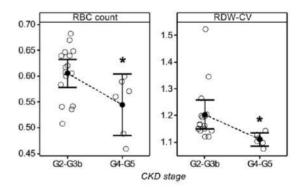
Figure 1 Variation of red blood cell count (10^6/µL) and red cell distribution width - coefficient of variation (%) as CKD/CKDu progresses into advance stages in Nachchaduwa

Log$_{10}$ transformed data were compared between CKD initial (n=16) and advance stages (n=6), and plotted on linear scale as mean, 95% confidence interval for the mean, and individual values.

* p<0.05 (student's t-test)
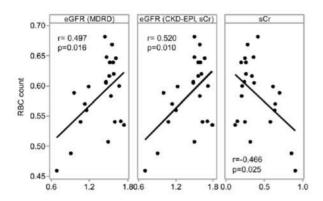
Figure 2 RBC associations with progressive kidney dysfunction in Nachchaduwa

Log$_{10}$ transformed data of RBC count (10^6/µL) and serum creatinine (mg/dL), and eGFR (mL/min/1.73m^2) were tested by Pearson's correlation, and plotted in linear axes (n=22).
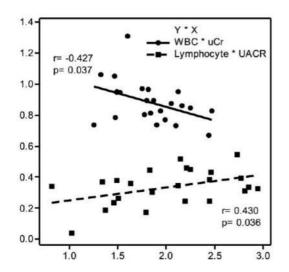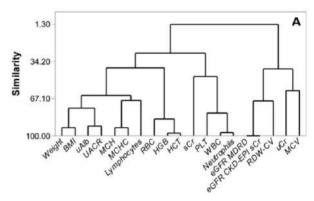
Figure 3 Leukocyte associations with progressive kidney dysfunction in Nachchaduwa

Pearson correlations of WBC count (10^3/µL) with urine creatinine (mg/dL), and lymphocyte count (10^3/µL) with urine albumin to creatinine ratio (mg/g) are shown. Data were log$_{10}$ transformed before analyses and plotted in linear scale (n=22).

RDW-CV showed a close relation with progressive kidney dysfunction (eGFRs) as indicated in both dendrogram (similarity; 69.2%, **Figure 4A**), and PCA

(**Figure 4B**). Tendencies of the platelet, neutrophil and total WBC counts to follow sCr were evident as well.
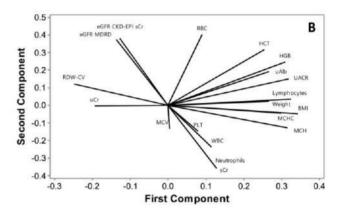
Figure 4 Red cell distribution width was related to eGFR during progressive kidney dysfunction in Nachchaduwa (n=23); A) cluster dendrogram, and B) loading plot of principal component analysis

Most of the CKD/CKDu patients in the study reveled one or more IRF that existed prior to initial diagnosis (**Table 1**). Hypertension remained the most predominant by percentage (60.9%) within the study population, as family history of nephropathies (56.5%) was a major IRF as well. Dyslipidemia (39.1%), systemic infections (malaria mostly of multiple episodes; 26.1%) and urological disorders (21.7%) such as urinary stones and recurrent urinary tract infections were notable.

Table 1 CKD Initiation Risk Factor (IRF) History of the participants of Nachchaduwa

IRF	% from total CKD
Diabetes mellitus	8.69
Hypertension	60.9
Autoimmune diseases	0
Cardiovascular diseases	0
Systemic infections; malaria	26.1
Systemic infections; leptospirosis	4.3
Dyslipidemia	39.1
Acute kidney injury	0
Urological disorders/ urinary stones/ urinary track obstructions/ recurrent urinary tract infection	21.73
Family history of CKD/ nephropathy	56.5
Drug toxicity	4.3
Snake bites	4.3

n=23 with many reporting more than one IRF

Less than 10% the participants in the study reported diabetes mellitus, the systemic infection; leptospirosis, drug toxicity, or snake bites as suspected IRF prior to diagnosis with the chronic renal failure. Minority of CKD subjects did not confirm prior presence of IRF suggesting that the fraction of unknown etiology (CKDu) among total CKD could be about 8% in the Nachchaduwa which is considered to be within CKDu endemic zone of the country.

4. DISCUSSION

Prior medical records of diagnosis and management were used to verify the chronic renal failure. The disease was further verified before recruitment using individual kidney dysfunction marker levels, eGFR (<90 mL/min/1.73 m^2) and UACR (>30 mg/g) measured in the present study. It resulted in recruitment of twenty-four CKD/ CKDu cases from inhabitants in Nachchaduwa village into a study group irrespective of non-proteinuria. All of them participated in the study. Moderate sample size of the verified chronic renal failure cases remains a limitation. However, data analyses essentially reproduced what has been reported from CKDu endemic North Central and Uva provinces of the country and elsewhere in relation to hematology and risk factor profiles pertaining to the chronic renal failure, in terms of the onset of anemia (Dmitrieva et al, 2013; Gunawickrama et al, 2022) and hypertension as a more dominant IRF than diabetes mellitus (Gunawickrama et al, 2020) in the endemic area. A true control of renal health is difficult to be constituted from CKDu endemic areas of the country. For that reason, data were compared between early (G2-G3b) and advance (G4-G5) stages of the chronic kidney disease and variations with the disease progression were followed accordingly.

PCA and cluster dendrogram were essentially used to reveal inter-variable relations among hematology, kidney dysfunction, and renal outcomes. The stringency was maintained by including only the variables that had a linear association (*rho*) stronger than ±0.2 with the disease progression.

Significantly declined (p<0.05) RBC count and RDW-CV in advance G4-G5 CKD stages as compared to early G2-G3b stages (**Figure 1**) could be considered as indicative of CKD associated anemia. RDW-CV indicates erythrocyte size variation, and its decrease mostly suggests hampered RBC production. Declining of the RBC count in advance stages (**Figure 2**) points to an increasing incidence of anemia in the study group as the chronic renal disease progresses, and as reported before (Dmitrieva et al, 2013). In participants, MCV, MCH and MCHC as well as hematocrit and total hemoglobin were neither changed (p>0.05) between early and advance stages nor correlated to disease progression, in terms of eGFR, UACR, sCr, or uCr. Further, the MCV remained within its normal range, 80-100fL (Bessman and Johnson, 1975) in 86% of the participants. Solak et al (2013) reported an unchanged MCV across stages G1-G5 involving 309 CKD patients. In such context, the results may collectively be considered as suggesting that renal malfunction induced anemia in Nachchaduwa could predominantly be normocytic.

Anemia is multifactorial in CKD (Portolés et al, 2021). Solak et al (2014) reported, anemia may emerge as early as stage G1 (>40% total CKD cases) and grow further in incidence as the disease progresses to end-stage renal disease (G5; ESRD) notably with a fraction showing low RDW-CV (<14%). It suggests

other routes to anemia in CKD as well. Normocytosis was shown to be the most common morphologic form in anemia in CKD (Mohammed and Mahmood, 2022) and its proportion increases as the disease progresses (Dmitrieva et al, 2013; Gluba-Brzózka et al, 2020). RDW-CV drop at G4-G5 of CKD/CKDu in the present study was notable. Low RDW occurs in CKD and other chronic illnesses (Hsieh et al, 2016; Tonelli et al, 2019) as certain authors report an increase as CKD progresses (Lu et al, 2017; Yonemoto et al, 2018; Roumeliotis et al, 2020). In a correlation study with anemic CKD patients, Emans et al (2011) reported that low RDW associated weak erythropoiesis and dwindling reticulocyte fraction. In such context, decreased RDW could mean hampered erythropoisis in Nachchaduwa study participants of chronic renal failure.

Increasing WBC and lymphocyte counts towards advance CKD stages in relation to uCr and UACR variations (**Figure 3**) and the relation of WBC and neutrophils to sCr (**Figures 4A, 4B**) could perhaps be linked to oxidative stress and chronic inflammation which understandably drive initial CKD towards ESRD (Oberg et al, 2004; Tucker et al, 2015).

The health, genetic, environmental, demographic or other factors that could be causal to initial renal damage of the chronic kidney failure are envisaged as CKD initiation risk factors (IRF). The geographical distribution of high-prevalence CKD that is commonly described as CKDu in dry zone of Sri Lanka is presumed by the present authors, to be linked to one or more hitherto unidentified risk factors limited to the same area. On the other hand, such proposition could explain the geographical delimitation of the disease as well. CKD is cosmopolitan and initiated by established IRF (Levey et al, 2005). The authors believe investigation into the individual risk factor history prior to chronic renal impairment may reveal obscure IRFs operating in the area. Literature on IRFs that could explain endemic CKDu in the dry zone of Sri Lanka appears to be scarce with exceptions that linked the disease to genetic predisposition (Wanigasuriya, 2012), agrochemical usage & paddy farming (Wimalawansa, 2014), metal exposure (Gunawickrama et al, 2022) and hydrogeochemistry &

drinking-water (Chandrajith, 2011). Search for unconventional IRF operating in the area is also the key to reveal etiology relations of CKDu, establish its frequency among total CKD in the dry zone, and for disease migration. Nachchaduwa CKD/CKDu population had only a minority (8%) whose disease could not be traced back to a conventional IRF hence CKDu. Present study points to the uncontrolled hypertension as the major conventional IRF in Nachchaduwa village (**Table 1**). The results are consistent with previous report (Gunawickrama et al, 2020) where hypertension was reported as a major IRF in both CKDu endemic Padaviya (31% total CKD) and Girandurukotte/ Madawachchiya (38% total CKD). Diabetes Mellitus has been reviewed as the dominant cause of CKD initiation internationally (Kazancioglu, 2013). In Sri Lanka dry zone however, IRFs such as hypertension, and systemic infections (multiple episodes of Malaria and Leptospirosis in particular), family history of nephropathy could be the leading causes of CKD.

5. CONCLUSION

The limited statistical power was a constraint in the present study. However, entire CKD/CKDu population was studied in Nachchaduwa which is endemic to CKDu and data were in general agreement with prior reports. The participants were comparable in demography so that confounders were minimal supporting results and conclusions. Results pointed to a predominantly normocytic anemia. Red cell count and RDW-CV followed kidney dysfunction and eGFR. It is suggested that fraction of unknown etiology among total CKD could be a clear minority in the area, and the major IRFs that led to chronic renal failure did not include Diabetes Mellitus.

6. ACKNOWLEDGEMENTS

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UNMANNED AERIAL SYSTEMS IN SRI LANKA: AN OPERATIONAL FRAMEWORK FOR LAND-BASED AIR OPERATIONS

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ABSTRACT

The Nagorno-Karabakh war in 2020 demonstrated the unprecedented paradigm shift in aerial warfare, with the Azerbaijan military successfully employing attack Unmanned Aerial Systems (UAS), commonly known as drones, to destroy enemy troops and defence systems. This study underscored the importance of comprehending and keeping up with the evolving trends of drone operations in the security realm. The study addressed the knowledge gap by providing valuable insights into defining an operational framework and integrated approach for drone operations in Sri Lanka. It emphasized the importance of aligning drone utilization with a defined operational framework to achieve favourable outcomes in military engagements. The conceptual framework is based on the review of theoretical studies. Besides, the study established a statistical association between the integrated approach and the employment of drones in the security realm, highlighting the significance of collaboration between different state agencies and the military. The study resorted to mixed-method research while conforming to a survey strategy. Primary data was collected through questionnaires and interviews, while secondary data was collected from literature and doctrines. The study explored that the operational framework must be based on purpose, time, space, and resources in the land and maritime domains. Further, centralised command and integrated operational environment must be established while enhancing collaboration in research and development projects to advance the drone industry in the country.

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1. INTRODUCTION

In the new millennium, formidable militaries vigorously develop drone technology and enhance their arsenals. Simultaneously, multinational corporations also utilize drones for multiple purposes, aiming to lower human involvement (Priyamal, 2022). Therefore, Sri Lanka needs to gain insights and keep pace with these evolving trends to progress alongside the contemporary world. It is noteworthy to write that in the post-conflict era, limited attention has been given to enhancing the country's military capabilities. Drones have no exemption, either. Therefore, it is imperative to comprehend and study the applicability and significance of drone operations in current and future warfare. This understanding will enable the necessary reforms in the country's force structures to align them with the evolving trends in drone technology. Besides, using drones in the maritime domain would provide a solid basis for addressing existing gaps, such as reach and required capabilities.

Background of the Study

The Nagorno-Karabakh War in 2020 symbolised an unprecedented paradigm shift in aerial warfare. Azerbaijan successfully gained complete control of the skies against Armenia within the six-week war, utilizing attack drones at a relatively low cost. Hunting and eliminating ground troops has become easier than ever before, and it is, too, at a significantly lower economy of effort (Detsch, 2021).

Figure 1. Azerbaijan drones attacking Armenian tanks Source: EurasiaNet (2020)

Further, the widespread use of drones has facilitated targeting troops hiding inside trenches in mountainous areas (Dixon, 2020). This accessibility of drones has demonstrated their effectiveness in targeting enemy troops, tanks, and air defence systems compared to conventional manned fighters (Ahmad, 2022; Priyamal, 2022).

According to Wijetunge and Wanasinghe (2021; 2023),drones have emerged as a dominant force on the modern battlefield, presenting a glimpse into the future of warfare. Therefore, it becomes imperative to thoroughly examine and articulate the various pathways of drone operations within the context of the Sri Lankan security landscape within the land domain.

Statement of the Problem

Drones have witnessed an unprecedented increase worldwide in the second decade of the new millennium. Wijetunge and Wanasinghe (2021) emphasized the widespread adoption of drones by state and non-state actors due to their cost-effectiveness and relatively simple technology. The Sri Lanka Air Force (SLAF) and Sri Lankan Army (SLA) have also recognized the importance of employing unmanned aerial vehicles (UAVs) in security operations and enhancing its capabilities for future applications. However, researchers learned that collaboration or a unified mechanism currently needs to advance drone operations in the country.

Following the Nagorno-Karabakh War in 2020, notable armies, including the US and Britain, have developed a school of thought regarding drone operations (Priyamal, 2022). Detsch (2021) and Dixon (2020) argued that off-the-shelf air power would undergo significant changes and dominate future battlefields. Therefore, the researcher has concluded that keeping pace with the evolving warfare dynamics is crucial to avoid the predicaments of small militaries in developing economies, which could have detrimental effects on national security. Thus, it is imperative to discover the roles that drones can play in the security realm of Sri Lanka, including the maritime domain. However, this study mainly focuses on land-based air operations.

Despite the increasing prominence of drones in

security, there is an apparent absence of empirical studies exploring the practical application of drone operations in this context. This knowledge gap hinders the development of informed strategies and guidelines for utilizing drones optimally in security operations. Therefore, this study aims to address this gap by laying a foundational basis to explore the determinants of practical drone applications within the security landscape and their empirical associations. By doing so, it seeks to provide valuable insights and contribute to advancing practical and evidence-based approaches to implementing drones in security operations.

Research Questions

What air power roles can drones execute in the country's security operations within the land domain?

How to define an operational framework for drone operations in Sri Lanka's land domain?

What are the empirical associations between the employment of drones in the security realm and operational framework and an integrated approach?

Research Objectives

To explore air power roles that drones can execute in the country's security operations within the land domain.

To define an operational framework for drone operations in Sri Lanka's land domain.

To examine empirical associations between the employment of drones in the security realm and operational framework as well as an integrated approach.

Significance of the Study

This study offers valuable insights into the strategic development of an operational framework for the military utilization of drones in Sri Lanka. Establishing a well-planned, thoroughly forecasted, and efficiently organized mechanism is indispensable

in this regard. The findings of this study will guide the implementation of an effective operational mechanism for the development, deployment, and utilization of drones in security operations within the land domain of the country. Researchers learned that no literature has been found concerning the operational framework for drone operations. Therefore, this will certainly add new knowledge to the existing limited literature and will help to bridge the knowledge gap.

Scope of the Study

The study mainly focuses on the application of drones in the security landscape of Sri Lanka. Besides, it involves exploring the roles and potential uses of drones for addressing security challenges in the country that encompasses land-based air operations. Thus, maritime security related air operations have not been discussed deeply. Hence, research has limited the scope to SLA and SLAF as the two principal drone operators in the country's land-based air operations.

2 METHODS

This section presents the methodology that supported the conceptual framework, the population, the sampling technique, the sample size, data analysis tools, etc. Besides, the researcher formulated hypotheses related to the study and subsequently discussed how these hypotheses were tested and data analyzed. The research design of the study was as follows.

Research Approach- The study was based on a deductive approach to test hypotheses and correlations.

Research Choice- The exploratory study employed mixed-method research.

Research Philosophy- The researcher used interpretivism as the study philosophy to interpret the reasons and meanings of the observed phenomenon.
Research Strategy- The study resorted to a survey strategy in view of exploring the views of Subject

Matter Experts (SME) on drone employment in Sri Lanka's security operations in the land domain.

Time Horizon- Cross-sectional time horizon was employed.

Technique and Procedure- Data collection and analysis are the techniques and procedures of the study. Primary data were collected through self-administered questionnaires and expert interviews, while secondary data were collected from previous research, journal articles, news, and web articles, as well as air power doctrines of regional/global Air Forces.

Conceptualisation

The schematically derived conceptual framework has reflected the prospects of the researchers. This study is structured around three research objectives and is designed to align with a deductive approach. Through an extensive review of the literature, a conceptual framework has been developed to guide the identification and testing of research hypotheses as well.
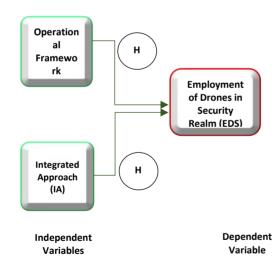
Figure 2: Conceptual framework
Source: Author (2024)

Operational Framework: The operational framework serves as a cognitive tool utilized by Commanders and staff to effectively visualize and articulate the application of combat power in terms of time, space,

and purpose, with available resources during operations (US Army Doctrine, 2017; Priyamal, 2022). Successful employment of drones on par with the operational framework resulted in favourable outcomes for Azerbaijan's military in the Nagorno-Karabakh war (Destch, 2021). Thus, researchers explored that operational framework has a significant relationship with the employment of drones in the security realm.

Integrated Approach*:* Land forces rely on joint, inter-agency, and multinational relationships to effectively carry out military activities. The SLAF and Army have acquired small-scale drones to support civil and law enforcement agencies (Joseph, 2021). Priyamal (2022) has concluded that a joint approach to the application of drones in security operations exhibits a positive correlation. Therefore, researchers discovered that a significant relationship prevails between the integrated approach and the employment of drones in the security realm.

Employment of Drones in the Security Realm: The application of air power in three distinct situations categorised as peace, crisis, and war (SLAF Doctrine, 2022; BAF Doctrine, 2014). Land operations in peacetime involve two types of operations such as combat stability and Military Aid to Civil Authority (MACA) (British Army Land Operations, 2010). Consequently, the researchers have identified that the employment of drones should be done following the aforementioned operations.

Hypotheses

Researchers have devised three hypotheses based on the conceptual framework and identified variables.

H_1 : A significant relationship exists between the operational framework and the employment of drones in the security realm.

H_{1_0} : No significant relationship exists between the operational framework and the employment of drones in the security realm.

H_2 : A significant relationship exists between the integrated approach and the employment of drones in the security realm.

H_{2_0} : No significant relationship exists between the integrated approach and the employment of drones in the security realm.

Operationalisation

Table 1: Operationalisation

Variable	Indicator	Measurement
Demographic	Gender Age Service Experience in the Drone field	Nominal scale Ordinal scale Nominal Ordinal scale
Operational framework	Time Space Purpose Resources	Nominal scale Ordinal scale Ordinal scale Ordinal scale
Integrated approach	SLA operators SLAF operators Police State agencies	Ordinal scale Ordinal scale Ordinal scale Ordinal scale
Employment of drones in the security realm	Combat stability Peace support Humanitarian Assistance and Disaster Relief (HADR) MACA	Ordinal scale Ordinal scale Ordinal scale Ordinal scale

Source: Author (2024)

Population

Population of research refers to any group of people or objects that are the subject of study in a particular survey (Sekaran and Bougie, 2016). Researchers identified drone operators of the SLA/SLAF, decision-makers in drone operations, and entities that utilize drone information as the most appropriate individuals to obtain first-hand information about operational engagements. Thus, the population consisted of individuals at the operational and tactical levels concerning drone operations within SLA and SLAF.

Therefore, researchers considered the study population as the sum of five strata: Officers/Soldiers from the 15th Drone Regiment (100), Directorate of Operations (05), Directorate of Military Intelligence (05), Commando Officers from the anti-hijack unit (25), and drone pilots of the SLAF (35) (SLA, 2022; SLAF, 2022). Hence, the total study population (N) is considered to be 170 individuals (100 + 05 + 05 + 25 + 35).

Sampling Technique

A sample is a subset of the population and comprises only a few elements from the entire population. Besides, identifiable subgroups within the population may be expected to have different parameters for a variable of interest (Sekaran & Bougie, 2016). Therefore, the researchers have chosen simple random sampling and stratified sampling techniques.

This involved the process of determining the sample size and stratification and subsequently selecting subjects randomly from each stratum. The stratum was identified as described in the preceding paragraph, namely Drone Regiment Officers/Operators (n_1), Officers from the Directorate of Operations (n_2), Officers from the Directorate of Military Intelligence (n_3), Commando Officers from the anti-hijack unit (n_4), and drone pilots of the SLAF (n_5).

Sample Size

Researchers used the Morgan table to define the sample size from the population (Krejcie & Morgan, 1970). Since the study population size was 170 (N), the sample size (n) was derived as 118 following the Morgan table. Therefore, researchers used the following equation to derive the sizes of strata, respectively n_1, n_2, n_3, n_4, and n_5 (Doane and Seward, 2008).

$$n_i = (n/N)N_i$$
$$\therefore n_1 = (118/170)100 \approx 70$$
$$\therefore n_2 = (118/170)05 \approx 3$$
$$\therefore n_3 = (118/170)05 \approx 3$$
$$\therefore n_4 = (118/170)25 \approx 18$$
$$\therefore n_5 = (118/170)35 \approx 24$$

Data Collection and Analysis - Primary data were collected using a self-administered questionnaire and semi-structured interviews. Researchers extracted expert views from top brasses in regional AFs such as India, Bangladesh, and Pakistan. Doctrines, journal articles, conference proceedings and books were contributed in secondary data. Quantitative data were analysed using SPSS 27, whilst thematic analysis was employed as the tool for the qualitative data analysis. Interview data were coded using the open coding technique where the redundant codes were omitted whilst five themes were derived and presented hereto. Furthermore, the researchers have conducted reliability tests, validity tests, descriptive statistics, bivariate analysis, correlation analysis, and regression analysis concerning the study. The confidence level used for the analyses was 95%, and the precision value was 5%.

3 RESULTS

This section elucidated the findings of the analysis and the results derived from the questionnaires and interviews. Subsequently, hypotheses are tested and discussed, along with the impact of independent variables (IVs) on the dependent variable (DV).

Findings

The researchers collected data from 110 respondents, resulting in a response rate of 93%. The reliability test results indicated a Cronbach's Alpha value of 0.89, suggesting that the results could be generalized up to 89%. The KMO value of 0.657 indicated that the sample size was adequate for conducting a factor analysis and generalizing the results. Furthermore, the skewness values of all variables were within the accepted range of -0.5 to +0.5. Moreover, the normality test results indicated a normal distribution.

Table 2: Reliability statistics

Cronbach's Alpha	N of Items
.780	23

Source: Author (2024)

Demographic data revealed that the majority (58%)

of respondents are within the age limit of 30-35 years. Further, more than 64% have engaged in drone operations between 0-5 years. Thus, it was explored that the majority of the sample have considerable experience in drone operations.
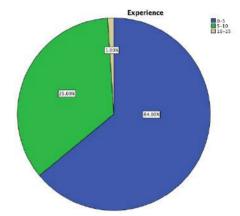
Figure 3. Experience in drone operations
Source: Author (2024)

Table 3: Association Analysis
Source: Author (2024)

		EDS	OF	IA
EDS	Spearman Correlation	1	.588**	.525**
	Sig. (2-tailed)		.000	.000
	N	110	110	110
OF	Spearman Correlation	.588**	1	.317**
	Sig. (2-tailed)	.000		.001
	N	110	110	110
IA	Pearson Correlation	.525**	.317**	1
	Sig. (2-tailed)	.000	.001	
	N	110	110	110

All the IVs exhibited a positive correlation with the DV, with p-values below the significance level of 0.05. It is important to note that in all cases, the Spearman correlation coefficient (r') values ranged from 0.5 to 1, indicating a strong relationship (Richard 1990; Sekaran and Bougie, 2016). Spearman correlation was considered since the study examined associations between ordinal variables (Saunders et al., 2018). Therefore, it is statistically

evident that strong relationships exist between the IVs of OF and IA with the DV of EDS.

The tolerance and Variation Inflation Factor (VIF) values obtained from the multicollinearity test confirmed that there was no risk of multicollinearity, indicating that the data was suitable for conducting multiple regression analysis. The tolerance values were above 0.2, and the VIF values were below 5. Besides, the minimum and maximum values of the standard residual statistic suggested that no outliers were present in the collected data. Furthermore, the ANOVA table indicated that the regression model provided a moderately good fit for the collected data.

Table 4- Collinearity Statistics

Model		Collinearity Statistics	
		Tolerance	VIF
1	OF	.892	1.121
	IA	.779	1.283
a. Dependent Variable: EDS			

Source: Author (2024)

Hypotheses Testing

In accordance with the aforementioned correlation analysis, hypotheses testing was done to test the relationships between IVs and DV.

Table 5: Association between IVs and DV

	EDS	OF	IA
Spearman Correlation	1	**.588****	**.525****
Sig. (2-tailed)		.000	.000
N	110	110	110

Source: Author (2024)

H$_1$: A significant relationship exists between the operational framework and the employment of drones in the security realm.
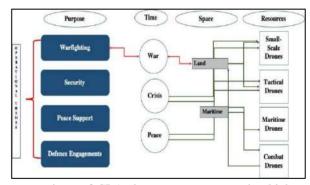
According to the respondents, a strong positive relationship prevails between OF and EDS. Further, the correlation coefficient of 0.588 with a p-value of 0.000 (P<0.05) signified that statistical evidence proved that **H$_0$ is rejected and H$_1$ is accepted** at 5% level of significance. Hence, it is implied that there is a positive relationship between the OF and EDS.

H$_2$: A significant relationship exists between the integrated approach and the employment of drones in the security realm.

It was found that a strong positive relationship prevails between IA and EDS. Further, the correlation coefficient of 0.525 with a p-value of 0.000 (P<0.05) signified a strong relationship between the two variables. Thus, **H$_2$ is accepted and H$_0$ is rejected** at 5% significance level. Hence, it is implied that a positive relationship exists between JAI and EAD.

Interview Results

Operational Framework. SLA is currently operating small-scale drones with limited operational capabilities since 2016 (Priyamal, 2022). However, there is a lack of a specific operational framework for drone operations in the country. Thus, it is necessary to define an operational framework that takes into account aspects such as time, space, purpose, and resources, while providing insights on operational themes, including warfighting, security, peace support, and defence engagements. The future

expansions of SLA drone engagements should be tailored to operate across all operational themes.

Figure 4. Operational framework for drone operations in Sri Lanka Source: Author (2024)

Integrated Approach. Interview results suggested that an integrated approach would be beneficial to boost the research and development of drone programmes according to the national requirement. In this regard, SLA, SLN, and SLAF as well as other agencies such as Police, Customs, Wildlife, Forest Department etc. and universities

must work collectively. Further, establishing an integrated drone research and development center for that purpose would be a better option.

Types of Drone Operations. Drone operations supporting land operations can be done by upgrading existing assets though necessary to acquire new platforms equipped with optimum Infra-Red (IR) and camera sensors to operate in the maritime domain. Drone operations in Sri Lanka mainly can be split into two tiers such as land and maritime operations. However, current capacities and capabilities are insufficient to cater to these demands owing to the non-availability of assets (Wijetunge and Wanasinghe, 2022; Priyamal, 2022).

Centralised Command. SLA operators are still novel to the operational context and necessary to be aware of other considerations that are compulsory for a flight of an aircraft within Sri Lankan airspace. A centralized command post is necessary to log down all the drone requirements of SLA and SLAF as well as other agencies such as the Police, Customs, Wildlife, Forest department, etc. This operations center must be under the operational command of SLAF since airspace management directly comes under the purview of SLAF. Hence, establishing an integrated drone operations monitoring cell that is equipped with an essential communication network is pivotal.

Research and Development.

Research work must be aimed at developing ISR, capabilities and attack drones. Hence, SLAF and SLA collectively need to continue R&D work with respect to developing drones compatible with conducting ISR and attack operations. The main challenges in this regard are developing drone engines, data links, IR optical and highly sensitive cameras and other sensors. Foreign assistance may be necessary to avail given acquiring technical know-how. Wijetunge and Wanasinghe (2022), underscored that air diplomacy can be leveraged to acquire technical know-how from foreign-friendly Air Forces. Therefore, SLAF can employ air diplomacy to advance its R&D capacities through air diplomacy.

Attaining Research Objectives

To explore air power roles that drones can execute in security operations of the country within the land domain. The study found that principal air power roles, such as ISR (Intelligence, Surveillance, and Reconnaissance) and attack, can be employed. However, neither SLA nor SLAF has this capability and is unlikely to develop in coming years owing to the absence of external threats. Currently, ISR operations can be employed in the land and maritime domains, though there is a need to enhance capabilities and capacities specifically for maritime operations. These roles will greatly benefit state authorities such as the police, wildlife, forest, and customs departments. It is also important to adhere to air traffic control (ATC) and air defence (AD) instructions to operate within Sri Lankan airspace. Therefore, establishing an integrated operational environment would address issues related to flight safety and air defence.

To define an operational framework for drone operations in Sri Lanka's land domain.

The findings indicate that currently, the SLAF and SLA are operating in isolation when it comes to drone operations. Therefore, it is necessary to establish a joint drone operations monitoring cell equipped with a robust communication network to ensure effective and timely communication, as well as to prevent unauthorized drone operations. The authors suggested that the SLA, SLN, SLAF, Police, Wildlife, Forest Department, and Customs must work collectively, taking into consideration factors such as time, space, purpose, and available resources. Besides, the SLAF and SLA should collaborate on research and development efforts to develop drones that are capable of conducting ISR and attack operations, subject to the necessity. Based on these findings researchers have designed an operational framework that is illustrated in Figure 4.

To examine empirical associations between the employment of drones in the security realm and operational framework as well as an integrated approach.

Quantitative data analysis illustrated that operational framework and integrated approach have strong correlations with the employment of drones in the security realm. Spearman's coefficient of correlation (r') values, respectively 0.588 and 0.525 at a significance level of 0.000, delineated that strong positive association between IVs and DV. Further, hypotheses testing also proved that H_1 and H_2 are accepted whilst H_{1_0} and H_{2_0} were rejected.

4 RECOMMENDATIONS AND CONCLUSION

The following recommendations have been formulated on par with the objectives

A. *To establish an integrated operational environment by integrating SLA, SLN, SLAF, Wildlife, Forest Department and Customs to cater to requirements being projected concerning all operational themes*

B. *To establish a centralized command that is led by the SLAF on drone operations.*

C. *To adapt the operational framework for drone operations of SLA and SLAF based on operational themes of warfighting, peace support, defence engagement and security on a par with time, space, purpose and resources.*

D. *To provide real-time drone picture-driven data to respective decision-makers to take prompt decisions that are driven by accurate data.*

E. *To conduct educational/awareness sessions for middle-grade Officers in SLA/SLAF about drone operations/technology in aerial warfare by expertise in the field.*

F. *To incorporate drone operations and technology into the training and education syllabuses of SLA/SLAF Officer Cadets and Officers' training/education programmes.*

G. *To conduct tactical air power missions concerning ISR in support of SLA land operations.*

H. *To establish a joint drone research and development (R&D) center with the*

collaboration of SLAF and SLA to develop an indigenous drone for SLA for operational and tactical purposes.

J. *To study the development of an indigenous combat drone for Sri Lanka.*

K. *To study the operational framework for employing UAVs/ small-scale drones in the maritime domain of Sri Lanka as a future research area. Sri Lanka's extensive maritime domain remains pivotal as the country aims to thrive as a maritime nation. Studies in this area would focus on how UAVs can augment surveillance, SAR, fisheries management, maritime law enforcement and environment monitoring.*

5. CONCLUSION

A new paradigm has emerged in respect of military drone operations, driven by the changing dynamics of warfare. The Nagorno-Karabakh War has provided esteemed insights into the effective employment of drones on the battlefield. Consequently, it is decisive to clearly define the types of operations, determine the extent of engagement, and identify the necessary apparatus required for security engagements. This strategic planning will ensure effective and informed decision-making regarding acquiring and deploying drones in the security realm.

The study explored the employment of drones in security operations (EDS), which has been determined by the operational framework (OF) and integrated approach (IA). Therefore, researchers conceptualised preceding determinants and operationalised the same to the collection of data through questionnaires and semi-structured interviews.

In conclusion, this research has shed light on the significance of developing a comprehensive operational framework for drone operations in Sri Lanka. The study underscored the global rise in drone usage and its impact on modern warfare, drawing insights from the Nagorno-Karabakh conflict. It

elucidated the need for SLA and SLAF to collaborate and establish a joint drone operation monitoring cell to facilitate effective communication and prevent unauthorized drone activities. Furthermore, the research emphasized the significance of joint efforts among various stakeholders, including SLA, SLAF, and other state authorities, in adhering to operational principles and optimizing the use of drones in different security domains. By tackling these key aspects, Sri Lanka can establish a robust and effective drone programme to bolster its security operations.

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A RETROSPECTIVE STUDY ANALYSING THE PROFILE OF CUTANEOUS LEISHMANIASIS CASES REPORTED TO A BASE HOSPITAL IN THE NORTH CENTRAL PROVINCE OF SRI LANKA

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ABSTRACT

Cutaneous leishmaniasis (CL) is the most prevalent clinical form of leishmaniasis in Sri Lanka. This study explored the epidemiological characteristics of CL patients at the Base Hospital, Medirigiriya, Sri Lanka, based on retrospective data collected during 2017-2022. Specifically, it determined the frequency of CL among the patients and examined the patterns of CL distribution in the selected population concerning demographic, spatial, and temporal factors. The research used the laboratory investigation reports of clinically suspected CL patients referred to the dermatological clinic during the study period. The smear test result, age, sex, and area of residence were collected and analysed using Microsoft Excel and SPSS software. A total of 1190 residents from the Medirigiriya area suspected of CL were screened, of whom 584 (49.1%) were positive by smear test. The annual positive cases increased from 2017 (42.8%) to 2022 (55.7%). The average annual incidence of CL per 100,000 population in Medirigiriya was estimated to be 122. Among the positive patients, the percentage of males (60.6%) was higher compared to females. Also, the 41-50 age group showed the highest percentage (21.2%) of CL positive cases. The month of July recorded the highest mean number of CL-positive patients. The main cluster of CL patients was in the Nawanagaraya and Medirigiriya Grama Niladari Divisions. Sex, age, area of residence of patients, and month of the year were the significantly associated risk factors (p<0.05) for CL infection in Medirigiriya during the study period. This research provides an understanding of the demographic and spatiotemporal factors associated with CL in Medirigiriya during 2017-2022 which would be important in designing strategies for the prevention and control of CL in the area. It is recommended that the identified risk factors be targeted for future research, surveillance, and implementation of control methods.

KEYWORDS: *Cutaneous leishmaniasis, Leishmania, Demographic distribution, Spatiotemporal distribution, Sri Lanka*

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1. INTRODUCTION

Leishmaniasis, caused by the protozoan belonging to genus *Leishmania* and transmitted to humans by sandfly vectors *Phlebotomus* and *Lutzomyia*, is one of the seven important neglected tropical parasitic diseases (Mathers et al., 2007), with around 1–2 million new cases and an estimated 350 million people at risk worldwide annually. (Torres-Guerrero et al., 2017). There is considerable diversity in the epidemiology, clinical features, and disease severity of leishmaniasis, and these variations are attributed to both parasite and host-related factors and the ecological characteristics of the transmission site (McCall and Matlashewski, 2010; Alvar et al., 2012; Gradoni, 2018; Guery et al., 2021). The genetic diversity of the parasites and vectors (Kariyawasam et al., 2017; Pathirage, et al., 2021), limited access to advanced diagnostic tests, and the knowledge gaps in the disease and at-risk populations, vectors, and reservoir hosts (Wijerathna et al., 2017; Jayathilake and Taylor-Robinson, 2020) are some of the potential challenges identified for controlling the disease in Sri Lanka.

Of the three main clinical manifestations of the disease; cutaneous (CL), muco-cutaneous (MCL), and visceral (VL) leishmaniasis, in Sri Lanka and many other countries, the highest number of cases are reported with CL (Siriwardana et al., 2012). CL causes skin sores frequently on the forearms, legs, and face that can leave scars and result in permanent impairment. The psychosocial burden of CL is high due to the disfiguring nature of the disease and the associated stigma (Nuwangi et al., 2024). Since the first CL case resulting from local transmission was documented in 1992 (Athukorale et al., 1992), it is now widely distributed throughout the country. The island is the most recently identified endemic focus in South Asia, with rising trends in disease prevalence (Siriwardana et al., 2012; Galgamuwa et al., 2018; Karunaweera et al., 2020; Karunaweera et al., 2021). CL in Sri Lanka exhibits seasonal trends (Sandanayaka et al., 2014; Galgamuwa et al., 2018; Sudarshani et al., 2023), likely due to the availability of habitats for the sand fly vectors and environmental factors such as rainfall, temperature, wind speed, and humidity (Galgamuwa et al., 2018; Wijerathna and

Gunathilaka, 2020b; Wijerathna and Gunathilaka, 2023). CL in Sri Lanka is also associated with socio-demographic and landscape factors (Galgamuwa et al., 2017; Wijerathna et al., 2020a), and a spatiotemporal expansion of the disease incidence is evident with distinct geographic patterns and disease hotspots (Wijerathna et al., 2020a; Karunaweera et al., 2020; Karunaweera et al., 2021, Jayasena Kaluarachchi et al., 2024). Thus, more research on the epidemiological determinants of leishmaniasis in Sri Lanka is necessary since the knowledge gaps complicate efforts to manage the disease.

Polonnaruwa is one of the five districts of the island with a high level of CL endemicity (Galgamuwa et al., 2018), however, the epidemiolocal profile of leishmaniasis in specific Medical Officer of Health (MOH) areas of this district is still limited, including for the Medirigiriya MOH (Sandanayaka et al., 2014). To contribute to this research gap, we aimed to explore the profile of CL patients attending the dermatology clinic of the Base Hospital, Medirigiriya, based on retrospective data collected during the period 2017-2022. The specific objectives of the study were to determine the frequency of CL patients among the study cohort and to find the patterns of CL distribution in the selected population to demographic, spatial, and temporal characteristics. An understanding of the epidemiological patterns is significant for developing effective control strategies, reducing the disease burden, and improving public health in Medirigiriya, Sri Lanka.

2. METHODOLOGY

The study was a retrospective, descriptive study of patients who had presented at the Base Hospital, Medirigiriya, with skin lesions. The study population consisted of patients referred to the dermatology clinic from January 2017 to December 2022. All patients clinically suggestive of CL (positive or negative for CL) from the Medirigiriya MOH area during the study period were included in the study. Data from those not from the Medirigiriya MOH area were excluded from the analysis.

Ethics approval

Ethical approval for the study was obtained from the Ethics Review Committee of The Open University of Sri Lanka (FH/ERC/22). The administrative approval for the study was obtained from the Regional Director of the Polonnaruwa district and the Medical Superintendent of the Base Hospital, Medirigiriya. Participants were not directly approached for data collection, only the laboratory reports were utilized for the study. A reference number was given for each patient report, and data were collected without the identification of the person.

Data collection and analysis

The sample included data from laboratory investigation reports for Giemsa-stained touch or impression smears for CL. The date of the report, smear test result, age, sex, and area of residence were extracted from the reports. The data were analysed with Microsoft Excel and SPSS version 23 software. Descriptive statistics and frequency distributions were used to present the CL-positive cases with respect to sex, age, and other characteristics. The annual incidence of CL cases per 100,000 population in Medirigiriya was estimated using the population data for the area obtained from the MOH office in Medirigiriya. The spatial distribution of CL cases in the MOH area was analysed based on the number of cases reported to the hospital from each Grama Niladari (GN) Division of the MOH area. Data were analysed for temporal variations in CL based on monthly and annual CL confirmed cases reported at the hospital during 2017-2022. The trends in CL cases during the six years were analysed in relation to demographic, spatial, and temporal characteristics using the chi-square test. A $p<0.05$ was considered statistically significant.

3. RESULTS

A total of 1190 records of clinically suspected CL patents of the Medirigiriya MOH area were collected from the laboratory reports.

Frequency of CL patients

A total of 584 (49.1%) screened patients were positive for CL.

There was a continuous increase in CL patients from 2017 to 2022 (Figure 1).

The number of individuals screened for CL at the Base Hospital, Medirigiriya, increased from 35 to 339 over the six-year period. The number and percentage of CL-positive cases also showed a continuous increase from 2017 (15, 2.6%) to 2022 (189, 32.4%). The annual incidence of CL cases in Medirigiriya was estimated to increase from 19 to 239 cases per 100,000 individuals for the period 2017 to 2022.
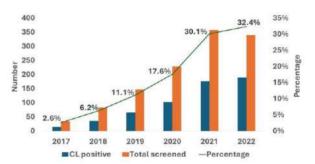
Figure 1: Distribution of CL patients at Base Hospital, Medirigiriya, from 2017 – 2022

Demographic characteristics of CL patients

Sex profile

Among the 584 CL positive cases (Table 1), the majority were male (62.3%). Of the 691 male patients screened for CL, 364 (52.7%) were positive. Among the 499 female patients screened for CL, 220 (44.1%) were positive. CL positivity was higher in males than in females in all study years ($p<0.001$). Findings showed a gradual increase in the number of male and female CL patients over time, with the highest number of male (n=125) and female (n=69) cases in 2022 and 2021, respectively.

Table 1: Distribution of male and female CL patients during 2017 - 2022

| Year | Number (%) | | | | Total |
| | Positive for CL | | Negative for CL | | |
	Male	Female	Male	Female	
2017	13 (37.1)	2 (5.7)	14 (40)	6 (17.1)	35
2018	21 (25.3)	15 (18.1)	37 (44.6)	10 (12.0)	83
2019	37 (25.2)	28 (19.0)	40 (27.2)	42 (28.6)	147
2020	61 (26.8)	42 (18.4)	60 (26.3)	65 (28.5)	228
2021	107 (29.9)	69 (19.3)	100 (27.9)	82 (22.9)	358

2022	125 (36.9)	64 (18.9)	76 (22.4)	74 (21.8)	339
Total	364 (30.6)	220 (18.5)	327 (27.5)	279 (23.5)	1190
Mean	60.7	36.7	54.5	46.5	198.3
SD	46.2	26.7	30.7	32.7	133.3

SD: standard deviation

Age profile

The majority (54.3%) of CL patients were in the 31-60 years age group, with the highest (21.2%) in the 41-50 group (Figure 2). There were no positive patients <1 year of age. The lowest percentage of cases (0.68%) was in the age group of >81 years. There was a significant variation in the age distribution of CL patients between 2017-2022 (p<0.001).
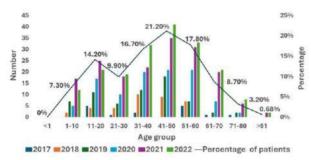
Figure 2: Distribution of CL patients based on age

The males and females showed a similar pattern of variation in CL with age, with the highest numbers in the 41-50 age group of both sexes (Figure 3).
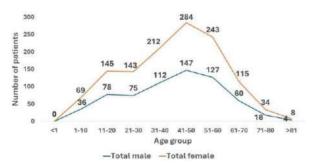
Figure 3: Distribution of CL positive males and females with age

Monthly distribution of CL patients

The total number of CL positive patients varied significantly across the months between 2017-2022 (p<0.001), with July showing the highest numbers (n-119; 20.4%) in all six years (Figure 4). A similar trend was observed for the monthly distribution of CL patients when considering individual years as well, where the July peak was consistent in all years, with a possible second peak in April and October in some years (Figure 4).
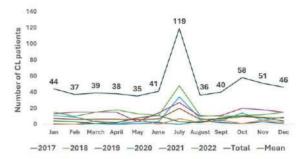
Figure 4: Monthly variation of positive CL patients across the six years

Spatial distribution of CL patients

The highest percentage of positive cases was reported from the Nawanagaraya GN division, followed by the Medirigiriya GN division (Figure 5). The total number of patients reported from these two GN divisions for the six-year period was >100. Out of the 45 GN divisions, 13 did not show any CL cases, while others showed at least a single patient. The variations in the spatial distribution of CL patients in the different GN divisions between 2017-2022 were statistically significant (p<0.05).
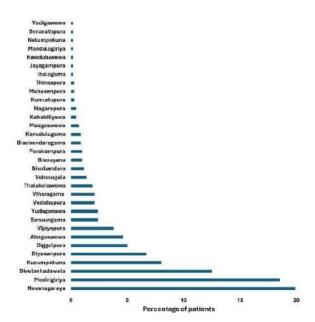
Figure 5: Spatial distribution of CL patients in GN divisions of Medirigiriya during 2017-2022

4. DISCUSSION

This retrospective study determined the frequency of CL among patients reporting to the dermatology clinic at the Base Hospital, Medirigiriya, and assessed the patterns of CL distribution in the selected population with respect to demographic, spatial, and temporal characteristics. Of the total 1190 clinically suggestive cases screened by skin smears between 2017 and 2022, from which 584 (49.1%) were reported as positive. The total number of tested cases as well as positive cases were observed to gradually increase over the years. Several reasons may have contributed to this increasing trend in the number of CL positive patients and the referred number of patients during the six-year study period. The number of patients referred for CL screening may have increased from 2017 onwards because the services of a dermatologist became available at the Base Hospital only in that year. Also, with time, the community would have become more aware of the disease, resulting in more individuals in Medirigiriya visiting the hospital for treatment.

In a previous study, the Medirigiriya MOH area in Polonnaruwa reported an incidence of 8–41 CL cases per 100,000 population (Sandanayaka et al., 2014). In comparison, our study reported an increased mean annual incidence of 121 cases per 100,000 population for the 2017-2022 period. CL is more distributed among people living in poverty (Firouraghi et al., 2023) and increases in incidence are likely to be connected to several reasons, such as, low income and lack of awareness of the disease or low education level (Wijerathna et al., 2020a; Dewasurendra et al., 2024), conducive climate and landscape (Wijerathna et al., 2020a; Maia-Elkhoury et al., 2021; Coates and Norton, 2021; Mohammadbeigi et al., 2021; Hassanein et al., 2023), population migrations and behaviours that increase exposure to vectors (Chaves et al., 2008; Dewasurendra et al., 2024) and the presence of animal reservoirs and breeding and resting places for the vectors (Feliciangeli, 2004; Wijerathna et al., 2020). Medirigiriya is an area with a hot and humid climate with many low-income people in the community; some live in part-built houses, which are good breeding places for the sand fly vectors (Feliciangeli, 2004). Further, in our study, the only

two GN divisions to record >100 positive cases were Nawanagaraya and Medirigiriya. Nawanagaraya is an area with high paddy cultivation and a large farming population, which may be an underlying cause for the high incident rate in that area. Medirigiriya, on the other hand, is the most urban area among the GN divisions, with a high population. We could therefore assume that these residents have a better awareness of the disease. Also, the hospital is within easy reach of this GN division. These factors may have contributed to people in this area seeking screening, increasing the number of detected CL cases in the Medirigiriya GN division. Our study is consistent with another study which had shown that early seeking of treatment was probably influenced by improved literacy, income and awareness, which would have led to improved CL diagnostic rates in a study cohort from the Southern Province, (Jayasena Kaluarachchi et al., 2024).

Among the patients that reported to the Base Hospital from the Medirigiriya MOH area, males were more likely to be CL positive compared to females, similar to the findings of studies done in Sri Lanka and other countries (Abdellatif et al., 2013; Siriwardana et al., 2019; Solomon et al., 2022; Sudarshani et al., 2023; Firouraghi et al., 2023; Sudarshani et al., 2024; Jayasena Kaluarachchi et al., 2024). The average male-to-female ratio of CL patients for the six-year period of our study was 1.7 similar to the statistics reported by Sudarshani, et al. (2019) and Silva et al. (2021). Only a minority of research from Sri Lanka (Kariyawasam et al., 2015) reported female predominance in their study cohort. This sex-based distribution among the CL patients is probable, as males are more likely to be exposed to infected sand flies because of their occupational activities in cultivation fields that provide suitable breeding and resisting habitats for these vectors. Though women also engage in the agricultural fields, they do so to a lesser extent than males, and they are also more likely to wear clothes covering the body, thus having better chances to avoid sand fly bites (Amarasinghe and Wickramasinghe, 2020; Saeidi et al., 2021). In a nationwide survey conducted in Sri Lanka, wearing protective clothing during outdoor activities was a significant factor in determining disease outcomes for males (Dewasurendra et al., 2024).

In Medirigiriya, the most affected were the 31-60 age group (54.3%), with the highest prevalence in the 41-50 group for both males and females during 2017-2022. Similarly, in some studies, the older working population was more likely to be affected by the disease (Reithinger et al., 2003; Nawaratna et al., 2007; Sandanayaka et al., 2014; Siriwardana et al., 2019; Karunaweera et al., 2020; Sudarshani 2023; Jayasena Kaluarachchi et al., 2024), but in others, the age range shifted to the <20 year-old population (Gurel et al., 2002; Hassanein et al., 2023). Similar to our findings, others also have reported that school children are at higher risk when compared to >60 age group (Dewasurendra et al., 2024; Sudarshani et al., 2024). The age groups that are more likely to engage with the outside environment get more exposed to the vectors, thus showing the highest CL positivity (Feliciangeli, 2004). In our study, the lowest number of cases were among the >80 year-old age group, while no patients were found in the <1 year of age, likely due to fewer outdoor activities. Comparatively, while some studies report that certain age groups of males show a higher CL prevalence similar to our findings (Ihsanullah et al., 2021, Jorjani et al., 2019), others report no difference between males and females and age group trends in CL positivity (Akhmedovich and Samadovna, 2022).

In our study, the monthly distribution of CL patients varied, with the highest mean number of CL cases reported in July for the six-year study period. Firouraghi et al. (2023) also reported that the number of positive cases in Iran fluctuated during the different months of the year, but the seasonal trends in CL distribution reported in different studies vary (Jorjani et al., 2019). In studies conducted in Sri Lanka during 2008-2012 (Siriwardana et al., 2012), and 2018 (Galgamuwa et al., 2018), the peak of positive cases in Polonnaruwa was reported during August-December, like the trend we observed in 2017 and 2019. In Ethiopia, the CL cases showed a sharp peak between July and September (Debash et al., 2022), but in Libya, a marked increase in numbers was observed in December (Ashour, et al., 2022). These monthly variations in CL may be attributed to environmental and ecological factors that affect sandfly breeding and cultivation activities at a site (Mohammadbeigi et al.,

2021). Studies from Sri Lanka and other regions of the world have shown that climatic factors such as humidity, temperature, and rainfall can affect CL incidence either positively or negatively depending on the geographical area (Toumi, et al., 2012; Rosales, et al, 2017; Sharafi et al., 2017; Azimi et al., 2017; Galgamuwa et al., 2018; Ramezankhani et al., 2018; Wijerathna and Gunathilaka, 2023).

Our study has contributed important characteristics of the CL patients in the Medirigiriya MOH area for a six-year period, which are important for understanding the epidemiology of this disease in this MOH. We have identified a few limitations in the study that could be overcome in future work. It is possible that the frequency of CL patients is underreported here because some of the patients in the Medirigiriya MOH area may not have sought treatment at the Base Hospital, Medirigiriya, instead preferring to visit the General Hospital, Polonnaruwa, or elsewhere. Also, some of the cases may have been misdiagnosed because the CL diagnosis was determined only by microscopy due to limited resources and facilities. It is important to confirm negative slit skin smear results for CL by more sensitive and specific molecular techniques (De Silva et al., 2017) as studies have reported over 90% detection rate of CL by PCR (Kariyawasam et al., 2015; Jayasena Kaluarachchi et al., 2024), whereas slit skin smear sensitivity was reported to be 59% (Sudarshani et al., 2023). Further, the laboratory reports of the CL patients contained limited information about the patients. Therefore, we could not analyse data based on their general clinical data, occupation, anatomical distribution, morphological typing (popular, nodular, or ulcerative), etc., to obtain a clearer picture of the disease and associated risk factors.

5. CONCLUSION

This research contributes epidemiological information on the demographic, spatial, and temporal characteristics associated with CL in Medirigiriya MOH during 2017-2022. Increasing trends in disease incidence in the last six years indicate the importance of improved case detection at the community level, strict adherence to case management protocols and control activities, and continued surveillance and

monitoring for the effective management and control of leishmaniasis in the Medirigiriya MOH area. Behavioural changes and education of people to accept and participate in control programs would also be useful in this regard. Further, the identification of age and sex groups at risk, as well as the vulnerable months of the years and GN divisions, suggests that awareness programs, treatment programs, and vector control programs must be targeted in relation to these factors to control the disease. The results reported herein therefore contribute to future research about CL epidemiology and the implementation of disease control measures in the Medirigiriya MOH area of Sri Lanka.

6. ACKNOWLEDGMENT

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DEVELOPMENT AND ANTIBACTERIAL CHARACTERIZATION OF HAND SANITIZER GEL FROM MINT LEAF EXTRACT (*Mentha arvensis* L)

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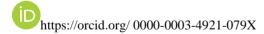
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ABSTRACT

Formulation of hand sanitizers with herbs extract to enhance safety and quality while maintaining effective antibacterial properties. This study aimed to formulate hand sanitizers with different concentrations of ethyl acetate extracts of Mentha arvensis leaves and assess their physiochemical properties and antibacterial activities. The plant material was collected in Jaffna and allowed to shade dry. The dried plant material was macerated with ethyl acetate for 48 hrs at room temperature. Two different formulations (A and B) were prepared with 5% and 10% plant extract. Organoleptic characteristics, pH, homogeneity, turbidity, and antibacterial activity were evaluated. The antimicrobial activity of formulations was estimated using the agar well diffusion method against Staphylococcus aureus, Pseudomonas aeruginosa and Escherichia coli by employing a formulation excluding plant extract as control and WHO standard hand sanitizer used as a positive control. Results indicated that Formulation B, containing 10% extract, demonstrated satisfactory physiochemical properties and antibacterial activity against the tested bacteria. Formulation A showed a maximum inhibition of 10.60 ± 0.58 mm against E. coli at 800 µg/ml, with no activity against S. aureus and P. aeruginosa at lower concentrations. In contrast, Formulation B demonstrated greater efficacy, achieving inhibition zones of 14.17 ± 1.04 mm for E. coli, 10.17 ± 1.04 mm for S. aureus, and 3.83 ± 0.76 mm for P. aeruginosa at 800 µg/ml. These results indicate that Formulation B shows significant potential as an effective hand sanitizer. Further stability evaluation of formulation B will ensure the evaluation of the clinical usage.

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1. INTRODUCTION

Microorganisms, such as fungi, bacteria, viruses, and protozoa, are abundant in nature but invisible to the unaided visible. They cause diseases in healthy individuals, especially bacteria causing a wide variety of diseases such as throat infection, cholera, meningitis, pneumonia, and urinary and GIT infections (Shaloo *et al*., 2017). Among these, Pseudomonas aeruginosa, Staphylococcus aureus, and Escherichia coli are important players in nosocomial infections. *Staphylococcus aureus* grows and survives in nasal secretions, and on the skin and causes minor to fatal diseases (Yaun and Vasquez, 2017). *Escherichia coli* is an opportunistic microorganism, causes urinary tract infections, certain strains produce enterotoxins that can cause traveler's diarrhea and occasionally cause serious foodborne disease (Baruah and Leclercq, 1993). *Pseudomonas aeruginosa* is commonly found as a nosocomial infectious agent and it causes disease in hospitalized patients and immunosuppressed people (Wani *et.al*., 2013).

Hand hygiene plays crucial preventive measure against the chain transmission of microorganisms. (Baruah and Leclercq, 1993). The historical evolution of hand cleansing practices emerged back in the 19th century, with alternative options like soap, water, and hand sanitizers containing at least 70% alcohol (Baruah and Leclercq, 1993). Several studies demonstrated that the presence of 70% of alcohol in sanitizer kills 99.9% of the bacteria on hands (Acharya *et,al*., 2018). As per WHO and CDC guidelines, hand sanitizer formulations may include one or more alcohols such as ethanol, isopropanol, or propanol, along with other active ingredients, excipients, and humectants. To ensure effective sanitization, it is recommended that hand sanitizers should contain between 60% to 95% alcohol, which serves as both an antimicrobial and antiseptic agent (Sommatis *et.al*., 2023) Sanitizers, available commercially in various formulations, offer a convenient and effective means of reducing bacterial counts, particularly associated with the reduction of traveler's diarrhea and vomiting. Studies exploring herbal hand sanitizers highlight the potential

synergistic antimicrobial effects of secondary metabolites present in plant extracts, such as alkaloids, terpenoids, tannins, and flavonoids (Patankar and Chandak, 2018). In comparison to liquid (spray) or foam hand sanitizers, gel-based hand sanitizers offer several benefits. One significant advantage is that gels can form a protective layer on the skin, providing longer-lasting protection. Additionally, hand sanitizing gels have a higher retention time on the skin, resulting in better adherence and a more moisturizing feel compared to other forms of hand sanitizers (Booq *et.al*., 2021)

Mentha arvensis L. is an herbal plant belonging to the family of Lamiaceae, features a dark green, quadrangular stem that grows 55-91 cm tall with opposite leaves. Known for its strong peppermint scent and pleasant taste, it is cultivated widely, originating in Japan and spreading to India, Australia, and beyond (Sharma *et.al*., 2013) (Chetia and Saikia, 2020). Various types of phytochemicals such as menthol, menthofuran, and cineol are present in different parts of the plant, and they can be used for different purposes including pharmaceutical formulations. These phytochemicals can be extracted by using organic solvents like chloroform, methanol, and ethyl acetate. According to a previous study, ethyl acetate leaf extract showed more anti-bacterial activity than other solvents (Sujana *et.al*., 2013). Further, *M. arvensis*, the plant contains various flavor compounds and is recognized for its cold-relieving properties, making it valuable in cosmetics and pharmaceuticals (Kapp et.al., 2020). Its leaves are particularly rich in flavonoids, alkaloids, and other secondary metabolites (Patel *et.al*., 2021). Additionally, *M. arvensis* exhibits antifungal, antiseptic, antioxidant, anti-inflammatory, sedative, and antitumor activities (Thawkar *et.al*., 2016) (Sevindik *et.al*., 2018). Considering the extensive tradition of using plants for medical purposes, *M. arvensis* shows promise as a natural and efficient option for hand sanitizers, perhaps protecting against microbial hazards.

There are several studies related to the formulation of hand sanitizer using the combination of herbal plant

extract and evaluation of their anti-microbial and physical parameter. Since there were no studies performed using a single plant extract of *M. arvensis L.* for the formulation of hand sanitizer, this study focused on the formulation and evaluation of *M. arvensis L.* leaf extract containing hand sanitizer.

2. METHODOLOGY

Collection of Plant Material

The *M. arvensis* L. (mint) leaves were collected from Inuvil, Jaffna, Sri Lanka and the plant was authenticated by Prof. Priyangani Senanayake at the Department of Plant and Molecular Biology at the University of Kelaniya using morphological characters.

Preparation of Plant Material

Fresh leaves were washed thoroughly with running tap water to get rid of mud sand, and other dirty particles completely and kept under the shade to dry and ground finely using a clean electric grinder to obtain a homogenous powder sample. It was macerated with ethyl acetate for 48 hours at room temperature. The supernatant was filtered using Whatman No 1 filter paper with a pore size of 11 µm using a vacuum suction pump. The filtrate was removed under reduced pressure below 45 °C using a rotary evaporator for dryness. The resulting crude extract was stored in a refrigerator at 4 °C until further use (John De Britto, Sebastian and Mary Sujin, R., 2012).

Preparation of Formulation

Formulations were prepared according to previous studies and standard industrial guideline in two forms (Surini, Amirtha and Lestari, 2018) (17. Lubrizol, 2011).

- Formulation A- containing 5% (W/V) mint extract and 60% ethanol.

- Formulation B- containing 10% (W/V) mint extract and 60% ethanol.

- Formulation C- Control hand sanitizer

- Formulation D- Standard hand sanitizer (WHO)

The required amount of carbopol 940 was weighed and transferred into the beaker glass containing deionized water. This solution was stirred using a magnetic stirrer after 24 hours, and tri-ethanolamine was added slowly with stirring until get proper gel consistency. Meanwhile, Plant extract was added to the ethanol along with glycerin, and polysorbate-20 into a separate beaker. This mixture was poured into a gel base and stirred vigorously using a magnetic stirrer. Finally, methyl paraben was added and finally, the volume was adjusted up to 30 mL using deionized water (Rahmasari *et.al*., 2020). A similar procedure was repeated for the preparation of negative control without having the plant extracts. The 70% alcohol-based hand rub was prepared based on the WHO guideline which was used as positive control. The composition of ethyl acetate in cooperated hand sanitizer is given in Table 1.

EVALUATION OF PHYSICAL PARAMETERS

Physical evaluation tests were done for all the prepared hand sanitizer formulations.

Organoleptic characteristics

Oduor and color of the formulation were observed manually (visual method).

Homogeneity and turbidity

It was ensured manually.

pH

pH of the hand sanitizer was determined by using a digital pH meter. The formulation was dissolved in 100 mL of distilled water and stored for two hours. The measurement was taken using a previously calibrated pH meter (Afsar and Khanam, 2016).

Table 1: Composition of ethyl acetate extract incorporated hand sanitizer.

Ingredients	Quantity		
	Formulation A (30 mL)	Formulation B (30 mL)	Formulation C (30 mL)
Ethanol (95%) (ml)	18.947	18.947	18.947
Plant extraction (g)	1.5	3	-
Glycerin (ml)	0.69	0.69	0.69
Carbapol 940 (g)	0.15	0.15	0.15
Triethanolamine	0.21	0.21	0.21
Polysorbate 20 (ml)	0.15	0.15	0.15
Methyl paraben (mg)	0.15	0.15	0.15
Deionized water (ml)	Up to 30 ml	Up to 30ml	Up to 30ml

ANTIMICROBIAL ACTIVITY

Test organisms.

In-vitro anti-microbial activity of prepared hand sanitizer formulations was evaluated by using the good diffusion method in Mueller-Hinton agar medium against the selected microorganism *Escherichia coli* (ATCC 25922), *Staphylococcus aureus* (ATCC 25923) and *Pseudomonas aeruginosa* (ATCC 9027).

Dilution procedure for test sample

A stock solution of formulation A was prepared by using 16 mg of prepared formulation and it was transferred into a 20 mL volumetric flask. Then 10 mL of sterile distilled water was added into each flask, and it was shaken well until all the gel dissolved completely. Finally, the volume was made up to 20 mL. From the stock solution various concentrations of sample (800 µg/ml, 400 µg/ml, 200

µg/ml) were prepared using serial dilution method. The same procedure was repeated for formulation B.

Determination of antimicrobial activity by agar well diffusion method

All above mentioned species of bacterial inoculum were prepared by suspending bacterial colonies in sterile normal saline directly to achieve the same density of the 0.5 McFarland standard (1-2 x 10^8 CFU/ml).

The agar plate was inoculated with the standard bacterial suspension described above. Using a sterile cotton swab, the bacterial suspension was carefully applied by rotating the swab several times and streaking it across the entire surface of the agar plate in a methodical manner. This process was repeated two additional times, with the agar plate rotated approximately 60 degrees each time to ensure a thorough and even distribution of the inoculum. Subsequently, the agar plate was left undisturbed to air dry for 3-5 minutes to allow the bacterial cells to adhere to the agar surface. Following inoculation, each plate was meticulously perforated with a 6 mm diameter sterile cork borer, creating precisely five bores on each plate (Patankar and Chandak., 2018).

Each test sample, consisting of 100 µL, was carefully introduced into the wells present in the inoculated Mueller-Hinton agar medium. Subsequently, the plate was placed in an incubator overnight at 37°C. As part of the experimental controls, a 0% mint extract (formulation C) and a 70% alcohol-based hand rub (formulation D) were employed as positive controls in this study. The experiment was conducted in triplicate to ensure the accuracy and reliability of the results. The antibacterial activity was quantified by measuring the mean zone of inhibition (in mm) produced by each formulation.

Statistical Analysis

The diameter of the zone of inhibition (in mm) was used as the indicator for the antimicrobial activity of samples. The results were expressed as Mean ± Standard Deviation of the mean. The antimicrobial activity of the formulations was analyzed with one-way ANOVAs followed by Tukey's test using

software, SPSS. Differences between means were considered significant if P-values lower than 0.05 (p<0.05)

3., RESULTS AND DISCUSSION

Yield percentages of extract of *M. arvensis L.*

The yield percentage of *M. arvensis L.* is shown in Table 2.

Table 2 Yield percentages of different extracts

Parts of plant	Type of solvent	Weight of crude extract (g)	Yield percentage (% w/w)
Leaf	Ethyl acetate	6.89	1.72

M. arvensis L. leaves were extracted successively with ethyl acetate using the maceration method exhibiting a yield percentage of 1.72%. Ethyl acetate was selected as the solvent for extraction as it exhibited strong antibacterial activity (Sujana *et.al.*, 2013). The low yield percentage might be due to solvent selection, extraction condition, method of extraction, variation in plant parts and variation of secondary metabolites in accordance with geographical area (Khan *et.al.*, 2022).

The results of the organoleptic characteristics and pH of the two formulations are shown in Table 3. The prepared sanitizer gel showed good gel characteristics and the color of the formulation was observed as dark green. The odor of the hand sanitizer was the odor of the mint leaves. The two formulations had a homogeneous consistency, characterized by an absence of turbidity or cloudiness. Its visual aspect was smooth and translucent, enhancing its overall aesthetic appeal. The pH values of the formulation A and formulation B gels were 4.43 and 5.54 respectively. pH value of B formulations is high compared to formulation A might by the presence of acidic compounds. Generally, hand sanitizer should have a pH similar to that of skin which falls a range of 4.5 to 6.5 (Fallica, *et.al.*, 2021). While formulation B falls within this acceptable range, formulation A is slightly below the

lower limit but still close enough to be considered suitable for skin compatibility though prolonged use could cause minor skin irritation (Malarvarnan, Sivasinthujah and Gnanakarunyan, 2023). This slightly higher pH in Formulation B may result from the presence of acidic compounds in the extract, but it aligns well with the skin's natural pH, offering better skin compatibility and potentially more stable antimicrobial efficacy. Given that both formulations demonstrate effective antibacterial activity, with Formulation B outperforming Formulation A, it is plausible that the pH of Formulation B contributes positively to its stability and enhanced antibacterial performance, particularly against bacteria like *E. coli* and *S. aureus*. Maintaining a pH closer to the skin's natural range likely ensures that Formulation B is more suitable for prolonged use while retaining its antimicrobial properties. The antimicrobial efficacy of various compounds can be influenced by pH levels. Studies on the antibacterial activity of plant extracts like *M. arvensis* often show that pH can affect the stability and bioavailability of active compounds. For ethanol-based hand sanitizers, a pH closer to the skin's natural pH promotes stability and enhances user comfort during long-term use (Gama *et.al.*, 2023).

The organoleptic characteristics and pH results of the two formulations are presented in Table 3. The prepared sanitizer gel exhibited desirable gel characteristics, with the formulation displaying a distinct dark green colouration. The scent of the hand sanitizer was reminiscent of mint leaves, providing a refreshing olfactory experience. Both formulations demonstrated a uniform consistency, devoid of any turbidity or cloudiness, and presented a visually appealing smooth and translucent appearance. The pH values of formulation A and formulation B gels were measured at 4.43 and 5.54, respectively. The higher pH value of formulation B compared to formulation A may be attributed to the presence of acidic compounds. It is noteworthy that hand sanitizers ideally maintain a pH level similar to that of the skin, typically falling within the range of 4.5 to 6.5 (Fallica, *et.al.*, 2021). Thus, both formulation A and B are within the acceptable standard pH range for hand sanitizers.

Table 3: Results of Physiochemical parameters

Parameter	Formulation	Observation
Colour	A	Dark green
	B	
Odour	A	Odour of the
	B	mint leaves
Homogeneity	A	Homogenous
	B	
Turbidity	A	No turbidity
	B	
Appearance	A	Smooth and
	B	translucent
pH	A	4.43
	B	5.54

Evaluation of antimicrobial activity of formulations

The test was conducted against three bacterial species *E. coli, S. aureus and P. aeruginosa*. The mean and standard deviation of the zone of inhibition are shown in Table 4.

Based on the results, both formulations A and B showed antimicrobial activity at 800 µg/ml. However, E. coli, S. aureus and P. aeruginosa showed resistance to formulation A at both 400 µg/ml and 200 µg/ml, except for E. coli, which was sensitive at 200 µg/ml. In contrast, E. coli, S. aureus, and P. aeruginosa were sensitive to formulation B at 400 µg/ml and 200 µg/ml, with the exception of P. aeruginosa at 200 µg/ml. The zone of inhibin of formulations A, B, Positive control and negative control is shown in figure 1, 2 and 3.

Table 4: The inhibitory effect of M. arvensis L. at different formulations on E. coli (ATCC 25922), S. aureus (ATCC 25923) and P. aeruginosa (ATCC 9027).

The type of hand sanitizer	Concentration (µg/ml)	Mean ± Std deviation of the zone of inhibition (mm) for E.coli	Mean ± Std deviation of the zone of inhibition (mm) for S. aureus	Mean ± Std deviation of the zone of inhibition (mm) for P. aeruginosa
Formulation A	800 µg/ml	10.60 ±0.58[c]	9.00 ± 1.00[c]	2.50 ±0.5[c]
	400 µg/ml	7.67 ± 1.5[d]	00±00[e]	00±00[d]
	200 µg/ml	00±00[f]	00±00[e]	00±00[d]
Formulation B	800 µg/ml	14.17 ±1.04[b]	10.17 ±1.04[b]	3.83 ±0.76[b]
	400 µg/ml	7.33 ±0.57[d]	5.83 ±0.28[d]	3.67 ±0.28[b]
	200 µg/ml	4.16 ±0.28[e]	2.33 ±0.57[d]	00 ±00[d]
Formulation C (Negative control)	800 µg/ml	00 ±00[f]	00 ±00[e]	00 ±00[d]
	400 µg/ml	00 ±00[f]	00 ±00[e]	00 ±00[d]
	200 µg/ml	00 ±00[f]	00 ±00[e]	00 ±00[d]
Formulation D (Positive control)	70% alcohol-based hand sanitizer	27.00 ±6.42[a]	26.00 ±3.60[a]	12.00 ±0.57[a]

In the table 4 Values are represented as mean±SD; Values with different superscripts in the same column differ significantly (P<0.05).

Figure 1: Zone of Inhibition in *E.coli.*

Figure 2: Zone of Inhibition in *S. aureus*

Figure 1: Zone of Inhibition in *P. aeruginosa*

The zone of inhibition for formulation A was found to be 10.60±0.577 mm, 9.00±1.00 mm and 2.50±0.5 mm for *E. coli, S. aureus* and *P. aeruginosa* respectively at 800 µg/ml. Likewise, formulation B showed 14.17±1.04 mm, 10.17±1.04 mm and 3.83±0.76 mm respectively at 800 µg/ml. Among both, formulation B showed a better antibacterial efficacy compared to formulation A.

When comparing Formulation A and Formulation B with the WHO-recommended hand sanitizer (formulation D), both formulations showed less antibacterial activity, particularly at higher concentrations. For *E. coli*, Formulation B achieved a 14.17±1.04 mm zone of inhibition, which, while lower than the positive control's 27.00±6.42 mm, still indicates considerable antibacterial potential.

Formulation A also performed moderately well, with an inhibition zone of 10.60±0.58 mm. Formulation B again showed 10.17±1.04 mm zone while 26.00±3.60 mm for the positive control against *S. aureus*. Formulation A followed closely formulation B with 9.00±1.00 mm, suggesting both could serve as viable antibacterial agents. Even for the more resistant *P. aeruginosa,* Formulation B recorded 3.83±0.76 mm, while Formulation A showed 2.50±0.5 mm, though still trailing behind the WHO recommended sanitizer's 12.00±0.57 mm. These results highlight that while Formulation D remains the most effective, Formulation A and B demonstrate sufficient antibacterial activity, making them promising candidates for further development and optimization. In contrast, the negative control (Formulation C) did not show any antimicrobial activity, confirming that the observed inhibition zones for Formulations A and B are due to their active ingredients.

In comparing formulated hand sanitizer formulations using *M. arvensis* with the referenced herbal sanitizer study, higher concentration formulation (B) showed a stronger zone of inhibition against *E. coli* (14.17±1.04 mm) compared to their polyherbal sanitizer (7±0.7 mm), suggesting superior efficacy of mint extract at higher concentrations. For *S. aureus*, both studies demonstrated similar antibacterial activity, with the polyherbal formulation showing 11±0.01 mm inhibition and formulation B showing 10.17±1.04 mm. However, the polyherbal sanitizer outperformed *P. aeruginosa*, showing a 9 mm inhibition zone compared to results of 2.50±0.5 mm for Formulation A and 3.83±0.76 mm for Formulation B. This suggests that while *M.arvensis* is effective against certain strains, a polyherbal approach incorporating other plant extracts, as used in the referenced study, may provide broader antibacterial efficacy, particularly against more resistant bacteria like *P. aeruginosa* (Acharya *et,al.,* 2018).

4. CONCLUSION

It concludes that formulation B with 10% of ethyl acetate extract demonstrated favorable physicochemical properties and proved effective reduction in bacterial counts. Further stability tests

should be done for the formulation B to evaluate the potential activities.

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CHARACTERIZATION OF MORPHOLOGICAL BRAIN CHANGES IN GENERALIZED EPILEPSY USING REGION BASED MORPHOMETRY

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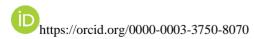
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ABSTRACT

Magnetic Resonance Imaging has been widely involved in detecting morphological brain changes in generalized epilepsy at voxel level. It is believed that region-based morphometry could provide better characterizations for macro structural changes in the brain with comparative advantages than voxel-based morphometry. The aim of this study is to detect regional brain changes associated with generalized epilepsy and to test the potential of regional brain changes in classification of patients with generalized epilepsy and non-epileptic subjects. 45 patients and 46 non-epileptic subjects were scanned using a 3 Tesla MRI scanner and 3D T1 weighted images were obtained. Images were pre-processed and region based structural metrics (grey matter volumes, white matter volumes, cerebrospinal fluid volumes, cortical gyrification, and sulcus depth) were developed using Computational Anatomical Toolbox (CAT12). Two sample t-tests were used to perform the univariate analyses and results were corrected for multiple comparisons (FDR corrected, $p < 0.05$). Grey matter volume reductions were detected in cerebellum, frontal lobe, temporal lobe, thalamus, and hippocampal region while bilateral white matter volume reductions were reported in cerebellum. In contrast, cerebrospinal fluid volume increments in left lateral ventricle were also detected. Reduced regional gyrification was detected in left posterior ramus of the lateral sulcus and reduced sulcal depths were detected in occipital pole, cuneus, and posterior ramus of the lateral sulcus in patients. Furthermore, pattern analysis revealed that each metric shows different discriminative abilities to distinguish patients with generalized epilepsy and non-epileptic subjects (Classification accuracy: 61.1%, 62.2%, 58.8%, 61.1% and 60% for GMV, WMV, CSFV, Cortical gyrification and sulcal depth respectively). In conclusion, this study provides a comprehensive understanding about regional structural changes (cortical and subcortical) associated with generalized epilepsy under region-based morphometry. However, pattern analyses do not provide adequate discriminative power and therefore the clinical utility of findings is limited.

KEYWORDS: *Generalized epilepsy, Grey matter, White matter, Cerebrospinal fluid, Cortical gyrification, Sulas depth, Region based morphometry, Classification*

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1. INTRODUCTION

Epilepsy is one of the most prevalent neurological conditions of the human brain that affects 70 million people in the world. It has several psychological, cognitive, and neurological consequences, and most people with epilepsy are untreated (Thijs *et al*., 2019).

The process which converts a healthy brain into one possible recurrent seizure is called epileptogenesis. This happens due to imbalance of inhibitory activity and excitatory activity within a neuronal network. As a result of this imbalance, there will be an excessive synchronization of function. It will cause disruption of normal neuronal networks and is able to interrupt other neuronal networks too (Thijs *et al*., 2019, Fisher *et al*., 2014).

According to the updated epilepsy classification, it is categorized into four types according to the onset of the disease, which are focal epilepsy, generalized epilepsy, combined generalized, and focal epilepsy and unknown onset (Fisher *et al*., 2014, Fisher *et al*., 2017). If abnormal electrical activity occurs in one hemisphere, it is called focal epilepsy and if an abnormal electrical activity occurs in both hemispheres, it is called generalized epilepsy (Thijs *et al*., 2019).

For over a decade, MRI has been used for epilepsy research and with the development of MRI, the examination and management of patients with epilepsy have undergone a revolutionary change (Oldendorf, 1984, Sostman *et al*., 1984). According to the current evidence, neuroimaging scientists prove that there is a specific standard protocol for structural imaging, and it is balanced with clinical optimization and diagnostic accuracy. The protocol involves identifying malformations of cortical development, spot abnormalities of the hippocampus, to hippocampal sclerosis and focal cortical dysplasia, vascular and calcified lesions (Sidhu *et al*., 2018).

Region Based Morphometry (RBM) is a method that is used to detect structural abnormalities region by region using probabilistic atlas maps. The regional volumes inside the region of interest (ROI) are detected for each tissue type (grey matter, white matter, and CSF) at native space of each brain and the estimated central surface is used to quantify ROI based surface values such as cortical gyrification and sulcus depth at native space (Tu *et al*., 2022).

Many Investigators have used voxel-based morphometry as an image processing method because it is applied in the whole brain, but it can be done as a comparison within different anatomical areas of the brain separately and more accurately by using Region based morphometry (Giuliani *et al*., 2005). So, it has been discussed that the region-based morphometry could provide better characterizations for macro structural changes in the brain with comparative advantage than voxel-based morphometry (Li *et al*., 2010).

As evidenced by previous studies, certain morphological brain changes associated with generalized epilepsy were detected by RBM. All types of epilepsies had lower normal brain volume and lower gray matter volumes in amygdala, frontal lobe, thalamus, putamen and caudate compared to healthy controls (Betting *et al*., 2006, Ke *et al*., 2017, Li *et al*., 2010). Furthermore, the latest evidence about that cerebellum acting as major area which showed reduced volume of both gray matter and white matter of patients who are with Idiopathic generalized epilepsy (Li *et al*., 2010).

The white matter integrity in idiopathic generalized epilepsy using tractography and ROI analysis has revealed significantly lower fractional anisotropy (FA) values of six white matter tracts related to the cerebellum (Liu *et al*., 2011). The morphological abnormalities related to CSF in lateral ventricles in patients with generalized epilepsy over healthy subjects proved that left lateral ventricle was enlarged (Betting *et al*., 2006).

A previous study has been conducted to observe several cortical changes such as cortical folding (gyrification), cortical developments and surface area. The researchers detected the following results for each hemisphere. Cortical developments were detected in several cortical regions, insula, cingulate cortex, temporal pole of temporal lobe and occipital pole of occipital lobe in the left hemisphere and cortical morphology changes were detected in insula, temporal

pole and precuneus in the right hemisphere.(Oyegbile *et al.*, 2004).

Comparing the findings of different structural metrics of different studies is difficult as they involved different sample sizes, different data processing strategies and different diagnostic stages of subjects. Therefore, a direct comparison of multiple structural metrics is necessary to understand how generalized epilepsy affects the human brain. We utilized multiple structural metrics to characterize regional brain changes in generalized epilepsy using region-based morphometry. Further, we tested the potential of using different region-based metrics in classification of patients with generalized epilepsy and non-epileptic subjects using multivariate pattern analysis (MVPA).

2. METHODOLOGY

Subjects

45 patients with generalized epilepsy and 46 non-epileptic subjects were included in the study. This cross-sectional study was approved by the ethics review committees of Faculty of Medicine, General Sir John Kotelawala Defence University, Sri Lanka. All the patients and the non-epileptic subjects were checked by an experienced consultant Neurologist and consultant Radiologist of University Hospital, KDU (UH-KDU). The patients were diagnosed by a neurologist using diagnostic manual published by International League Against Epilepsy (ILAE) by the evaluations including patient history, electroencephalography (EEG) recordings and neuropathological examination. All the patients with the absence of systemic medical illnesses or other central nervous system disorders, and with no history of traumatic head injuries or substance abuse were included in the study. First-degree relatives with epilepsy or other epilepsy syndromes were considered for an additional exclusion criterion of non-epileptic subjects.

Magnetic Resonance Image Acquisition

MRI data was acquired using a 3.0 Telsa MRI scanner (Philips) and an 8-channel head coil. 3D T1-Weighted images were collected using turbo spin echo (TSE) sequence. The specific parameters used in this process include an 8 ms repetition time (TR), and 4 ms echo

time (TE), 8 degrees flip angle (FA), a 256 mm × 256 mm field of view (FOV), a 256 × 256 matrix, 1 mm slice thickness and no gap, and 170 slices in sagittal planes. The head was securely positioned using ear plugs and foam pads during the scanning process.

Image Preprocessing

Raw Images (DICOM) were converted to NiFTI format and verified to align with the same orientation as the reference images available in the Statistical Parametric Mapping 12 (SPM12) software. Preprocessing was conducted utilizing the Computational Anatomy Toolbox 12 (CAT12) and pipeline included bias field correction, local and global intensity normalization, and noise reduction. Additionally, all brain images underwent skull stripping using adaptive probability region-growing (APRG) techniques. Then, the preprocessed images underwent RBM analysis using CAT12 toolbox.

Region Based Morphometry

Brain segmentation into GM, WM and CSF tissue categories was done using integrated Markov Random Field and Adaptive Maximum a posterior segmentation procedure. These methods are designed to minimize reliance on tissue probability maps, enhancing accuracy in the segmentation process. CAT 12 enables estimation of tissue volumes for different regions and surfaces using atlas maps called neuromorpometrics and aparc2009 respectively. The tissue volumes inside the region of interest (ROI) were detected for each tissue type (grey matter, white matter, and CSF) at native space of each brain. Cortical surfaces were reconstructed using projection-based thickness (PBT) method. The estimated central surface was used to quantify ROI based surface values for cortical gyrification and sulcus depth at native space (Tu *et al.*, 2022).

Univariate Statistical Comparisons

CAT 12 enables statistical comparisons in region-based estimations through the 'ROI analysis' module. Group level Differences between individuals with epilepsy and non-epileptic subjects in regional grey matter, white matter, cerebrospinal fluid volumes, cortical gyrification, and sulcus were identified using

two-sample t-tests. The inter-individual differences of brain sizes were accounted using Total intracranial volumes (TIV) of each subject. The findings were eventually adjusted for false discovery rate (FDR) to account for multiple comparisons (p<0.05).

Multivariate Pattern Analysis

Multivariate pattern analyses (MVPA) were conducted to compare generalized epilepsy patients with non-epileptic subjects using whole brain regional volumes (ROI-based values of GM, WM, and CSF) and surface values (ROI-based values of cortical gyrification and sulcal depth). The analysis was performed utilizing the MVPANI toolbox (http://funi.tmu.edu.cn) in conjunction with the linear support vector machine implementation in LibSVM. All participants were divided into 91 folds, with the initial 45 subjects consisting of individuals with epilepsy and the subsequent 46 subjects comprising non-epileptic individuals.
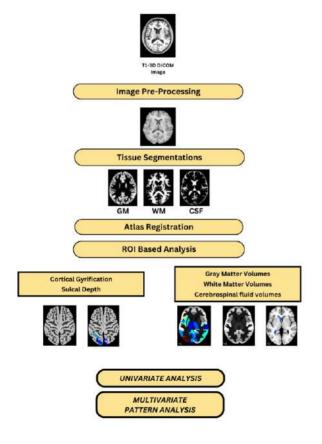
Figure 1: Image-processing Workflow of Region-based Morphometry (GM, grey matter; WM, white matter; CSF, cerebrospinal fluid)

To assess the classification performance, a linear support vector machine (SVM) and the leave-one-subject-out cross-validation method were utilized across all 91 subjects. The mean accuracy of classification was determined through this procedure.

During each cross-validation iteration, a classifier was trained using training dataset (90 folds) and tested on the remaining dataset (1-fold), resembling the training dataset that resulted in classification accuracy for the cross-validation step. The significance of the final accuracy was evaluated against chance level accuracy using permutation tests (n=5000), with the corresponding p-value calculated. Specifically, the p-value indicated the proportion of permutations where the classification accuracy equalled or surpassed the observed accuracy. A p-value of p<0.0002 (1/5000) was assigned if the observed accuracy was approached by none of the 5000 permutations *(Ediri Arachchi et al.*, 2020). Image processing steps are shown in Figure 1.

3. RESULTS

Univariate Statistical Comparisons

We found widespread regional volume reduction in gray matter, a slight volume reduction in white matter and a slight volume increase in CSF in generalized epilepsy compared to non-epileptic subjects as shown in Figure 2 and results are summarized in Table 1. The regional cortical changes (reduced cortical gyrification and sulcus depth) are shown in Figure 3 with the results summarised in Table 2 respectively.

Gray matter volume reductions were detected in inferior occipital gyrus, cerebellum exterior, transverse temporal gyrus, cuneus, occipital fusiform gyrus, middle temporal gyrus, thalamus Proper, calc calcarine cortex, lingual gyrus, and superior occipital gyrus bilaterally. Besides, frontal operculum, posterior insula, anterior orbital gyrus, planum temporale, angular gyrus, middle occipital gyrus, planum polare, anterior insula, posterior cingulate gyrus, parietal operculum, central operculum, lingual gyrus, precuneus, gyrus rectus, basal forebrain and occipital

pole regions were detected unilaterally in the left hemisphere. Further, temporal pole, hippocampus, posterior orbital gyrus, superior temporal gyrus, superior temporal gyrus, fusiform gyrus and inferior
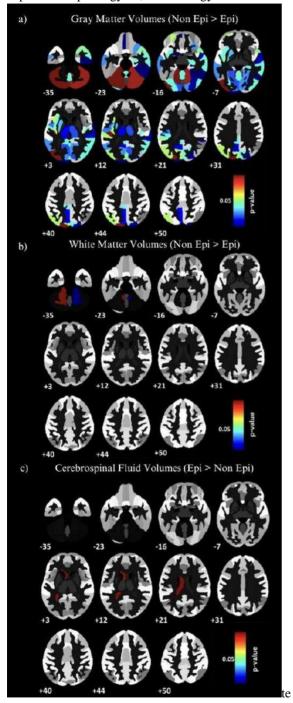
Figure 2: Regional grey matter volume reductions in patients with generalized epilepsy compared to non-epileptic subjects detected by Region-based morphometry (panel a), regional white matter volume

reductions (panel b) and cerebrospinal fluid volume increment (panel c). All detected areas, indicated in blue to red (corresponding p values obtained from two-sample t tests), had reduced GM, WM volumes and increased CSF volume in patients with generalized epilepsy compared with non-epileptic subjects. (p< 0.05, FDR Corrected).

temporal gyrus were detected unilaterally in the right hemisphere of patients with generalized epilepsy (Figure 2a).

A notable volume reduction in white matter was found to be significant in cerebellum (Figure 2b) and an increment of CSF volume was reported in the left lateral ventricle (Figure 2c).

Table 1: Regional gray matter, white matter volume reductions and cerebrospinal fluid volume increment detected by region-based morphometry (RBM) in patients with generalized epilepsy compared to non-epileptic subjects.

Hemisphere	Region (Neuromorphometrics atlas)	T value	P value
GM volume changes			
Left hemisphere	Inferior occipital gyrus	4.3	0.001
	Cerebellum Exterior	4.1	0.001
	Transverse temporal gyrus	4.1	0.001
	Frontal operculum	4.1	0.001
	Posterior insula	3.7	0.003
	Cun cuneus	3.6	0.003
	Anterior orbital gyrus	3.6	0.003
	Planum temporale	3.6	0.003
	Angular gyrus	3.5	0.003
	Middle occipital gyrus	3.5	0.003

	Occipital fusiform gyrus	3.5	0.003
	Planum polare	3.3	0.004
	Anterior insula	3.2	0.004
	Posterior cingulate gyrus	3.2	0.004
	Parietal operculum	3.2	0.004
	Putamen	3.2	0.005
	Middle temporal gyrus	3.1	0.005
	Calc calcarine cortex	3.1	0.005
	Central operculum	3.0	0.006
	Lingual gyrus	3.0	0.007
	Thalamus Proper	3.0	0.007
	Precuneus	2.9	0.009
	Gyrus rectus	2.7	0.009
	Basal forebrain	2.9	0.009
	Occipital pole	2.8	0.009
	Superior occipital gyrus	2.7	0.001
	Cerebellum exterior	4.0	0.001
Right hemisphere	Temporal pole	3.4	0.003
	Hippocampus	3.4	0.004
	Transverse temporal gyrus	3.3	0.004
	Inferior occipital gyrus	3.3	0.004
	Middle temporal gyrus	3.2	0.004
	Cun cuneus	3.2	0.004
	Lingual gyrus	3.1	0.005
	Posterior orbital gyrus	3.0	0.005

	Thalamus Proper	3.0	0.006
	Superior temporal gyrus	3.0	0.006
	Calc calcarine cortex	2.8	0.008
	Superior occipital gyrus	2.8	0.008
	Occipital fusiform gyrus	2.8	0.008
	Fusiform gyrus	2.7	0.009
	Inferior temporal gyrus	2.7	0.009
WM volume changes			
Left hemisphere	Cerebellum White Matter	3.9	0.0008
Right hemisphere	Cerebellum White Matter	3.6	0.0010
CSF volume changes			
Left hemisphere	Left Lateral ventricle	2.5	0.006

A slight reduction of cortical gyrification was detected in the posterior ramus of the lateral sulcus of left hemisphere as shown in Figure 3a. A considerable reduction of sulcus depth was detected in planum polare of the superior temporal gyrus, posterior ramus of the lateral sulcus, occipital pole, inferior segment of the circular sulcus of the insula, and anterior transverse temporal gyrus bilaterally. In addition, anterior transverse collateral sulcus, intraparietal sulcus and transverse parietal sulci, para hippocampal gyrus, para hippocampal region of the medial occipital-temporal gyrus, superior segment of the circular sulcus of the insula, superior occipital gyrus, medial occipito-temporal sulcus (collateral sulcus) and lingual sulcus, superior occipital sulcus and transverse occipital sulcus regions were detected for sulcus depth reductions in left hemisphere. Furthermore, transverse

temporal sulcus, cuneus, planum temporale or temporal plane of the superior temporal gyrus were detected for sulcus depth reduction in right hemisphere as shown in Figure 3b.
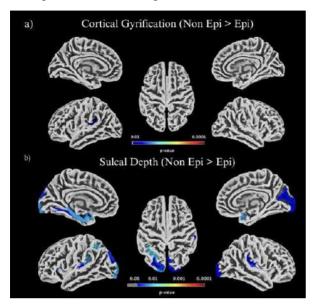
Figure 3: Regional cortical gyrification surface value reductions (panel a) and regional sulcal depth surface value reductions (panel b) in patients with generalized epilepsy compared to non-epileptic subjects detected by region-based morphometry. All detected areas, indicated in blue to red (corresponding to p values obtained from two-sample t tests), had reduced cortical gyrification and sulcus depth surface values in patients with generalized epilepsy compared with non-epileptic subjects. (p< 0.05, FDR Corrected). The regions are displayed based on aparc2009 atlas.

Table 2: Regional cortical gyrification and sulcal depth reductions detected by region-based morphometry (RBM) in patients with generalized epilepsy compared to non-epileptic subjects.

Hemisphere	Atlas region (Aparc 2009)	T value	P value
Cortical gyrification			
Left	Posterior ramus of	4.0	0.009
Hemisphere	the lateral sulcus		
Sulcal Depth			
Left Hemisphere	Vertical ramus of the anterior segment of the lateral sulcus	4.6	0.001
	Anterior transverse collateral sulcus	4.0	0.004
	Intraparietal sulcus and transverse parietal sulci	4.0	0.009
	Planum polare of the superior temporal gyrus	3.6	0.009
	Posterior ramus of the lateral sulcus	3.2	0.013
	Occipital pole	3.2	0.013
	Para hippocampal gyrus, Para hippocampal part of the medial occipital-temporal gyrus	3.2	0.013
	Superior segment of the circular sulcus of the insula	2.9	0.024
	Superior occipital gyrus	2.8	0.028
	Medial occipito-temporal sulcus (collateral sulcus) and lingual sulcus	2.8	0.032
	Inferior segment of the circular sulcus of the insula	2.6	0.038
	Superior occipital sulcus and transverse occipital sulcus	2.6	0.038

	Anterior transverse temporal gyrus	2.6	0.040
Right Hemisphere	Planum polare of the superior temporal gyrus	3.3	0.013
	Anterior transverse temporal gyrus	3.2	0.013
	Transverse temporal sulcus	3.1	0.019
	Inferior segment of the circular sulcus of the insula	3.0	0.023
	Posterior ramus of the lateral sulcus	2.6	0.038
	Occipital pole	2.6	0.038
	Cuneus	2.6	0.038
	Planum temporale or temporal plane of the superior temporal gyrus	2.5	0.040

Pattern classification analyses were performed to classify patients with generalized epilepsy and non-epileptic subjects. These analyses were based on different structural measures such as grey matter volumes, white matter volumes, cerebrospinal fluid volumes, cortical gyrification and sulcus depth. The pattern analysis revealed that each metric shows discriminative power to distinguish patients and non-epileptic subjects (Classification accuracy: 61.1%, 62.2%, 58.8%, 61.1% and 60% for GMV, WMV, CSFV, cortical gyrification and sulcal depth respectively). Pattern classification accuracies and corresponding null distributions are shown in Figure 4.
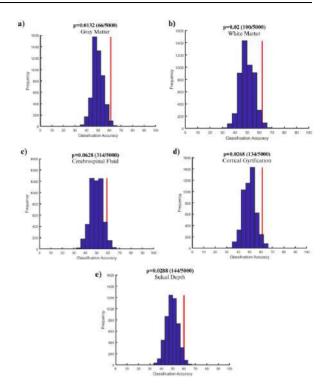
Figure 4: Pattern classification accuracies of WM, GM, CSF, Cortical gyrification, and Sulcal depth of patients with generalized epilepsy differentiated with non-epileptic subjects using 5000 permutation tests.

The classification accuracy is represented by red straight lines, while null distributions from 5000 permutations are represented by bell-shaped GM, WM, CSF, Cortical gyrification and Sulcal depth distributions with 50% center point. The percentage of number of permutations that were greater than or equal to the actual classification accuracy was used to derive the p values. (p-value for GM – 0.0132, p-value for WM – 0.02, p-value for CSF – 0.0628, p value for cortical gyrification – 0.0268 and p-value for sulcal depth- 0.0288)

4. DISCUSSION

We used Region Based Morphometry to characterize morphological brain changes in generalized epilepsy over non-epileptic subjects. We found significant morphological changes for multiple metrics considered in our study. Further, the above metrics have been well performed in classifying patients and non-epileptic subjects.

A limited number of studies have been performed for generalized epilepsy using RBM and most of them have been confined to one type of metric. Our study being comprehensive and systematic work, we used both volume (GM, WM, and CSF) and surface parameters (cortical gyrification and sulcus depth) in the same study. We believe that these findings could provide a better insight into structural characteristics of brain cortex and sub-cortex in patients with generalised epilepsy.

As strengths of using region-based morphometry, it makes possible due to pre specified areas that were used to find cortical volume differences. Besides, the ROI method shows anatomical validity subsequently and absolute volume values of the voxels of specified regions compared to the given results of concentration of voxels by VBM. In VBM the brains are analysed at voxel level and therefore it is more prone to multiple comparison errors at statistical analysis. In contrast to VBM, RBM shows less multiple comparison errors as the comparison is performed between limited number of regions (Giuliani *et al*., 2005, Seyedi *et al*., 2020).

Grey matter volume reductions detected in our study (cerebellum, frontal lobe, temporal gyruses, thalamus, and hippocampal region) have been well repeated by many previous studies in different extent (Betting *et al*., 2006, Ciumas and Savic, 2006, Daswatte *et al*., 2023, Ke *et al*., 2017). The study (Ciumas and Savic, 2006) detected volume reductions as follows, cerebellum (Epi : 56.6 ± 6.9 cm^3, Hc : 67.8 ± 6.9 cm^3), thalamus (Epi : 6.5 ± 0.6 cm^3, Hc : 7.2 ± 0.6 cm^3), hippocampus (2.3 ± 0.6, Hc : 2.3 ± 0.4), caudate (Epi : 4.2 ± 0.5 cm^3, Hc : 4.9 ± 0.5 cm^3), putamen (Epi : 56.6 ± 6.9 cm^3, Hc : 5.9 ± 0.5 cm^3), amygdala (Epi : 1.6 ± 0.3 cm^3, Hc : 1.6 ± 0.4 cm^3). However, apart from most of the literature, several regional grey matter volume reductions in our study were only reported unilaterally (right hippocampus, right fusiform, right superior frontal, right inferior occipital, right superior parietal and left post central, left thalamus, left middle frontal, left putamen, left insula). Other than that, our study observes reduced GM volume in cingulate gyrus bilaterally, and another study selected 6 ROIs of cingulate cortex (t values: 3.35, 3.45, 4.13, 4.24, 3.20, 3.14 for left anterior, right anterior, left middle, right

middle, left posterior, right posterior respectively) for which reduced GM volumes (Ke *et al*., 2017).

White matter volume reductions detected in our study bilaterally in cerebellum have been well repeated by many previous studies in different extent. The study (Li *et al.*, 2010) revealed that FA values were significantly lower in AAL regions of cerebellum -6-R and cerebellum -4-5-R unilaterally in the right hemisphere. (p values: 0.002). Another study revealed significant lower FA values of 6 white matter tracts related to the cerebellum (Liu *et al.*, 2011). Moreover, (Betting *et al.*, 2006) found that there were WM abnormalities in frontal lobe bilaterally.

Amongst the limited number of studies which were performed to detect CSF changes in generalised epilepsy patients over non-epileptic subjects, stated that there was an enlargement of left lateral ventricle while our study also detected and described a slight increment of CSF in left lateral ventricle (Betting *et al.*, 2006). Fraction of CSF was increased (pre-and postcentral gyrus, superior, middle, inferior, medial frontal gyrus) according to another study (Ciumas and Savic, 2006).

Only a limited number of research studies have been performed to observe gyrification and sulcal depth. Similar results in comparison to our study showed in the regions which were occipital pole of occipital lobe, insula in left hemisphere unilaterally, cuneus in right hemisphere unilaterally and temporal pole of temporal lobe bilaterally with Oyegbile *et al*., 2004 study. Apart from that, this study observes a reduction of cortical gyrification in the left posterior ramus of the lateral sulcus unilaterally and anterior transverse collateral sulcus, intraparietal sulcus and transverse parietal sulci, para hippocampal gyrus, para hippocampal region of the medial occipital-temporal gyrus, lingual sulcus and regions were detected for sulcus depth reductions in the left hemisphere. Furthermore, transverse temporal sulcus, cuneus, planum temporale or temporal plane of the superior temporal gyrus were detected for sulcus depth reduction in right hemisphere.

Our study can be considered as the first evidence for differentiating patients with epilepsy and non-epileptic subjects by using multiple structural metrics under region-based morphometry. This study used both volumetric values and surface values for multivariate comparisons of regional morphological changes of epilepsy patients over non-epileptic subjects. More specifically, white matter had the highest classification accuracy of 62.2 % and 61.1 % for gray matter, 58.8 % for cerebrospinal fluid. According to the surface data, cortical gyrification had 61.1 % classification accuracy and 60% sulcal depth as well. Overall, poor CSF changes detected in epilepsy patients as compared to gray matter and white matter changes may be the cause of the reduced classification accuracy of CSF in differentiating between the epilepsy and non-epileptic subjects.

We observed several limitations in the study. Since this is a cross-sectional study, the study was conducted based on the data available on the radiology database. Therefore, it was difficult to find some baseline characteristics such as age, gender and clinical data on all subjects in the database. Then, the sample size was limited and that may have contributed to reduced statistical power and we were unable to conduct further subgroup analysis due to the modest sample size. The clinical impact of the above morphological changes was not considered in this study due to the cross-sectional nature of the design. Further, it would be better to determine dynamic brain developments by examining the changes over time in future studies.

5. CONCLUSION

In conclusion, our research study provides a comprehensive understanding about regional morphological changes associated with generalized epilepsy using region-based morphometry. It describes both cortical and sub-cortical regional volume changes associated with generalized epilepsy. Furthermore, the multivariate approach provides low accuracies that may not be instrumental for applying clinical diagnosis of the condition.

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UTILIZING TRADITIONAL KNOWLEDGE FOR DEVELOPMENT IN SRI LANKA: A LEGAL ANALYSIS WITH A SPECIAL EMPHASIS ON INTELLECTUAL PROPERTY LAW

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ABSTRACT

Traditional Knowledge was not originally recognized as a part of the realm of intellectual property rights as its unique attributes did not align with the theoretical underpinning of intellectual property rights. Nevertheless, an emerging trend occurred with Traditional Knowledge becoming susceptible to unauthorized appropriation by third parties without sharing benefits with the knowledge holder, which was commonly referred to as biopiracy. Consequently, developing nations, along with indigenous communities, started advocating for an expansion of the scope of intellectual property law to protect and preserve Traditional Knowledge. Sri Lanka, often renowned for its cultural and biodiversity richness, is a treasure trove of Traditional Knowledge. However, the absence of an adequate legal framework addressing Traditional Knowledge, coupled with a number of failed Legislative attempts such as the Genetic Resources – Access and Benefit Sharing Act of 2000 and 2009 Bill has placed Sri Lanka in a disadvantageous position. Therefore, it is the objective of the researcher to introduce a comprehensive legal framework related to Traditional Knowledge, under IP law, considering the rights of the knowledge holders and the potential for commercialization to achieve the development of the country. This study looks at international standards and Indian laws and policies to gain insights on enhancing the Sri Lankan legal framework. Consequently, the researcher proposes several defensive and positive measures that can be implemented to strengthen the legal framework pertaining to Traditional Knowledge in Sri Lanka. The researcher finds that Sri Lanka could benefit from a sui generis law that takes into account the dual objectives of creating value from Traditional Knowledge and safeguarding the rights of knowledge holders, thereby promoting the country's development.

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1. INTRODUCTION

This study seeks to explore the challenges associated with Traditional Knowledge in Sri Lanka and analyze the potential reforms required within the current intellectual property framework for the protection and management of Traditional Knowledge, with the aim of harnessing its potential for the country's long-term development objectives while recognizing the interests of the Traditional Knowledge holders.

The advancement of technology resulted in a profound shift from the labor-intensive economic model of the industrial age to a 'knowledge-based economy,' where economic growth is highly driven by knowledge, innovation, and intellectual assets. The success and expansion of science-based technologies such as biotechnologies and advanced pharmaceutical manufacturing methods underscore the power of knowledge in driving economic growth. This massive success further highlights the significant role of the Intellectual Property Rights (IPR) regime in effectively regulating and managing knowledge. Unlike conventional IP rights such as patents, copyrights, and trademarks, Traditional Knowledge (hereinafter referred to as TK) involves a category of knowledge that is inherent to indigenous peoples and local communities and has a long history and cultural traditions. At the present era, this special type of 'knowledge' known as TK has shaped the global knowledge economy, especially through the biotechnological revolution, during which the application of recombinant DNA and DNA sequencing procedures spurred TK's commercial applicability in different areas, especially in the agricultural and pharmaceutical sectors (Dagne, 2012). Nevertheless, at first, Traditional Knowledge was largely disregarded and excluded from the realm of intellectual property, often being viewed as part of the public domain by western nations, which spearheaded the development of international norms.

Scholars often rationalize the exclusion of Traditional Knowledge from intellectual property rights by referring to the narrow utilitarian theory that IPRs are designed to induce innovation and intellectual creativity. (Dagne, 2012) suggests that the absence of intellectual property rights (IPR) protection leads to inadequate incentives for innovators, which, in turn, diminishes the societal benefits derived from innovation. Thus, the utilitarian standpoint does not coincide with the principles of TK, as Indigenous people and local communities are dedicated to creating, preserving, and passing knowledge as an essential aspect of their survival and group cohesion rather than for any financial gain or incentive for commercialization of inventions.

Therefore, TK and its applications were originally viewed as part of the "commons," referring to resources openly accessible for the collective benefit of humanity, thus positioning them as "global commons" (Dagne, 2012). This provided the leeway for different entities to freely encroach upon and commercialize products developed using TK associated with specific indigenous or local communities in developing countries, without sharing any profits with them. Such widespread misappropriation, misuse, and exploitation of TK beyond its traditional use have resulted in the emergence of a troubling phenomenon known as biopiracy. Hence, developing countries and several indigenous communities started raising concerns emphasizing the need to expand the scope of intellectual property law beyond its narrow focus to address the wider public interest and development-related concerns. Similarly, Sri Lanka, a developing nation, is currently grappling with the challenges posed by the illegal acquisition of bio-resources and the consequential impact on its diverse TK.

Thus, the present study will assess the legal protection afforded to traditional knowledge in Sri Lanka, in light of the existing intellectual property law framework. Furthermore, recommendations will be proposed, taking into account the findings and references drawn from India and examining their intellectual property measures carried out in relation to TK to promote progress.

Accordingly, this study will commence by delineating the concepts of 'Traditional Knowledge' and 'development.' Subsequently, it will delve into international standards relevant to TK. Next, the

article will engage in a comprehensive analysis of Sri Lanka's legal framework concerning TK, followed by a review of Indian policies and laws aimed at protecting of TK. The study will culminate with an overview of its findings.

2. METHODOLOGY

This study adopts the qualitative research methodology to address the challenges pertaining to TK that has arisen in Sri Lanka, while employing a doctrinal legal study to assess the legal framework related to Traditional Knowledge within the context of intellectual property law in Sri Lanka. It seeks to identify the international standards, Indian laws, and policies pertaining to TK and provides suggestions to improve the legal framework in Sri Lanka. The findings of this study will be utilized to propose a sui generis law for TK in Sri Lanka, with the overarching aim of fostering economic growth while upholding the rights of the knowledge holders. The researcher employs primary sources such as international standards, domestic laws, and case law, while secondary sources, including books, and journal articles, are utilized to provide further insights.

Sri Lanka, a nation characterized by its rich biodiversity and vibrant cultural heritage is in critical need of an adequate legal framework, as it is continuously facing threats of misappropriation of TK by diverse entities. Thus, in its endeavor to suggest a robust legal framework that safeguards the interests of the knowledge holders while facilitating development, this study will engage in a conceptual analysis of the terms 'Traditional Knowledge' and 'Development' as follows.

3. DISCUSSION

Traditional Knowledge

Traditional Knowledge (TK) is a category of living knowledge that is deeply embedded in historical and cultural heritage and passed down through generations among indigenous peoples and local communities. It forms an integral part of the cultural or spiritual identity of the knowledge holders. Van den Daele identifies TK as "embedded knowledge," which extends beyond useful information to encompass

significant social and cultural meanings (Van den Daele, 2004).

As there is no uniform definition, TK is at times defined in a general sense to include the concept of 'Traditional Cultural Expressions' (hereinafter referred to as TCEs) such as dances, poetry, riddles, folk tales, folk songs, instrumental music, and handicrafts. In a strict meaning, TK is distinguished from TCEs and is found to take the form of know-how, customs, beliefs, rituals, practices and innovations (WIPO, 2018). These may take the form of knowledge pertaining to plant breeding techniques, preparation of medicine and food, irrigation methods, social norms, spiritual and religious beliefs, ceremonies and symbols etc. It is present in a wider range of contexts, inter alia scientific, technical, agricultural, medicinal, ecological, and biodiversity-related knowledge (WIPO, 2018).

The significance of TK is particularly emphasized in the management and conservation of biological resources. The Convention on Biological Diversity (CBD), being the first international treaty to formally recognize TK, highlights the vital role of protecting TK in order to preserve biological resources.

It is pertinent to note that the implementation of legal frameworks that protect traditional knowledge can contribute to the conservation of biodiversity, the preservation of cultural traditions, the promotion of intercultural communication, and ultimately help to achieve the development goals of a country.

Development

The term 'development' simply denotes the state of improvement in the standard of living. It can be viewed as a multidimensional concept that transcends beyond the concept of economic growth, incorporating other factors such as social progress and environmental sustainability as well. The parameters of development have often been subject to change and have been defined by scholars from numerous perspectives. Amartya Sen's capabilities approach shifts the focus from traditional economic indicators to a broader aspect of human flourishing, ultimately enhancing individuals' capabilities that drive development (Sunder, 2008). The capabilities

approach has been further elaborated upon by other scholars, such as Nussbaum, and currently serves a significant role in shaping international instruments and frameworks related to development.

Grounded in the notion of human dignity and the inherent worth of every individual, Sen's capability approach acknowledges the intersectionality of capabilities and human rights. Thus, the right to participate in cultural life, enjoyment of progress in the arts and sciences, rights of minority and indigenous people, and preservation of cultural heritage, including TK, remain integral components of rights-based development (Article 27, Universal Declaration of Human Rights, 1948).

In addition, the principle of sovereignty over natural resources is an integral part of the right to self-determination, as stated by the UN General Assembly in 1962 (United Nations General Assembly, 1962). Thus, it is of the utmost importance for developing nations to protect their sovereignty over their natural resources and wealth, including protection of Traditional Knowledge.

The protection of TK within the framework of intellectual property law is typically carried out through two main avenues: the defensive approach and the positive approach (Kumar, Das, 2010). The defensive approach aims to prevent unauthorized third parties from obtaining or maintaining intellectual property rights owned by knowledge holders. The positive approach places emphasis on the recognition of the rights inherent to indigenous peoples or local communities in relation to TK. Both of the above approaches serve to ensure the rights of the aforementioned communities are protected. Moreover, the commercialization of TK, which is facilitated by the intellectual property law framework, can lead to improved standards of living for the knowledge holders, which may ultimately benefit the economic growth of the country. In addition, this may further incentivize the preservation of TK among knowledge holders. Hence, establishing a comprehensive legal framework in intellectual property law concerning TK is crucial to facilitating long-term development goals.

International Standards

In the early 1990s, international attention was drawn to the threats posed to biodiversity and the need for the conservation of biological resources. This was further catalyzed by the voices of indigenous communities, scientists, environmentalists, and developing countries. Accordingly, steps were taken to implement CBD, the Nagoya Protocol, and various WIPO mechanisms pertaining to TK, and Genetic resources. Despite the lack of explicit provisions related to TK, and genetic resources, the Trade Related Intellectual Property Rights' (TRIPS) Agreement has recognized the importance of safeguarding TK and TCEs in the 2001 Doha Declaration, under the influence of developing countries (Kumar, Das, 2010).

CBD

The idea of the Convention on Biological Diversity (CBD) was introduced during the Rio Convention, also known as the Earth Summit, in 1992 as an instrument to address challenges posed to biodiversity (Convention on Biological Diversity, 1992). It is the first international legal instrument to explicitly address the need to protect TK as a means of preserving biological resources. CBD can be identified as the first step to shifting genetic resources and their associated TK from the realm of the 'global commons' to one where nations can exercise their sovereign rights.

The core principles of this Convention are rooted in the three main pillars of conservation of biological diversity, sustainable use of its components, and fair and equitable sharing of the benefits arising from the use of genetic resources (Article 1, Convention on Biological Diversity,1992). It further ensures that the fair and equitable sharing of the benefits should be achieved by appropriate access to genetic resources and by appropriate transfer of relevant technologies (Article 1, Convention on Biological Diversity,1992).

The Nagoya Protocol on Access and Benefit-Sharing

With the aim of strengthening the third pillar of the CBD, i.e, equitable sharing of benefits under the CBD, the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising

from Their Utilization was put into effect in 2010. Unlike its precursor, the Bonn Guidelines, the Nagoya Protocol employs stricter language, featuring terms such as 'enforced' rather than 'encouraged' as a binding legal mechanism. It regulates better access and the fair and equitable distribution of benefits derived from the use of TK held by indigenous and local communities. In this protocol, Article 5 specifically stipulates the measures related to fair and equitable benefit-sharing that the acceding parties should follow. As per Article 7 of the Nagoya Protocol, accessing TK associated with genetic resources requires prior informed consent or approval, along with the active involvement of indigenous and local communities. This underscores the importance of reaching a mutual agreement between the parties involved. (Article 9, The Nagoya Protocol on Access and Benefit-Sharing, 2010). The provisions outlined in Article 9 require the members to actively promote and foster the participation of users and providers in the conservation and sustainable utilization of genetic resources. Article 12 requires the implementation of mechanisms to inform potential users about the obligations related to TK associated with genetic resources (Article 12, The Nagoya Protocol on Access and Benefit-Sharing, 2010). Additionally, parties are mandated to support the development of community protocols, minimum requirements for mutual agreements, and contractual clauses by indigenous and local communities, with a particular emphasis on women, to ensure equitable benefit sharing arising from the utilization of TK connected with genetic resources.

The Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS)

After CBD recognized the sovereign rights of nations over their biological diversity, the TRIPS Agreement was introduced to ensure effective and adequate protection of intellectual property rights (IPRs) for new inventions, technologies, and products developed by individual or corporate bodies. It should be noted that the provisions of the TRIPS Agreement does not provide explicit protection for the TK and innovations of indigenous and local communities within its provisions. Nevertheless, according to Dutfield, it

affords the member states the flexibility to create an unconventional intellectual property protection framework, particularly through Article 1 (Mugabe, 1999).

In relation to patentable subject matters, Article 27(3) of the TRIPS agreement excludes plants and animals other than microorganisms from patentability (Article 27(3), The Agreement on Trade-Related Aspects of Intellectual Property Rights, 1994). Accordingly, it obliges countries to recognize patents on microbiological life forms. Nonetheless, it is worth noting that the criteria set forth in the TRIPS agreement related to patentability seem to align with the patent norms observed in the industrialized member states of the WTO. Accordingly, the provision outlined above enables biotechnology companies in industrialized countries to readily secure patent rights on different microbiological life forms for the advancement of pharmaceutical and agricultural industries. This has led to pressure from India, Brazil, and African countries, raising concerns and prompting discussions within the TRIPS Council related to safeguarding TK. This led to a new commitment within the Doha Declaration of 2001, to protect TK while taking fully into account 'the development dimension' (Kumar, Das, 2010)

In addition to the aforementioned international instruments, several other mechanisms have been implemented to address the safeguarding of TK at the international level. For instance, the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP) is one such instrument that affirms rights of the indigenous communities to preserve, protect, and develop their cultural heritage, including TK (Article 31, United Nations Declaration on the Rights of Indigenous Peoples, 2007). The International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) acknowledges the significance of farmers' TK in the conservation of plant genetic resources and encourages fair and equitable benefit-sharing. In addition, the Intergovernmental Committee of the WIPO on Intellectual Property and Genetic Resources, Traditional Knowledge, and Folklore (IGC-GRTKF) has addressed several intellectual property concerns related to TK, GR, and TCEs.

Moreover, in the year 2021, the United Nations officially declared the United Nations Decade on Ecosystem Restoration (2021-2030), recognizing the essential contribution of indigenous peoples and local communities in the effort to restore ecosystems, biodiversity, and associated TK.

Sri Lankan Context

Sri Lanka is known for its diverse ethnic cultures, traditions, values, and a rich biological diversity that includes genetic resources. Although agriculture remains the lowest contributor to Sri Lanka's GDP (7.7%), the country has historical recognition for being self-sufficient in the production of rice (Department of Census and Statistics, 2024). Not only is Sri Lanka globally recognized for its exceptional production of tea, rubber, and coconut, but it also holds the title of being the top global producer and supplier of authentic cinnamon, ranking fourth in terms of cloves production and fifth in nutmeg production (Murigi, 2020). In 2022, Sri Lanka was granted geographical indication certification from the European Union Commission for Ceylon cinnamon, after being recognized for its quality, the long tradition, and the rich history behind its production. The main traditional medical practices in Sri Lanka include Ayurveda, Siddha, Unani, and Deshiya Chikitsa (Weragoda, 1980). Both the Ayurveda and Deshiya Chikitsa practices utilize plant and herbal remedies in disease treatment, with Ayurveda employing approximately 2000 species and Deshiya Chikitsa utilizing about 500 (Weragoda, 1980). In addition, *kem* is a practice used for many purposes, such as healing rituals and agricultural practices. The farmers in Sri Lanka engage in a variety of unique traditional cultivation methods that are unique to the island. Moreover, owing to the wide range of climatic, topographic, and soil conditions present on the island, Sri Lanka is renowned for its dense and diverse array of plants, animals, fungi, and microorganisms, solidifying its reputation as a global biodiversity hotspot.

Nevertheless, throughout the years, TK in Sri Lanka has encountered a multitude of challenges. The unauthorized appropriation of biological resources and associated TK, commonly referred to as biopiracy, presents a significant challenge in Sri Lanka. The most common plant species affected by illegal trafficking in Sri Lanka at present include Walla patta (*Gyrinops walla*), Kothala Himbutu (*Salacia reticulate*), and Handun (*Santalum album*) (Amarajeewa, 2021).

One of the early cases of biopiracy was recorded in the 1970s, during which a foreign company smuggled out Binara flower (*Exactum trivernium*), an endemic plant, to Sri Lanka and sought to obtain patents for the plant, albeit with trivial modifications. One of these patents covered the Maha Binara (*Eitrinervum macranthum*) flower, which is a variant of the Binara flower with drooping stems (Dawoodbhoy, 2019).

In 1985, the Japanese Patent Office approved a patent application, titled "Preventive for Dental Caries" over twelve medicinal plants (Marsoof, Kariyawasam, Talagala, 2022). These products were derived from traditional dental care products that have been in use for generations. Another incident involves a patent license secured by a scientist in New York for the extraction of a plant protein originating from Batu Karawila (*Mormodica chrantia*), which has been scientifically proven to possess therapeutic properties for the treatment of tumors and HIV infections (Marsoof, Kariyawasam, Talagala, 2022).

Notably, the exploitation of the Kothala Himbutu (*Salacia reticulata*), an endemic plant in Sri Lanka, has become a prominent example of bio-piracy, which caught public attention. A Japanese pharmaceutical company named Morganite Jintan KK and an American company called Shaman Pharmaceuticals Inc. had developed a potent glucose inhibitor named salacinol based upon this plant (Marsoof, Kariyawasam, Talagala, 2022). Nevertheless, the therapeutic efficacy of Kothala Himbutu in diabetes management was already recognized in traditional medicine. As per Dr. Gunawardena, out of the 132 patent applications over this plant, 114 are against the interests of Sri Lanka (Gunawardena, 2017).

In addition, Prof. Wijesundara specifically drew attention to instances where plant trafficking is conducted by misleading the authorities. One such case involved the export of Kekatiya (*Aponogeton*

crispus) with the false claim that they were *Aponogeton ulvaceus,* a plant species originating from Madagascar. However, it was later discovered that the plants in question were not the same species as the ones found in Madagascar. Consequently, the exportation of the Kekatiya plant was prohibited, and appropriate measures were taken (Amarajeewa, 2021).

Another incident involved the landmark case concerning the Neem plant patent, which was revoked following protests initiated by India. The company argued that their neem supply originated from Africa rather than being sourced from Asia or India. But, upon review of the registers of the Forest Department of Sri Lanka, it was later identified that the seeds claimed to have been procured from Kenya were, in fact, sourced from Sri Lanka. Accordingly, the patent was revoked (Amarajeewa, 2021). Thus, it becomes evident that there are specific cases in which biopiracy is carried out by exploiting the prevailing administrative authorities and the existing legal framework.

It is crucial to emphasize that such practices not only contribute to the diminishing of cultural identity and biodiversity but also have economic ramifications due to the potential loss of revenue and economic prospects. Parties that capitalize on TK often do not share the benefits of the inventions related to TK with the knowledge holders. Moreover, it is also worth mentioning that the Central Bank in Sri Lanka values the plant based solely on its timber worth without recognizing any intellectual property value associated with the biodiversity in the country (Amarajeewa, 2021). Hence, it is crucial for Sri Lanka to establish an effective legal framework that not only safeguards and conserves TK but also facilitates its commercialization, taking into consideration the rights of the knowledge holders.

Existing Legal Framework in Sri Lanka

Under Article 27(14) of the Constitution, Sri Lanka recognizes the state obligation to protect, preserve, and improve the environment for the benefit of the community (Article 27(14), Constitution of the Democratic Socialist Republic of Sri Lanka, 1978). Further, the reciprocal duty of every person in Sri

Lanka to protect nature and conserve its riches is highlighted under 28(f) of the Constitution (Article 28, Constitution of the Democratic Socialist Republic of Sri Lanka, 1978). Accordingly, the above two provisions provide a general recognition of the government's responsibility to safeguard the environment. Several pieces of environmental legislation have been implemented, upholding the principles embedded in the above two fundamental laws. Nonetheless, none of the above statutes directly deals with Traditional Knowledge.

Sri Lanka, being a member of the World Trade Organization (WTO), has enacted the Intellectual Property Act No.23 of 2006 in line with the TRIPS Agreement. It is pertinent to note that the IPA is the only legal instrument that provides protection for TK in Sri Lanka. Nevertheless, the scope of protection in IPA is limited to Traditional Cultural Expressions and does not afford legal protection for genetic resources or the associated TK (Hewa Geeganage, 2022).

Copyright Law

Section 5 of the IPA interprets the term "expression of folklore," while Section 6 recognizes folklore as a protectable work under copyrights. Section 24 of the IPA delineates different forms of exclusive rights granted for folklore expressions, along with their limitations. Furthermore, this provision stipulates that the source of such TCEs must be indicated and that a prescribed fee be levied for the purpose of cultural development. As corresponding provisions for genetic resources and associated Traditional Knowledge are lacking, it poses a significant drawback in the IPA framework.

Patent Law

Patent law, Section 62(3) b excludes plants, animals, and microorganisms that are not genetically altered from patentability. Thus, it is in recognition of domestic law that plants, animals, and microorganisms which are not genetically altered are in the public domain. It should be noted that the Intellectual Property Bill originally stipulated that microorganisms are patentable, although it is not the same case for plants and animals. The Supreme Court in re Determination of the Intellectual Property Bill

determined that its necessary that patentability should only be recognized within transgenic microorganisms and not of all the microorganisms (S.C. Special Determination Nos. 14, 15 16/2003). Accordingly, in order to address its unique needs, Sri Lanka has tailored the provisions of the IPA, deviating from strict adherence to the TRIPS Agreement.

Nevertheless, it is pertinent to note that the recognition of plants, animals, and microorganisms in their original form as part of the public domain may open the door for entities, which engage in biopiracy to take advantage of boundless possibilities, underscoring the necessity for restrictions. Hence, laws must be introduced mandating the requirement of consent from the knowledge holder for the usage of plants, animals, and microorganisms associated with TK for patents.

<u>Geographic Indications</u>

Moreover, the enactment of the Intellectual Property (Amendment) Act 2022 (Act No. 7 of 2022) aims to safeguard geographical indications upon registration. In the realm of intellectual property, it pertains to products or services that originate from a territory or a specific region or locality within that territory, where the quality, reputation, and characteristics of the goods are essentiality attributed to the geographical origin. The use of Geographical Indications (GIs) can indirectly safeguard TK by preventing the misuse of goods derived from TK associated with a specific region or the false association of goods with a particular geographical area (WIPO, 2014). Moreover, when integrated with effective branding strategies, GIs have the potential to not only alleviate the decline of TK but also enhance export performance and ultimately contribute to the long-term development objectives of the country. In addition, under trademark law, the collective marks and certification marks may provide indirection protection by helping establish the authenticity and quality of the goods associated with TK and prevent misuse.

Draft Laws and National Policies

Moreover, even though Sri Lanka has ratified the CBD, there is no existing legal framework in place to specifically deal with access to genetic resources and associated TK. In 2000, efforts were made to introduce a draft law titled, the Genetic Resources – Access and Benefit Sharing Act of 2000, which did not progress to become a part of the national law (Marsoof, Kariyawasam, Talagala, 2022). Moreover, in 2009, a draft legal framework for the Protection and Management of Traditional Knowledge was introduced by the Intellectual Property Office of Sri Lanka which was not incorporated into Sri Lankan legal framework. This proposal provided for registration of traditional knowledge and proposed the establishment of a TK registry. The proposal further recognized knowledge holders' rights and their limitations and proposed the protection for 50 years from the date of registration or death of the holder. In cases where a group of knowledge holders are involved, the term of protection lasts until the death of the last surviving knowledge holder. Moreover, the proposal provided for licensing of TK. Nevertheless, the above proposed legislative attempt was not successfully implemented. Furthermore, several weaknesses could be identified in relation to the 2009 Bill.

One of the major drawbacks appears to be the lack of involvement of the indigenous community in the decision-making process. Furthermore, the traditional knowledge fund suggested under Section 26 require further revision to effectively benefit the knowledge holder. Accordingly, it is imperative that the control and freedom in maintaining the funds are entrusted to the knowledge holders themselves. Although, the minimum royalty and license fee can be prescribed by the Government, it is necessary that the governmental intervention remains minimal. In addition, Section 17(1) empowers DG to disclose information regarding knowledge holder and the benefits of TK to third parties subject to a prescribed fee. Nevertheless, in order to ensure the confidentiality of TK, it is necessary that such information should be disclosed subject to the prior consent of the original knowledge holder. Furthermore, Section 17(2) under the proposal provides the DG and any other state officer access to register of TK in the discharge of their duties. Nevertheless, the proposal seems to lack any accountability mechanism to ensure lawful access of

TK by State Officers. The draft law further requires clarity in relation to the procedure of obtaining prior informed consent, especially when multiple knowledge holders exist. In addition, the draft law does not seem to have strong protection against misappropriation by foreign entities. Accordingly, it is imperative that these deficiencies be rectified in any future legislative endeavors.

In 2020, National Policy and Strategies on Traditional Knowledge and Practices Related to Biodiversity was introduced. This included proposals for amendments to be made to intellectual property laws to combat the unauthorized use of TK and bad faith practices in knowledge sharing. Nevertheless, no significant progress has been made in implementing these proposals (National Policy and Strategies on Traditional Knowledge and Practices related to Biodiversity, 2020). Furthermore, in the same year, a National Policy on Access to Biological Material and Benefit Sharing was introduced to provide a mechanism related to access of biological resources and associated TK and to encourage fair and equitable sharing of benefits derived from biological resources and associated TK, with due consideration for intellectual property rights issues (National Policy on Access to Biological Material and Benefit Sharing, 2020).

The aforementioned legal policies do not possess the power to compel adherence. Hence, the absence of binding legal statutes concerning biological resources, and the associated Traditional Knowledge can be identified as a notable deficiency within the legal system.

Indian Legal Framework and Other Initiatives

India is a country with a rich diversity of species and is considered one of the countries with the largest megadiversity in the world. India has been at the forefront of the global movement to introduce international instruments related to TK. It should be noted that India has followed a defensive approach, seeking to guard against unauthorized intellectual property rights obtained by third parties over Traditional Knowledge, rather than pursuing a positive approach (Kumar, Das, 2010).

Patent Law:

India has not recognized the patentability of TK within the Patents Act, 1970. Especially Section 3(p) of the Patents Act 1970 excludes any TK or an aggregation or duplication of known properties of traditionally known component(s) (Section 3(p), Patents Act, 1970). Nevertheless, under Section 10(4)(D)(ii) of the Patents Act 1970, lawmakers have ensured that patent applicants disclose the sources of TK and the origin of the invention in question in case TK is involved (Section 10(4)(D)(ii), Patents Act, 1970).

Moreover, the Patents (Amendment) Act, 2005, was later enacted with the special aim of protecting and preserving the rights of indigenous communities. These amendments were introduced alongside the Prior Informed Consent (PIC) and benefit-sharing requirements of the Biological Diversity Act, 2002, to effectively address the challenges posed by biopiracy at a domestic level (Jose, 2021). The 2005 amendments have outlined several bases for refusing a patent application or canceling a patent. These bases include failure to disclose or misrepresentation of the geographical origin of biological resources associated with the patent and anticipation of the patent having regard to the knowledge of the indigenous community (Jose, 2021).

The Geographical Indications of Goods (Registration and Protection) Act, 1999

As mentioned earlier, GIs can be utilized for obtaining indirect protection over TKs. The Indian Geographical Indications of Goods (Registration and Protection) Act provides legal protection over TK, which is associated with particular geographic areas and prevents misuse of GIs related to specific goods involving TKs. Further, it prevents the false attribution of traditional practices followed during the manufacturing of goods belonging to a certain area.

The Biological Diversity Act 2002 (BDA)

India has introduced the BDA to addresses access to genetic resources and associated knowledge by foreign individuals, companies, or institutions, and to ensure equitable sharing of benefits from the use of these knowledge and resources by the country and the

people. It necessitates the permission of an authority named the National Biodiversity Authority, whenever a person has applied for a patent involving biological resources and/or associated TK (Section, 19, Section 21, The Biological Diversity Act, 2002).

Moreover, another key highlight would be the Traditional Knowledge Digital Library (TKDL), initiated by the Indian government, which contains a digital database of Traditional Knowledge associated with medicinal and other plants. The database is classified according to the Traditional Knowledge Resources Classification (TKRC) system, which is linked to the International Patent Classification (IPC) system, which helps prevent the approval of patents that are already in the public domain (WIPO, 2011). Moreover, village-wise Community Biodiversity Registers (CBRs) are established in all states for documenting all knowledge, innovations, and practices (Kumar, Das, 2010).

Moreover, India has taken several measures to ensure access by users with prior consent and just and equitable benefit sharing among the users and the knowledge holder, parallel to Article 8(j) of the CBD. Accordingly, India has introduced a model of benefit sharing, referred to as the TBGRI Model or Pushpangadan Model, that was first applied to a patent of herbal formulation named 'Jeevani' obtained with a mutual agreement with the Kani Tribe in India. Pursuant to the model, the Kani tribe was granted a 50% share of the royalty and license fee. The majority of the Kani tribe agreed to establish a trust, which was fully owned and managed by the tribe themselves.

4. RECOMMENDATIONS:

When assessing the required legal reforms to safeguard TK in Sri Lanka, it is crucial to focus on two elements of protection: defensive protection and positive protection. Defensive protection involves the prevention of the unauthorized acquisition or maintenance of IP rights by third parties outside the community of knowledge holders.

Hence, in order to adopt a defensive stance, it is essential to make several amendments to the existing patent law in Sri Lanka. Similar to the Indian Patent

Law, Sri Lanka should introduce amendments to the existing provisions of patent Chapter in the IPA to require disclosure of the geographical origin and the community from whom the knowledge was obtained. Furthermore, grounds for cancellation or revocation of the patent should include the non-disclosure of origin or misrepresentation of origin of the biological resources relevant to the Patent. The Director General of the Intellectual Property Office should be granted explicit authority to revoke or cancel a patent in such instances.

There are several laws in Sri Lanka that impose criminal liability on parties engaged in biopiracy. However, it is suggested that the willful non-disclosure of the source and geographical origin of biological resources used in the invention or misrepresentation should be recognized as intellectual property-related offenses under Chapter XXXVIII of the IPA (Intellectual Property Act, No. 36 of 2003).

Furthermore, measures need to be taken to establish a searchable database of traditional medicine in Sri Lanka, akin to India, that is interconnected with international patent search databases. This will gather evidence of prior art in Sri Lanka and effectively prevent the approval of patent applications that involve bioresources and associated TK belonging to Sri Lanka on an international level. Moreover, it should strike a balance, where they serve as evidence of prior art globally while also maintaining the confidentiality of the knowledge belonging to indigenous populations and other communities.

The positive approach entails recognizing the intellectual property rights of knowledge holders and enabling them to acquire, assert, and use TK and TCEs, as well as to control their uses and to benefit from commercial exploitation. Some jurisdictions have introduced sui generis law specifically recognizing the intellectual property rights of the indigenous people and the local community, while other jurisdictions try to utilize the existing IP legal framework to protect TK and TCEs.

Moreover, the strategies delineated in the National Policy and Strategies on Traditional Knowledge and Practices Related to Biodiversity 2020 included

acknowledgement of the intellectual property rights of Traditional Knowledge holders. Hence, it is suggested that Sri Lanka implement a sui generis law that specifically aims at recognizing the rights related to biological resources and associated TK in conjunction with the existing IPA.

Accordingly, sui generis law should be introduced, which grants rights to knowledge holders upon registration. Moreover, the registry must ensure that the intricate details of TK remain confidential, even when conducting searches for prior art. The legal framework must clearly outline the subject matter eligible for protection, the duration of protection, and the criteria for eligibility for protection. Furthermore, the nature of the rights granted to the knowledge holder and the limitations on the said rights should also be provided. To ensure the fair resolution of any conflicts that may arise between the users and knowledge holders, and knowledge holders themselves, it is crucial to establish a separate dispute resolution mechanism. Alternatively, the Director General of the NIPO can be empowered with the appropriate authority to determine such matters. Moreover, stronger provisions should be introduced to protect the traditional knowledge from being misappropriated by foreign entities.

In addition, provisions related to the commercialization of TK should be included in the sui generis law. In relation to commercialization of TK, it is imperative to give due consideration to two aspects as per the CBD, especially concerning access: obtaining prior informed consent for the access of bioresources and TK and ensuring a just and equitable sharing of benefits between the knowledge holder and the user (Article 15(4), Article 15(5), Convention on Biological Diversity, 1992).

Moreover, at present, the National Policy on Access to Biological Material and Fair and Equitable Benefit Sharing (NPABM&FEBS) ensures that the material transfer agreement (MTA) is entered into with prior informed consent (PIC) for access and with mutually agreed terms (MAT) (Clause 6(iii), National Policy on Access to Biological Material and Fair and Equitable Benefit Sharing, 2020). In accordance with the above

policy, the recognition of knowledge holders' rights is ensured through contractual terms. Nevertheless, it is necessary to recognize the rights of the knowledge holders, going beyond contractual provisions, with the capacity to impose civil as well as criminal liability in instances of willful infringement.

It is pertinent to note that the draft laws titled, Genetic Resources – Access and Benefit Sharing Act 2000 and the Legal Framework for the Protection of Traditional Knowledge in Sri Lanka 2009 have included some of the above recommendations regarding defensive and positive protection within their proposal. However, these draft legislations failed to materialize and have been subject to numerous criticisms. Hence, provisions of the previous draft laws could be integrated into the sui generis law, provided that they are revised as per the contemporary needs of the country.

5. CONCLUSION

With its abundant cultural and biological diversity, Sri Lanka stands as a country of immense TK. Nevertheless, TK in Sri Lanka remains vulnerable due to the absence of a legal framework that directly addresses the challenges concerning TK. While the Intellectual Property Act (IPA) partially safeguards Traditional Cultural Expressions, it does not afford protection for genetic resources and the associated TK. It is pertinent to note that Sri Lanka has witnessed multiple failed initiatives to regulate biological resources and TK. Moreover, the national policies enacted have not provided a satisfactory resolution either. Hence, it is imperative for Sri Lanka to implement a comprehensive legal framework that maximizes the economic potential of TK, while also upholding the rights of its holders. In light of the foregoing, the researcher concludes that Sri Lanka, in its pursuit of rights-based development, should introduce a sui generis law that encompasses both the recognition of rights and provisions related to commercialization.

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REVIEWING THE EFFICIENCY AND REALITY OF PREVENTION OF DOMESTIC VIOLENCE ACT, NO.34 OF 2005 THROUGH THE LENS OF FEMINIST PERSPECTIVES

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ABSTRACT

Domestic violence is a timeless topic which has been even in the legislative discourse. This paper analyses the Prevention of Domestic Violence Act, No.34 of 2005 in light of two feminist theories, namely, liberal feminism and third world feminism. Even though one may celebrate the incorporation of the above Act, it is problematic to what extent the Act satisfies its objective of prevention of domestic violence. By utilizing the Black Letter Methodology, the author finds that regardless of the Act being a gender-neutral law on its surface, in its practical application it intersects with many gendered aspects which ultimately discriminates women. Thus, the responsible authorities have not been successful in effectively addressing such inherent issues of the Act. The purpose of this study is to suggest solutions while highlighting theoretical underpinning a d justifying in reference to selected international conventions. As per the knowledge of the author this is the only Sri Lankan paper which analyses the Prevention of Domestic Violence Act, No.34 of 2005 in light from feminist legal perspectives.

KEYWORDS: *Domestic violence, Gender discrimination, Liberal feminism, Third world feminism*

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1. INTRODUCTION

Initially in the Western world different strands of feminism emerged advocating for gender equality and non-discrimination based on sex, which eventually influenced the Eastern minds. The subject-matter of this research paper is broadly located within the feminist legal theories; thus, the focus is Sri Lanka.

It is accepted that violence against women diminishes the attainment of equality and breaches fundamental rights and/or freedom of women which restricts their ability to enjoy their lives to the fullest. The imbalance of power has resulted in discrimination and dominance over women throughout the history. In comparison to male counterparts, females are compelled to hold an inferior position (UNGA Resolution 48/104, 1993).

Firstly, the discussion focuses on analyzing the Prevention of Domestic Violence Act, No.34 of 2005 (hereinafter referred to as PDV Act) in light of liberal feminism referring to gender-equality.

The Second portion of the discussion is inspired by the notion of gender justice. It contains three recommendations for progressive improvement of the law. The theories, namely, cultural feminism and third-world feminism provide theoretical underpinnings of the recommendations. Further, the author refers to the Convention on Elimination All Forms of Discrimination against Women (1979) (hereinafter referred to as CEDAW) and Declaration on the Elimination of Violence against Women (1993) to further substantiate the recommendations.

2. METHODOLOGY

Using Doctrinal Research Methodology, commonly referred to as Black Letter Approach, the author has examined the observed research gap and developed recommendations for legal improvements. The Prevention of Domestic Violence Act, No.34 of 2005, alongside relevant international conventions have been examined as primary sources. Additionally, International and Comparative Research Method has assisted to analytically refer similar factual scenarios of different cultural and country settings. Research papers, journals, and textbooks were chosen by the author as suitable secondary sources. The author has explored additional internet resources to utilize the most updated data. Above mentioned methods are the most suitable approaches for conducting this research as they permit the author to complete desk-based research critically studying the selected materials.

3. RESULTS AND DISCUSSION

Part – 3.1.

3.1.1. The Prevention of Domestic Violence Act, No.34 of 2005 - Through the Lens of Liberal Feminism

Domestic violence by intimate partner affects people worldwide, where most of the victims are females. The legislative intention to tackle the issue nationally resulted in PDV Act.

Liberal feminism advocates for gender-neutral laws and the equality between men and women. In light of which, PDV Act can be evaluated as an Act which reflects the interests of liberal feminism while making progress in the Sri Lankan legal system in terms of gender equality.

Firstly, liberal feminists argued that instead of abolishing coverture of marriage (it means the gender hierarchical common law model of marriage that travelled from England to the colonies), the revolutionary- era political leaders highlighted the marriage as *a social contract to which women freely consented* (McClain et al., 2022).

The same societal approach in Sri Lanka resulted in the lengthy delay in incorporating a law to prevent domestic violence.

When examining the overall PDV Act, one can argue that it explicitly prohibits domestic violence against wives under Section 23 by the gender-neutral term 'spouse'. This implicates that though the female party may or may not have consented to the marriage, such wife shall not be subjected to violence upon the marriage. Even liberal feminism adherent John Stuart Mill acknowledges in his book 'The

Subjection of Women (1869)' that the principle of *'legal subordination of one sex to the other'* was *'wrong'* and is required to be replaced by *'a principle of perfect equality, admitting no power of privilege on one side, nor disability on the other.'*

Secondly, Ginsburg who was an American lawyer and judge who served as an associate justice of the Supreme Court of the United States indicates the distinct treatment for men and women in law was justified upon 'natural' differences of the sexes which accompanied to *female subordination and to their confined 'place' in man's world.*[7] She identifies this as the 'fundamental premise' of the 1970s cases such as *Frontiero v. Richardson* 411 U.S. 677 (1973) and *United States v. Virginia* 518 U.S. 515 (1996).

It is obvious that women, especially wives are the most common victims of domestic violence because of being subjected to violence of their husbands, confined to his desires, and being domestically controlled due to the power imbalance between men and women in domestic spheres. As a practical aspect, even though physical harm may not be presented, emotional and/or phycological violences is more frequently seen but gone unseen in many domestic violence cases. Such emotionally abused wives may adjust themselves to tolerate the violence and many even do not realize that it is a form of domestic violence, because of being trapped in the patriarchal societal idea that if it is domestic violence then, it means only physical harm and nothing more. This is a perfect example for Ginsburg idea; *women have their confined 'place' in man's world*. Due to social, cultural, economic, and family pressure, it is unlikely for such mentally abused Sri Lankan wife to repudiate her marriage.

In such context PDV Act's recognition of emotional abuse as a type of domestic violence under Section 23 is a salutary approach to establish gender equality. This legal recognition extends the parameter beyond the traditional patriarchal ideology in terms of domestic violence against women.

Fourthly, liberal feminists contend that laws that prevent women from engaging in economic, cultural and social activities are frequently portrayed as *'protective'* and favourable. If the same were put on some members of racial or ethnic minorities, such laws would certainly be regarded unacceptable (McClain et al., 2022).

Due to the potential risk of reverting back to gender stereotypical protectionism, liberal feminists do not advocate for the protection of women.

As PDV Act does not make favourable steps for women, it is obviously in accordance with the liberal stance. The Act gives the Magistrate's Court the authority to grant Protection Orders and/or Interim Orders based on the particular facts of each case as per Sections 5 and 10. Nevertheless, the Act mentions nothing on the necessity of giving special attention (which one may argue essential due different consequences that a woman may encounter) to particular facts in case where the woman is the victims. Additionally, Section 17 of PDV Act ensures accessing the regular court system for both male and female. As a result, both parties enjoy formally equal legal rights, which liberal feminists view as uplifting of gender equality.

Fifth, even with obvious disparities between men and women, liberal feminism primarily supports symmetry or 'formal equality' under the law. Williams argued that *'it is the better path to 'true' equality; a constitutional principle and a condition for substantive equality of the sexes'* (McClain et al., 2022). In terms of PDV Act, it is evident that PDV Act functions in a gender-neutral manner and aligns precisely with the legal equality that liberal feminism demands. Thus, through liberal feminism lens, the Sri Lankan legal framework for gender equality is gradually developing.

Lastly, it ought to recall that liberal feminists constructed and promoted the term 'sexism' to describe beliefs and societal norms that maintain women in subordinate roles, which they saw as the root of discrimination (McClain et al., 2022). One distinguishing characteristic of the PDV Act is that cohabiting partners are also within the purview of the Act. Leaving the marital relationships aside, this discourages the perception that women are men's

property, to be used solely for sex or violence to satisfy male desires.

partners are also within the purview of the Act. Leaving the marital relationships aside, this discourages the perception that women are men's property, to be used solely for sex or violence to satisfy male desires.

The extended PDV Act's application is salutary approach, because it clarifies; that a woman (wife or others) consenting to sexual activities, shall not be the base of violence. Further, if such a case occurs, the respondent cannot simply deny his wrong under PDV Act, stating that it is an illicit and/or extra-marital relationship. Therefore, this initiative offers a protection for women to not to objectified merely as an element of sexual pleasure in intimate relationships.

3.1.2. The Necessity of Advocating for Further Developments - Through the Lens of Feminism

There are essentially three ways that the law is experienced: Structure, Substance, and Culture. The study above indicates the substance (the PDV Act) is gender neutral. Nonetheless, citizens do not experience law only in its substance. Thus, women (the term 'women' is utilized to emphasis the greater disadvantage towards the women in this gender-neutral law) may experience or be discriminated against by substance, structure and/or culture.

It is established above that the law relating to Prevention of Domestic Violence is one such instance where the law is neutral. However, the implementation may result in discriminating women, because the law has failed to provide a room for a gender-sensitive approach.

Thus, this is an area where women would face structural discrimination though the substance provide a neural basis. The cultural influence was also seen in the reluctance to accept this legislative reform at the initial stages where the issue came to the public discourse.

Notwithstanding the analysis in the preceding section, the realities at the grassroots level and

cultural constraints question whether the objective of PDV Act is realistically achieved. Thus, one may justifiably contend that despite the PDV Act's inception being a progressive step in the direction of gender equality, it has consistently upheld patriarchal and male-centered traits.

According to MacKinnon, apart from formulating a *solution indigenous* to the issue, the early feminist legal perspective implied that equality meant women being the same as men (MacKinnon, 2005). This approach could have been influenced by the Social Dominance Theory which emphasizes the social oppression based on sex and the unequal societal structures on men and women.

Therefore, the necessity of developing PDV Act is apparent even through the liberal feminism, where it received numerous critiques mainly due to its ignorance of unique characteristic orrequirements of women such as pregnancy. Additionally, it is stated that *Common Law made tradition into law, and tradition did not favor sex equality… it has historically reflected social structure, custom, habit, and myth to give legal sanction and legitimacy to men's social power overwomen* (MacKinnon, 2005).

Therefore, *it is problematic whether the gender-neutral approach in the substance of law has been successful in ensuring gender justice, not mere gender-equality.* Equality may not be meaningful if it lacks justice. From one hand, *the structure and the culture have withdrawn women from benefiting the gender-neutral law* and on the other hand, *PDV Act has failed to recognize unique and gender-sensitive aspects.* Thus, *one can comment that PDV Act is aiming to minimally interfere into the private lives* by restricting its scope, without stepping into incorporate gender or rather female sensitive approaches.

Upon the above grounds, further development for this area of law can be identified mainly through cultural and third world feminism.

Part – 3.2.

3.2.1. Suggesting Incorporating Battered Women Syndrome Defense through the Lens of Cultural Feminism

The term 'cultural feminism' refers to a certain set of values and conduct that support the notion women and men are essentially different either due to gender-specific social development or due to fundamental biological disparities. These sexual disparities are said to bring all women together in a shared sisterhood beyond the boundaries such as class, age and race (Ghodsee, 2004).

The researcher was inspired to propose this recommendation by the Washington Supreme Court decision, *State v. Allery* (2023) MT 25, because by ruling that '*the expert evidence may have a substantial bearing on the woman's perceptions and behavior at the time of the killing and is central to her claim of self-defense',* it emphasizes the importance of incorporating battered women syndrome as a defence, especially in domestic violence scenario.

Cultural feminism seeks to accommodate women's unique needs while maintaining the status quo. Put it differently, the goal of cultural feminism is to identify ways to lessen the worst effects of patriarchy. As a feminist legal theory, which advocates for female concerns, cultural feminism has been responsible for obtaining women essential and significant rights and facilities in the United States, Western Europe, and occasionally throughout the developing countries (Ghodsee, 2004).

One such cases connects with domestic violence is the *Battered Women Syndrome Defense* which is a result of long-term domestic abuse. This is an even more *progressive step towards gender justice that can be incorporated into the Sri Lankan legal system, moving beyond gender equality*. Thus, this progressive *suggestion is made to the substance of the law*, which can be incorporated by way of an Amendment Act to the PDV Act.

Though the first initiation of the defense was conducted in the United States of America, it is applicable to every region because, regardless of a victim's country, the traumatization she endures will always be severe. In support of cultural feminism, battered women syndrome is recognized particularly as a self-defense in terms of interpreting the word 'provocation' by giving a more gender-sensitive approach.

It is stated that women from jurisdictions where battered women syndrome is accepted are now protected from male- biased self-defense laws and have greater opportunities to defend themselves before the law (Ghodsee, 2004).

One may argue that Sri Lankan courts have already recognized accumulative or sustained provocation cases such as *Premalal v Attorney General* (2000) 2 SLR 403, *W.A. Gamini v Attorney General* CA/142/2003, *Mutubanda* (1954) 56 NLR 217 so that there is no need of separately recognizing battered women syndrome.

Firstly, although cumulative anger is applicable gender neutrally to anyone covering the entire provisions of the penal code, the *focus here is prevention of domestic violence, where many of the victims are females, and especially married women*, who have ultimately become the killers of their male partner. For instance, because many of the incidents reported have occurred in married homes, this illustrates how the husband takes advantage of marital coverture as a tool to control his wife due to their unequal power. It is imperative that a defense tailored to these women be recognized by law, as it is problematic for a law that is basically gender neutral to provide relief for issues that are particularly gender sensitive.

Secondly, *cultural feminism's value on masculine and feminine reasoning patterns provides a further justification*. it is mentioned that *circumstances under battered women syndrome do not meet the legal assumptions for self-defense under existing law*. Thus, the fact that it is extremely difficult for women to argue in court for a self-defense plea indicates the necessity of the defense to be recognized in law (Ghodsee, 2004).

it is further stated that the objective of battered women syndrome is to eliminate male-centric definition of self-defense and to make equal the adjudication procedure for women before the law. Furthermore, it has been suggested that the court ought to apply criteria that differ from those of the *stereotyped 'reasonable man', or even 'reasonable woman' who is submissive and passive and willingly submit to assault* (Nigam, 2016).

Thirdly, an additional rationale for this is that*, in contrast to an individual who has been subjected to provocation, a victim of battered women syndrome undergoes a significantly traumatizing experience,* which is understood only by way of a subjective approach towards such women, as they are. Therefore, if the Act is truly intended to guarantee women's rights and advance gender equality, a gender-sensitive strategy must be taken to establish gender justice.

The prevailing law on self-defense does not consider the psychological state of a battered woman, which may not seem similar to the psychological state seen as typical of a rational male.

battered women syndrome was brought up by the judiciary to assist in clarifying the defendant's psychological status, taking account the surrounding circumstances, which compelled her to commit the crime. When addressing common cases involving women who have experienced long-term cycles of violence, judges must consider the anxious psychological state of the victims (Nigam, 2016).

Further, the suggestion of recognizing battered women syndrome is substantiated by the Indian High Court case; *State v Hari Prashad (2016)*. In the same case, the court differentiated battered women syndrome from 'grave and sudden provocation' stating that it is based on anger and not fear. Further, the court admitted that the though *'she is a victim in her life, the legal system would have treated her as an offender. The provocation by Hari Prashad became her compulsion to end the domestic relationship and she did by taking the extreme step of suicide'.*

Further, when adopting this reform, a significant burden may lie on the structural part among the three basic units where the law is experienced. Changing the substance of the law is time-consuming. In all the jurisdictions where the battered women syndrome defense was adopted, the initiative was taken by the judiciary, not the legislature. it is also evident that where the substance is gender neutral, the judicial approach is very critical in interpreting the laws to achieve actual justice.

As the Sri Lankan courts without any hesitation adopted the defense of cumulative anger by extending the defense of grave and sudden provocation, battered women syndrome can also be judicially recognized as a branch of 'provocation' and/or 'self-defense', which applies in cases based on male and female intimate partner relationships.

As stated above cultural feminism *celebrates* the unique reasoning between male and female. In accordance with the above notion, the importance of acknowledging female views is emphasized in *Dr. Sodhi v. Union of India* 367/2009 & CMS 828, 11426/2009 *'sexual harassment is a subjective experience, and we prefer to analyze harassment from the [complainant's] perspective. A complete understanding of the complainant view requires an analysis of the different perspectives of men and women…'*

It is noteworthy that laws should creatively uphold gender justice than merely moving with gender equality.

3.2.2. Suggesting a Structural Reform and Amendments for Special Laws through the Lens of Third World Feminism

There was internal criticism for feminism theories for their lack of diversity. For an example, in her critique of intersectionality, Kimberlé Crenshaw criticised feminist argumentation for omitting Black women's experiences and highlighted that people can be subjected to *discrimination or disempowerment on several avenues, including race, age, class, sexual orientation, or gender identity* (McClain, 2022).

Unlike in other feminism jurisprudence which developed upon a study of horizontal discrimination, third world feminism has adopted a vertical study of discrimination. This strand of feminism is aiming to seek into intersectionality or divisions within the umbrella term of women. *The argument is that to guarantee substantive or transformative equality, the law needs to be drastically reformed to suit these marginalized women, because it is fundamentally prejudiced against them in the categories such as culture, race, and religion, where various standards are used to treat them.* Due to these pressing differences which are daily encountered by such women it is *inappropriate to identify women as a homogeneous group whose diversity has not been considered.*

Hence, in terms of Sri Lanka's domestic violence, women such as of minority groups, in rural communities, women in detention and with disabilities can be considered as more helpless (UNGA Resolution, 1993) than an educated women from urban areas.

Therefore, regarding such women who are subjected to a double jeopardy in the system, meaning firstly they discriminated because they are women, and then horizontally, due to various reasons such as ethnicity, race, culture, poverty, location, literacy and education, practical solutions are essential to ensure that they enjoy access to justice effectively and efficiently. Since the PDV Act is to provide a mechanism for domestic violence victims to seek redress, unless the mechanism is accessible for those who further disadvantaged the objective of PDV Act shall not be achieved.

For example, the option for a non-working rural woman who is relying on her male counterpart to go to the Magistrate's Court and undergo all the expenses that would incur in the litigation is limited than for a woman with income. This economic violence with the marital status has made the first women further vulnerable in domestic violence.

However, since the reform of the substance of the law is a long-term process, such women would enjoy justice, if the structure is framed as to their benefit which will then gradually change the culture of the law.

Therefore, apart from formal court structure, Regional Legal Aid Clinics, which are solely dedicated to the effective implementation of PDV Act are suggested to be instituted. Irrespectively an amendment to PDV Act, the Minister in-charge of the subject shall establish such centers by way of a Gazette Notification or with the aid of international and/or national organizations. Thus, the female representation of those centers must be mandatory.

This was practically implemented in India in June 2020. As per UN official news the first Legal Aid Centre of its kind on an Assamese tea estate opened in the Udalguri area, with professional assistance from UN Women. To enable them to legally assist women in these communities, UN Women trained lawyers from the area on sexual harassment and domestic violence laws related to workplace.

Secondly, amendments to Special Laws namely, Kandyan Marriage and Divorce Act, No.44 of 1952 (hereinafter referred to as KMDA) and Muslim Marriage and Divorce Act, No.13 of 1951 (hereinafter referred to as MMDA) can also be emphasized as progressive suggestions to prevent domestic violence in terms of the substance of law. This has also been emphasized in the UN CEDAW Committee's Concluding Observations on the Eighth Periodic Report of Sri Lanka (CEDAW/C/LKA/CO/8) where the necessity of amending MMDA was reiterated.

As correctly pointed out by the third world feminists, in considering married women in SL, the wives who are governed by those two Acts are further discriminated than a wife under Marriage Registration Ordinance No.19 of 1907.

Section 32 of KMDA requires a wife to prove husband's adultery coupled with incest or gross cruelty, whereas husband proving wife's mere adultery is sufficient for divorce. Section 23 of MMDA allows a man to marry a girl under the age of twelve years and does not stipulate on a minimum age of marriage.

Though one may argue that these do not directly fall within the purview of domestic violence, it is no doubt that marital status with one spouse's superiority over the other may result in violence. The issue is that the legislature, by allowing the cultural and religious norms to be legally acknowledged, by itself has provided grounds which indirectly promote domestic violence.

Thus, India has prohibited by law one of such long-prevailed, highly contended practice among some castes, *'Sati'*. After the incident of Roopkuvarba Kanwar, the Government of Rajasthan enacted Sati (Prevention) Act, 1987 which later became an Act of the Parliament of India as The Commission of Sati (Prevention) Act, 1987.

As the suggestion made above to the structure of law, making amendments to the substance of law is equally important to mitigate vertical violence and discrimination encounter by marginalized women. Further, Williams thought that the best venue for advancing substantive equality for women was in legislatures (McClain et al., 2022).

3.2.3. Justifying the Suggesstions in Reference to CEDAW

Firstly, Article 1 the term 'discrimination against women' substantiates the recognition of both horizontal and vertical discrimination, by its reference to the words *sex* and *marital status.*

Secondly, the suggestion to incorporate the defence of battered women syndrome can be supported by Article 2 of CEDAW where it requires the States to adopt appropriate legislative and other measures, including sanctions to prohibit all discrimination against women (Article 2[b]). Further, the same Article demands to repeal all discriminatory national penal laws (Article 2[g]). Thus, it is possible to interpret battered women syndrome into spectrum of self-defense.

Thirdly, in support to the establishment of legal clinics, Article 2(c) is important, as it provides to safeguards women and establish their rights and protection through public institutions including national tribunals.

Fourthly, Article 2(f) adopts a much broader view in eliminating discrimination by incorporating the word 'culture and practices', because not that every woman will experience cultural barriers to the same extent. The protection under this Article is compatible with the third world feminism, where vertical study is emphasized.

Fifth, the States are mostly welcome to take necessary actions to alter societal and cultural norms regarding men's and women's actions to eradicate biases, customs, and any other practices where the superiority of one sex or *stereotyped roles for men and women* are encouraged (Article 5).

The above-mentioned Articles support to suggestions under domestic violence, where the element of violence is undoubtedly the discrimination encountered by women.

Finally, it is interesting to note how the teachings of cultural feminism have influenced CEDAW. The Preamble states that when implementing the Articles of the Convention, the State shall acknowledge factors such as female contribution to the family welfare, and the social significance of maternity where women in reproduction shall not be a ground for discrimination. This is a prominent example for cultural feminism as they celebrate, but not discriminate the differences between male and female.

3.2.4. Justifying the Suggesstions in Reference to Declaration on the Elimination of Violence against Women (1993)

As CEDAW does not adequately addresses the element of violence, this Convention was brought up by recognizing the immediate necessity of universal application of female's rights to assure equality, security, and dignity for women.

Article 1 of this Convention broadly interprets 'gender-based violence against women' including but not limited to physical, sexual or psychological harm. Interestingly, the Convention includes both public and private spheres, it is not possible to rule out violent domestic environment as something to be dealt with full privacy.

It is always justified to adopt gender sensitive mechanism as under Article 3 as it imposes State obligation to secure non-violent environment preserving equal opportunities, protection before the law and favourable employment conditions where under Article 3(h) then women's right not to be subjected to inhuman or degrading treatments is achieved.

Most importantly, Article 4 can be related to actions against structural and cultural discrimination of women. It is clearly expressed *that any custom, tradition or religious consideration* which silently encourages or permits violence against women shall not be invoked.

On contrary, the Convention allows the parties to adopt positive measures which overrides the mechanism provided by the Convention. This implies that actions for violence against women cannot be limited and that the established international standards welcome their State parties to pursue the goal of zero violence to the maximum of its ability.

4. CONCLUSION

As per the above analysis one can state that, PDV Act is a progressive step, irrespective of its inherent failures under real scenarios. Therefore, incorporation of recommendations stated under Part II are essential to uplift the value of PDV Act.

In conclusion it should be noted that the enhancement of prevention of domestic violence shall materialized the long-term dedication of various feminists during various periods of time, where the ultimate goal is 'gender equality' and 'gender justice'.

5. LIMITATIONS

This paper limits its scope for two feminist approaches due to the objective of providing a deeper analysis in comparison with the PDV Act and practical instances of the society. Thus, the author has only unitilised CEDAW and Declaration on the Elimination of Violence against Women (1993) as those are the most cruicial and directly connected international conventions with the underlining topic of the study which is, 'violence against women'.

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A CLUSTERING APPROACH TO DETECT IMPOSTER SYNDROME AMONG SRI LANKAN UNDERGRADUATES

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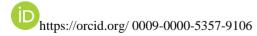
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ABSTRACT

Imposter Syndrome is another name for perceived fraudulence, which is characterized by feelings of personal inadequacy and self-doubt that endure despite education, achievement, experience and success. This is not a disease or abnormality, so there is no obvious reason to imposter emotions. Therefore, even if they suffer from imposter syndrome, they are not able to know this. The results of an undergraduate with imposter syndrome may be inappropriate academic choices, the impact on mental health and social isolation. The aim of the present study is to develop a computerized framework based on a data mining strategy to identify the Severity Level of imposter syndrome for Sri Lankan undergraduates. Thus, this research shows whether the person suffers from imposter syndrome as Low or Moderate or High in level. During the model development, a formal questionnaire was developed examining different influencing factors like depression, anxiety, parentification, family expectations, perfectionism, and low trait self-esteem that can affect the imposter syndrome of an undergraduate and was used to collect data from Sri Lankan undergraduates. In this study, five different unsupervised machine learning techniques, namely K-means, K-medoids, Spectral Clustering, Hierarchical Clustering and Gaussian Mixture Model Clustering were used. Clustering was selected as the best approach as it allows to detect patterns and similarities associated with undergraduates linked to imposter syndrome. To calculate the goodness of the clustering algorithms, the Silhouette index and the Calinski-Harabasz index were used. Among these five clustering algorithms, the best result was shown in the three clusters of K-means Hence, the finalized method helps to predict and classify severity levels of imposter syndrome among Sri Lankan Undergraduates into three groups as low, moderate or high. The research found that among 316 data points, 32.28% showed a low level of imposter syndrome, 16.77% displayed a moderate level, and 50.95% exhibited a high level.

KEYWORDS: *Imposter Syndrome, Sri Lankan Undergraduates, Clustering, Severity Level*

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1. INTRODUCTION

Psychologist Audrey Ervin says imposter syndrome can apply to anyone who is "unable to internalize and own their successes". Imposter Syndrome (IS) or perceived fraudulence or impostor phenomenon is the belief that, despite education, experience, success, and accomplishments, they are underestimated by others. Psychology researchers Pauline Clance and Suzanne Imes, introduced the phrase "Imposter Syndrome" for the first time in 1978. People with Imposter Syndrome believe that their achievement is not a result of their abilities or intelligence, but rather only pure luck, external fault, or hard work (Maqsood *et al.*, 2018). Those who have this syndrome worry that others will recognize them as frauds. Students are one of the high-risk groups for this syndrome. In modern society, there is huge competition among children in the field of education. Among them, the competition between undergraduates is high. Therefore, undergraduates may unknowingly suffer from imposter syndrome. There is no obvious reason to imposter emotions because this is neither a disease nor an abnormality. Instead, several factors may combine to trigger them, such as the pressures of perfectionism, increasing social comparisons, overworking, undermining one's own achievements, fear of failure and discounting praise (Maqsood *et al.*, 2018). Therefore, even if they suffer from imposter syndrome, they are not able to know this. Considering the effects of IS on undergraduates, it is important to investigate this in advance as the students can then take necessary steps to avoid it. (Maqsood *et al.*, 2018; Bravata *et al.*, 2020)

Considering prior studies in foreign countries, these studies have proven that impostor syndrome is a serious public health problem for undergraduates. No research has yet been published on impostor syndrome among Sri Lankan undergraduates. That means there is no source to know whether there is impostor syndrome among Sri Lankan undergraduates. When compared to western countries, Sri Lanaka is having different cultural aspects and educational settings. Hence this research covers various aspects by analyzing hidden patterns associated with imposter syndrome in Sri Lankan context. Additionally, this study fills important gaps related to mental health and machine learning while considering evidence-based insights. While drawing attention to it, it is very important to find out whether undergraduates in Sri Lanka have imposter syndrome or not.

No sufficient mechanism exists to determine the IS severity level, and no data mining framework has been applied to predict the level. Hence, the present research study's main aim is to implement a model to predict the severity level of imposter syndrome among Sri Lankan undergraduates. This study incorporates five unsupervised machine-learning techniques, such as K-means, K-medoids, Spectral Clustering, Hierarchical Clustering and Gaussian Mixture Model Clustering. such a strategy has not been explored. The Silhouette index and the Calinski-Harabasz index, two widely used performance metrics, were employed in the results to confirm the suggested technique's enhanced performance.

2. LITERETURE REVIEW

This research has mainly investigated the IP level of Sri Lankan undergraduates who are studying in state and private universities in Sri Lanka. Many studies on IP have been done with undergraduate students in foreign countries. But currently, no any research has been conducted to develop a computer based model to determine the level of IP in Sri Lanka.

Some studies have been done to determine the extent to which imposter syndrome affects university students (Qureshi *et al.*, 2017). Similarly, several studies have been conducted on how imposter syndrome affects university students based on factors, such as perfectionism, psychological distress, mental health and personality traits related to imposter syndrome (Wang, Sheveleva and Permyakova, 2019). Many researchers have collected data from a variety of questionnaires. Some researchers used the Clance Imposter Phenomenon Scale Questionnaire (Maqsood *et al.*, 2018) and Young Imposter Scale Questionnaire based on random sampling. The collected data were analyzed using Preliminary analyses, Mediation analyses, Moderation analyses, Correlational patterns and Regression analyses. From the final results of these studies, statistical findings (results are shown

quantitatively) show how imposter syndrome affects undergraduates.

(Sullivan and Ryba, 2020) conducted a study and revealed that 57% of pharmacy and 15% of medical students in the United States, exhibit imposter syndrome, according to the most recent IS research. Indeed, on a worldwide and regional scale, IS growing to be a substantial public health risk. For instance, Pakistan and Malaysia both had prevalence rates of 47% and 45.7%, respectively, for IS among medical students. (Qureshi *et al.*, 2017)

Only one research has been published on IS regarding Sri Lanka. The number shows that the topic of Impostor syndrome is new to Sri Lanka. This research was based on MBA students. The impact of context-dependent factors were examined, such as job fit career stage and organizational tenure, on imposter fear using accomplishment goal theory as a foundation. To learn more about the causes of imposter fears, factors like self-efficacy , gender and achievement-related qualities were investigated. Key findings indicate that according to both studies and job fit impostor fears are frequently predicted by organizational tenure and career stage. Similar levels of imposter fears were expressed by men and women, and impostor fear was predicted by self-efficacy and locus of control. The findings on Sri Lankan personality predictions are also same with those from studies with a North American focus, showing the concept's cross-cultural applicability. These research results aid in the development of focused management strategies that support the creation of treatments like orientation programs that improve socialization processes and lessen concerns about impostor fears. (Kumar, Kailasapathy and Sedari Mudiyanselage, 2022)

Furthermore, one study has been conducted to prove the use of computational techniques such as data mining. In this study, the prediction of medical students' (Holliday *et al.*, 2020) IS was carried out using the YIS scale and three distinct machine learning approaches: neural network, ensemble learning and random forest (Khan *et al.*, 2022).

3. METHODOLOGY

Conduct a Comprehensive Literature Review

A Comprehensive analysis has been carried out to identify the factors of IS and to gather the required background knowledge from existing studies.

Data Collection

In order to identify the factors influencing IS for undergraduate students, a literature review has been conducted. Based on previous studies, seven factors have been selected as the causal factors of impostor syndrome in an undergraduate. These are depression, parentification and family expectations, anxiety, perfectionism, low trait self-esteem, fear of failure and comparison. (Fassl, Yanagida and Kollmayer, 2020)

After selecting the factors, a structured questionnaire of twenty-eight questions was created and prepared in both Sinhala and English languages as the data set was collected from the undergraduate community in Sri Lanka. This questionnaire includes twenty-one questions based on seven factors (Yaffe, 2023) with three questions per factor and seven demographic features, including gender, field, level, GPA, platform, accommodation and hours. This "factors twenty-one item questionnaire" is in Likert type.

Data were collected from 18th February 2022 to 6th June 2022 from public and private undergraduate students in Sri Lanka from the first to the fourth years. It was assured the survey participants that all information they provided would be treated in strict confidence and used only for research. A Google form was created and distributed it among undergraduates from various universities. Ultimately, 350 successful data was collected for analysis.

Data Preprocessing

The quality data was obtained after applying several preprocessing techniques. The pre-processing helped extract the required data from the entire data set to perform proper data mining. Out of the twenty-eight features from gathered data, twenty-one are survey entries based on a Likert scale, and except for two numerical columns (GPA and hours), the rest are entries based on various categorical values, such as

gender, year, field of study, etc. First, One-Hot Encoding was used to convert the categorical values into numerical values that could be given to the machine learning algorithms to better predict. Next, outliers were detected in the numerical column (hours) using a box plot and handled them using the IQR method. Then, the noise or non-linear values in the hours column were divided into three bins using the smoothing by bin boundary method. After data visualization, some unnecessary data were removed by identifying data that were not important for future processes. Finally, missing values were filled in with the most frequent values in that column. 316 proper observations remained for the research analysis after cleaning the raw data.

Algorithm Implementation

Unsupervised learning was used for prediction since there was not a labeled dataset. The clustering approach allows to detect patterns and similarities among undergraduates who may exhibit imposter syndrome characteristics. These methods can reveal student groups who share similar physiological and behavioral features linked to imposter syndrome. The data was analyzed using five unsupervised machine learning methods: K-means, K-medoids, Spectral Clustering, Hierarchical Clustering and Gaussian Mixture Model Clustering. Python was used as the programming language for algorithm implementation.

Validation indices describe how efficiently an algorithm partitions data into clusters. To select the most suitable and precise algorithm, validation indices named the Silhouette index and the Calinski-Harabasz index were used in this study.

Final Prediction

The finalized model was used to test with five clustering algorithms with two indices from three to ten clusters. The most suitable data mining model was chosen upon in accordance with its performance. According to the highest performance gained from the Silhouette index and Calinski-Harabasz index, to implement the model in this study the K-means approach was chosen as the data mining model.

Jupyter 6.4.5, a web-based interactive computing notebook environment, was used to perform the main data preprocessing tasks, including outlier treatment, filling in missing values and smoothing data, and selecting the most suitable and accurate algorithm. Once the model is developed, an undergraduate can identify the level at which he or she suffers from imposter syndrome. If the results are moderate or high, the undergraduate can take the necessary steps to suppress them.

4. RESULTS ANS DISCUSSION

Selection of the model

After gathering the data from undergraduates in several Sri Lankan universities, pre-processing techniques were applied to the data to obtain suitable data for the model development. Then the application of unsupervised learning techniques in machine learning was carried out. As shown in TABLE 1, the five clustering algorithms, with three to ten clusters, were compared with two validation indices, namely the Silhouette index and the Calinski-Harabasz index. Based on the results of the validation indices, the total number of clusters was finalized, and the best efficient cluster could be selected accordingly. From Table 1, it is clearly observed that all the indices decrease or increase after the third cluster and in terms of indices, we can confirm that the third cluster is the best as compared to other clusters.

Table 1: Overall performance of the algorithm

Clustering Algorithm	Validity Indices	Total Number of Clusters		
		3	4	5
K-means Clustering	Silhouette Index	0.1765	0.1443	0.1464
	Calinski-Harabasz Index	59.9749	50.8048	44.9126
K-medoids Clustering	Silhouette Index	0.0467	0.0689	0.0443
	Calinski-Harabasz Index	22.3996	29.3210	24.3665
Spectral Clustering	Silhouette Index	0.1685	0.1367	0.1354
	Calinski-Harabasz Index	58.7778	49.7090	44.2493
Hierarchical Clustering	Silhouette Index	0.1594	0.1483	0.1378
	Calinski-Harabasz Index	56.8646	46.2755	41.0024
Gaussian Mixture Models	Silhouette Index	0.1756	0.1588	0.1512
	Calinski-Harabasz Index	59.9072	50.2033	44.7649

This table illustrates that the Silhouette index and Calinski-Harabasz index in the three clusters are higher in the K-means algorithm compared to other clustering algorithms. Therefore, we have concluded that K-means clustering produces better results.

Model Results

After the model development research revealed that, higher levels of imposter syndrome were associated with higher GPAs. Based on this finding, the cluster labels of the three clusters in the K-means are mapped to the levels as Low, Medium and High.

Based on the calculation of the K-means method with the help of Jupyter software, as a result, out of 316 undergraduates, The study has identified 102(32.28%) undergraduates as "low" level, 53(16.77%) undergraduates as "moderate" level and 161(50.95%) undergraduates as "high" level.

Research findings

After reviewing the experimental results, it was found that a significant percentage of undergraduates in Sri Lanka suffer from impostor syndrome, as most undergraduates belong to moderate and high levels. Previous studies have revealed that third-year (Maqsood *et al.*, 2018) and fourth-year (Villwock *et al.*, 2016) students have a higher prevalence and severity of impostor syndrome. Reflecting research findings, these indicate that third and fourth years undergraduates suffer from moderate/high categories of IS. From that point of view, the academic year affects on impostor syndrome in the Sri Lankan undergraduate context. According to some studies, women were twice as affected as men (Fraenza, 2016). Similarly, female respondents had more impostor syndrome than male respondents in our observation.

Among the seven selected factors, some factors represent the most influential factors on undergraduates with a high level of IS, while others have the least influence on undergraduates with a low level of IS. According to these findings, for undergraduates in Sri Lanka depression and anxiety are the most influencing factors, while parentification and family expectations, perfectionism and low trait self-esteem are the least influencing factors.

The goal of the study was to develop a more accurate predictive model for impostor syndrome among Sri Lankan undergraduates. Also, this study attempts to address a relatively new research area.

This study was able to conclude four major findings. It revealed that there are significant undergraduate students in the high and moderate categories, which are severity levels. The severity level of IS was higher in female respondents than in male respondents. IS was not limited to a particular academic year and this study proved that impostor syndrome is a significant public health problem for university students in Sri Lanka.

Nowadays, some undergraduates study in a physical learning environment while others study in a virtual learning environment. Therefore, the special point to be mentioned here is that when the undergraduates answer the questionnaire from the corresponding learning environment, the data they provide may have less impact on the accuracy of the proposed algorithm.

5. CHALLENGES AND LIMITATIONS

With the current data set, Severity level of imposter syndrome was divided into three main levels as low, medium and high. But time to time these influential factors can be changed with various economic and social factors. Data was collected from both private and state university students. State university students might have different schedules, learning environments or accessibility issues compared to private university students. It might lead to an uneven sample. It will lead to limit the generalizability of the research findings. There is a dynamic and evolving nature of imposter syndrome. Questionnaire always may not capture this dynamic nature of the syndrome.

Sometimes students may not reveal their genuine ideas for these kinds of questionnaires and it may affect to make correct assessments on the dataset.

6. CONCLUSION

This is the first study that focus on impostor syndrome based on Sri Lankan undergraduates. Identifying a well-fit model for predicting the severity level of impostor syndrome is the main goal of this study. To determine whether an undergraduate has IS, a Likert-type questionnaire was developed based on demographic factors and the factors selected after conducting the literature survey. Through the use of a Google form, data was collected from various universities in Sri Lanka for the research. Unlabeled dataset led to follow clustering approach in this study. Using two validation indices, the outcomes was compared of five machine-learning clustering algorithms. When comparing the performances, the three clusters of the K-means algorithm scored higher on the validation indices. Finally, the three cluster labels in K-means are mapped as low, moderate, and high. The present study confirmed that the severity of IS was higher in female undergraduates than in males. Also, IS was limited to a specific academic year, and third-year and fourth-year undergraduates suffered from moderate/high categories of IS. Based on the findings of the study, respective institutions and governing authorities should take necessary actions and implement policies to assist students experiencing imposter syndrome.

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INVESTIGATING THE MEAN TEMPERATURE OF ACCRETION DISKS AND MASS TRANSFER RATES IN CATACLYSMIC VARIABLE STARS THROUGH ORBITAL CHARACTERISTICS

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ABSTRACT

Cataclysmic variable (CV) stars, characterized by their dynamic binary systems composed of a white dwarf and a donor red dwarf star, exhibit intricate mass transfer processes crucial for understanding their evolutionary pathways. This study delved into the theoretical investigation of mass transfer processes occurring within non-magnetic CV stars analyzing their orbital characteristics. A selection of eleven CV systems, encompassing a diverse range of subcategories, were chosen for the analysis of this research. Well-established Fourier and Lomb-Scargle algorithms were utilized to identify the most effective algorithm in determining the periodicity of their light curves. The calculated orbital periods for the aforementioned CV sample were then leveraged to determine the mean temperature of their accretion disks. This determination was achieved through established techniques which used spectroscopic Balmer emission lines and Stromgren photometric observations. These techniques provide robust measurements of the physical properties of accretion disks within CVs. Finally, a strong correlation was established between mean temperature of the disk which determined through spectroscopic method and system's mass transfer rate which determined via various techniques and algorithms.

KEYWORDS: *ACCRETION DISK, CATACLYSMIC VARIABLE STARS, MASS TRANSFER RATE, ORBITAL PERIODS*

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1. INTRODUCTION

Cataclysmic variable stars, also referred to as explosive variables, are variable stars that vary their brightness based on phenomena like flares or mass ejections of a star. Typically, CVs are binary star systems that have a white dwarf and a normal star companion (which can be a red giant). The white dwarf is referred to as the "primary" star and the normal star as the "companion" or the "secondary" star. The secondary star loses material onto the white dwarf via accretion and create an accretion disk around the primary star. CVs are mainly divided into two types, namely, Non-magnetic CVs and Magnetic CVs. The classification depends on the strength of the magnetic field of the white dwarf. Both types have several subtypes of CVs. Classical Novae, Recurrent Novae, Dwarf Novae, Novae Likes are the main subtypes of the non-magnetic CVs, while Polars and Intermediate Polars are the subtypes of magnetic CVs.

In non-magnetic CVs, the released matter from the secondary star which was under the gravitational attraction of the primary star (white dwarf), do not fall directly to the surface of the white dwarf but create an accretion disk around the primary star. This heated accretion disk, white dwarf, the hot spot of the accretion disk (and occasionally the side of the secondary star which face towards the white dwarf) are the main luminous areas that the observers could observe, and these observations can be used to derive intrinsic properties of the systems like mass transferring rates from secondary to primary, CV evolutions likewise.

Mass Transfer Rate

The mass transfer rate is the main parameter of the accretion disk temperature structure and if the accretion is assumed to be in local thermal equilibrium, temperature of the disk with radius can be stated as,

$$T(R) = (T_*)\{(R_w/R)^3[1-(R_\omega/R)^{1/2}]\}^{1/4}$$

Equation 1

Where the R_w is the radius of the white dwarf, R is the radius of the accretion disk which is correspond to the $T(R)$. T_* is defined in the [Pringle (1981)] as,

$$T_* = [3GM_\omega\dot{M}/8\pi\sigma(R_w)^3]^{1/4}$$

Equation 2

Where G, M_w, σ are universal gravitational constant, mass of the white dwarf and the Stefan-Boltzmann constant respectively.

The mean temperature of the disk can be defined as,

$$T_m = (1/A_{disk})_i\int^e T(R)\,dA$$

Equation 3

Where A_{disk} is the area of the accretion disk.

If the corresponding radiuses for the integral limits of the T_m are taken as R_i and R_e then the disk area and dA can be stated, $A_{disk} = \pi(R_e^2 - R_i^2)$ and $dA = 2\pi R\,dR$ and substituting the $T(R)$ from Newton's generalization of Kepler's third law gives the T_m as,

$$T_m = \{[2(T_*)\,R_w^{3/4}]/[R_e^2 - R_i^2]\}\,_i\int^e[R - R_w^{1/2}\,R^{1/2}]^{1/4}\,dR$$

Equation 4

Where R_i and R_e are inner radius and the outer radius of the disk.

If we assume the mass transfer is independent from the R and the mass rate is constant throughout the accretion disk and then it would become,

$$\log \dot{M}(gs^{-1}) = 17.35 - 4\log\xi + 4\log(T_m/10^4) - \log(M_w/M_\odot)$$

Equation 5

Where $M_\odot$ is solar mass and

$$\xi\,(cm^{-3/4}\,10^8) = 10^8/(R_e^2 - R_i^2) \times\,_i\int^e[R - R_w^{1/2}\,R^{1/2}]^{1/4}\,dR$$

Equation 6

For the given set of R_w, R_e and R_i the ξ can be solved numerically. Echevarria (1994) stated that the ξ does not greatly depend on the R_w and R_i for larger outer radiuses the log(ξ) almost independent from the R_w

and R_i. So the $\log(\xi)$ depends on the external radius greatly. Then the ξ become,

$$\xi/10^8 = [4(R_e^{5/4} - R_i^{5/4})]/[5(R_e^2 - R_i^2)]$$

Equation 7

For the $R_e \gg R_i$

$$\xi/10^8 \approx (4R_e^{-3/4})/5$$

Equation 8

The solutions for the ξ behave according to the $R_e^{-3/4}$ value for most of the R_e values. Thus, Echevarria (1994) suggests an analytical approximation to the integral with $R_e^{-3/4}$ term, multiplied by a factor which is less than unity and which accounts for deviations of ξ at small values of R_e given by,

$$\log \xi = 7.90 - (3\log R_e)/4 + \log [1 - 1.15(R_i R_w/ R_e^2)^{2/5}]$$

Equation 9

Then the mass transfer rate can be written as,

$$\log \dot{M}(gs^{-1}) = 15.74 + 4 \log (T_m/10^4) + 3 \log (R_e/10^{10}) - 4 \log [1 - 1.15(R_i R_w/ R_e^2)^{2/5}] - \log (M_w/M_\odot)$$

Equation 10

Equation 10 can be stated from the term of orbital period by using Roche lobe, orbital period relationship that holds for all the semi-detached binary and we take [Echevarria (1983)] modified to the primary star;

$$(R_L/R_\odot) = 0.2400 (M_w/M_\odot)^{1/3} P(h)^{2/3}$$

Equation 11

Where the *P(h)* is the orbital period of a system in term of hours.

For $R_w = aR_i$ and $R_e = bR_L$ where the a and b constant values substitute by using the (Hamada & Salpeter, 1961) mass radius relation for white dwarfs. We assume that the mass-radius relationship is valid for the cataclysmic variables.

From the analytical approximation of Paczynski (1985) and Anderson (1988) the relationship becomes,

$$(R_w/R_\odot) = 0.0128 (M_w/M_\odot) \times [1 - (M_w/1.458M_\odot)^{4/3}]^{0.47}$$

Equation 12

From substituting the relationship to the Equation 2.10 then it became,

$$\text{Log } \dot{M} = 16.41 + 4 \log (T_m/10^4) + 2 \log [P(h)] + 3 \log b + 4 \log \{1 - ([0.1102a^{-0.4}/ b^{0.8}][M_w/M_\odot]^{-8/15}).[1 - (M_w/1.458M_\odot)^{4/3}]^{0.37}.[P(h)^{8/15}]\}$$

Equation 13

Of the last two terms which have opposite signs, with the first one dominating for a combination of very massive white dwarfs, low values of *b* and values of *an* approaching unity. Since the last term is always greater than zero it tends to balance the 3log(b) term, especially for systems with low mass white dwarfs and small values of *a*. [Echevarria (1994)] showed there that for most cases we can safely set *a* and *b* equal to unity, and have a simplified mass transfer rate relation become,

$$\text{Log } \dot{M} = 16.41 + 2 \log P(h) + 4 \log (T_m/10^4)$$

Equation 14

Determination of Mean Temperature Using Spectroscopic Method

Obtaining disc temperatures from emission line ratios could be an unreliable process, since the lines could be formed only within the external parts of the disc, where they are the main coolant. During this case we will observe a kinetic temperature of the external parts which is constant. Accordingly, if the lines are formed during a photo-ionized region above the disc, the line temperatures are probably going to be fixed at a temperature close to 10000K. There are, however, more samples of cataclysmic variables which Balmer lines present very broad wings indicating large velocities which may only be explained if they are formed at the inner parts of the disc. Moreover, the road ratios in many of those objects have values which

follow very simple LTE calculations for a series of uniform layers of hydrogen at high densities. It is also important to understand what range of values we should always expect Echevarria (1994).

Figure 04 in Echevarria (1994) shows the mean temperature as a function of external disc radius for various mass transfer rates. These are derived using the numerical integrations of ξ, with log Rw = 8.90, log Ri = 8.95 and assuming log Mw = 0. just for very large mass transfer rates the mean temperature rises above 30000K. For log ($\dot{M}$) < 16 it falls below 10000K for all values of Re. the rationale for this behaviour is just that the lower temperatures within the disc dominate because they're produced at much larger areas than the inner accretion rings.

Comparison with the line ratios calculated by Drake and Ulrich (1980) for a high-density uniform slab of hydrogen indicates that the Balmer decrement of cataclysmic variables is a function of the mean temperature in the emitting region of the accretion disk of the primary. The accretion discs are not a slab of uniformly distributed density at the same temperature, but we may think of them as a series of uniform density rings at several temperatures. This collection of rings will show the mean temperature value, and the mean temperature can be used to find the mass transfer rate.

The Doppler line profile can be given by Balmer line profiling using the ratio between H_γ/H_β and H_δ/H_β. The relevant equations as follows Drake and Ulrich (1980).

$$H_\gamma/H_\beta = 1.57 \ \{[\exp(29599/T_m) - 1]/[\exp(33153/T_m) - 1]\}$$

Equation 15

And,

$$H_\delta/H_\beta = 1.97 \ \{[\exp(29599/T_m) - 1]/[\exp(35085/T_m) - 1]\}$$

Equation 16

The line ratios must be corrected for the interstellar absorption, and it can be calculated by the following,

$$\log [I(\lambda)/I(H_\beta)] = \log [F(\lambda)/F(H_\beta)] + C(H_\beta)f(\lambda)$$

Equation 17

Where the $F(\lambda)$, $C(H_\beta)$, $f(\lambda)$ are observed flux, logarithmic reddening correction at H_β and reddening function normalized at H_β which derived by normal extinction law (Whitfold, 1958).

Determination of Mean Temperature Using Strömgren Photometry

Another method to determine the mean temperature of a CV system is to use broad band photometry of the disk continuum. First step is to derive a relationship between mean temperature and Strömgren b-y index. Then the relationship can be used to find the mass transfer rate according to the Strömgren b-y index.

Echevarria (1994) suggested a logarithmic relationship between b-y index and the mean temperature as follows.

$$\text{Log} (T_m/10^4) = A + B \log (b\text{-}y)$$

Equation 18

Figure 09 in Echevarria (1994) gives the values for the A and B for both blackbody approximations and the main sequence star approximations according to Crawford (1975), Crawford (1979) and Johnson (1966). For blackbody approximation A = - 0.303 and B = - 0.187 (Hayes & Lathem, 1975). For main sequence star's approximation, A = - 0.316 and B = - 0.236 (Crawford, 1975; Crawford, 1979; Johnson, 1966).

Then the Equation 18 is changed as follows for both approximations accordingly.

For blackbody approximation,

$$\text{Log} (T_m/10^4) = - 0.303 - 0.187 \log (b - y)$$

Equation 19

For main sequence star approximation,

$$\text{Log } (T_m/10^4) = -0.316 - 0.236 \log (b - y)$$

Equation 20

So according to the relationship between mean temperature and Strömgren b-y indices, we can derive the new relationship among orbital period, Strömgren b-y index and mass transfer rate for both approximations. For blackbody approximations;

$$\text{Log } \dot{M} = 15.20 + 2 \log P(h) - 0.75 \log (b - y)$$

Equation 21

And for main sequence star approximations;

$$\text{Log } \dot{M} = 15.14 + 2 \log P(h) - 0.94 \log (b - y)$$

Equation 22

We will use the black body approximation to derive the mass transfer rate because the main sequence star can generate slightly higher values than actual values Echevarria (1994).

Research Gap

While significant studies have been conducted on cataclysmic variable stars (CVs), the understanding of how orbital characteristics, the mean temperature of accretion disks, and mass transfer rates are interconnected is still insufficient. Most existing research either focuses on one aspect, such as temperature distribution of accretion disk or mass transfer rates, without connecting these parameters to each other.

Objective

This research will investigate observational data from multiple CVs and their impact on the mass transfer rate and mean temperature of the accretion disks.

2. METHODOLOGY

Cataclysmic Variable star systems were chosen in a variety of types for analysis.

Further, their respective properties were also analyzed under the scope of the present research.

Table 01: Selected cataclysmic variable star systems

Name of the CV	Type of the CV
GK Per	UG/NA
EM Cyg	UGZ
AH Her	UGZ
U Gem	UGSS
EX Hya	UG
RU Peg	UGSS
SS Cyg	UGSS
SS Aur	UGSS
TW Vir	UGSS
YZ Cnc	UGSU

UG, NA, UGZ, UGSS, UGSU are U Geminorum-type variables (often called as dwarf novae), fast novae, Z Camelopardalis-type variables, SS Cygni-type variables and SU Ursae Majoris-type variables respectively.

Light Curves of the CV systems

As a basic source for the variable star observations retrieval and further details of variable stars the AAVSO database (American Association of Variable Stars Observers) was used (https://www.aavso.org/). The raw observation data from AAVSO including observation dates (in Julian dates), magnitude, uncertainty of the observation, observation bands, observer Code were downloaded from the AAVSO as a tab delimited text file for further analysis. The data obtained by the AAVSO required several filtering processes to achieve the required data format for the

further analysis. The raw data was contained data under following columns. JD(Julian dates), Magnitude, Uncertainty, HQuncertainty, Band, Observer Code, Comment Code(s), Comp Star 1, Comp Star 2, Charts, Comments, Transfomed, Airmass, Validation Flag, Cmag, Kmag, HJD, Star Name, Observer Affiliation, Measurement Method, Grouping Method, ADS Reference, Digitizer, Credit. From these columns as previously stated the time (Julian dates), observe magnitudes and the error of the

magnitude data were filtered for a single observer. The filtering process for the single observer is important to avoid generating of incorrect light curves by overlapping observations over time for a single system.

As the next and more specific database by observations SuperWASP database was used to access the raw observations (https://www.superwasp.org/).
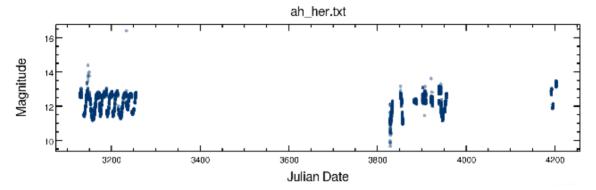
Figure 01: Light curve data of AH Her CV system
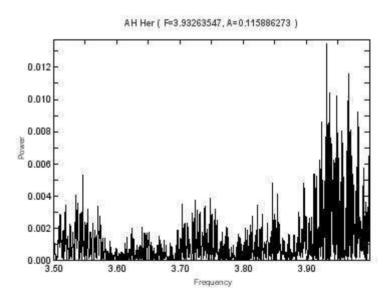
Figure 02: Power Spectrum of AH Her for Fourier algorithm using Period04

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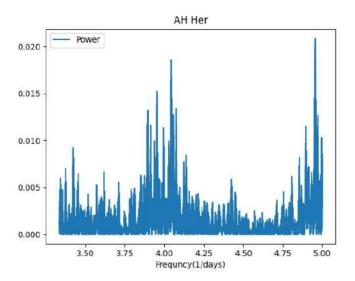
Figure 03: Power Spectrum of AH Her for Lomb-Scargle algorithm by Vartool

The data downloaded from the SuperWASP database did not require filtering because the downloadable .CSV file only contained time (Julian dates), observed magnitudes and the error of the magnitude by the WASP telescopes.

For the analysis of the light curve Period04, Vartools and NASA exoplanet periodogram tools were used, depending on the spread of the light curve. To obtain the power spectrum of the light curves, both Fourier and Lomb-Scargle analysis algorithms were used.

Stromgren photometric observations

Table 02: Stromgren photometric observations of the CV systems, (Echevarria (1994))

Name of the CV	b	y	(b-y)
GK Per	13.34	12.77	0.57
EM Cyg	13.45	13.16	0.29
AH Her	12.67	12.55	0.12
AH Her	12.92	12.77	0.15
U Gem	14.43	14.19	0.24
U Gem	14.91	14.59	0.32
U Gem	14.13	13.84	0.29
EX Hya	14.12	13.95	0.17

RU Peg	13.34	12.81	0.53
SS Cyg	12.23	11.7	0.53
SS Aur	15.12	14.97	0.15
SS Aur	11.01	10.99	0.02
SS Aur	11.13	11.11	0.02
TW Vir	13.16	13.12	0.04
YZ Cnc	13.6	13.47	0.13
YZ Cnc	15.38	15.17	0.21
YZ Cnc	12.14	12.13	0.01
IR Gem	12.8	12.79	0.01

Spectroscopic observations

Table 03: Observations of Balmer emission lines $H_\beta, H_\delta, H_\gamma$ and $C_{H\beta}$, (Echevarria (1994))

Name	EW(H_β)	FHγ	FHδ	CHβ
GK Per	11	0.85	0.57	0.32
EM Cyg	11	0.96	-	0.07
	3	1.15	-	0.07
AH Her	24	0.9	-	0.04

	26	0.84	0.82	0.04
U Gem	15	0.85	0.81	0.04
EX Hya	74	0.65	-	0.05
RU Peg	4	1.02	0.45	0.08
	5	0.98	0.66	0.08
	16	1.19	1.49	0.08
	28	0.72	-	0.08
SS Cyg	40	0.81	0.74	0.06
	74	0.8	-	0.06
	70	0.76	0.66	0.06
	67	0.76	0.57	0.06
	30	1.08	1.02	0.06
	32	0.98	0.49	0.06
	25	1.17	1.35	0.06
SS Aur	58	0.72	0.53	0.15
	76	0.89	-	0.15
	95	0.84	0.73	0.15
	106	0.82	0.67	0.15
	122	0.85	0.58	0.15
TW Vir	78	0.92	0.75	0.2
	14	0.89	0.73	0.2
	70	0.73	0.6	0.2
	96	0.85	0.78	0.2
	73	1.05	0.99	0.2
YZ Cnc	80	0.89	0.76	0.13
	131	0.83	0.71	0.13
	42	1.01	0.97	0.13
	92	0.77	-	0.13
IR Gem	116	0.77	0.63	0.11
	81	1.08	0.87	0.11

EW = Equalent width of H_β line and the observed Balmer line widths are represented as the ratio with the H_β line. $C_{H\beta}$ = Logarithmic reddening correction at H_β

3. RESULTS AND DISCUSSION

Mean Temperature of CV systems by Photometric method

Mean temperatures by photometric method were calculated using the Equation 18 and the photometric values from Table 02.

Table 04: Mean Temperatures by Photometric method

Name	(b-y)	Tm(K)
GK Per	0.57	5529.06
EM Cyg	0.29	6273.81
AH Her	0.12	7399.34
AH Her	0.15	7096.93
U Gem	0.24	6499.81
U Gem	0.32	6159.38
U Gem	0.29	6273.81
EX Hya	0.17	6932.76
RU Peg	0.53	5604.80
SS Cyg	0.53	5604.80
SS Aur	0.15	7096.94
SS Aur	0.02	10344.45
SS Aur	0.02	10344.45
TW Vir	0.04	9086.88
YZ Cnc	0.13	7289.41
YZ Cnc	0.21	6664.15
YZ Cnc	0.01	11776.06
IR Gem	0.01	11776.06

Mean Temperature of CV systems by Photometric method

Using the Equations 15,16,17 and the values from the table 03 the mean temperature of systems were calculated.

Table 05: Mean temperatures by spectroscopic emission line widths

Name	FH_γ	FH_δ	CH_β	Tm(K)	
				H_γ	H_δ
GK Per	0.85	0.57	0.32	7000	5000
EM Cyg	0.96	-	0.07	14500	-
	1.15	-	0.07	7700	-
AH Her	0.9	-	0.04	6600	-
	0.84	0.82	0.04	5800	6500
U Gem	0.85	0.81	0.04	5900	6400
EX Hya	0.65	-	0.05	4100	-
RU Peg	1.02	0.45	0.08	9100	3850
	0.98	0.66	0.08	8000	5200
	1.19	1.49	0.08	16300	43000
	0.72	-	0.08	4700	-
SS Cyg	0.81	0.74	0.06	5600	5800
	0.8	-	0.06	5500	-
	0.76	0.66	0.06	5000	5150
	0.76	0.57	0.06	5000	4550
	1.08	1.02	0.06	10500	9000
	0.98	0.49	0.06	8000	4000
	1.17	1.35	0.06	14500	19500
SS Aur	0.72	0.53	0.15	4800	4400
	0.89	-	0.15	6800	-
	0.84	0.73	0.15	6200	5950
	0.82	0.67	0.15	5900	5450
	0.85	0.58	0.15	6300	4750
TW Vir	0.92	0.75	0.2	7600	6300
	0.89	0.73	0.2	7200	6100
	0.73	0.6	0.2	5100	5000
	0.85	0.78	0.2	6400	6700
	1.05	0.99	0.2	11000	9600
YZ Cnc	0.89	0.76	0.13	6800	6200
	0.83	0.71	0.13	5900	5700
	1.01	0.97	0.13	9100	8700
	0.77	-	0.13	5300	-
IR Gem	0.77	0.63	0.11	5300	5000
	1.08	0.87	0.11	11200	7300

Light Curve Analysis using Fourier Algorithm

Table 06: Highest peak values of Power spectrum using Fourier algorithm

Name	Frequency (1/Days)	Orbital period (Days)
GK Per	0.496279762	2.014992503
EM Cyg	3.04363308	0.328554715
AH Her	3.9326354	0.258116
U Gem	5.997668271	0.166731462
SS Cyg	3.41830001	0.292543076
TW Vir	5.002102819	0.199915923
YZ Cnc	11.76594041	0.084991082
IR Gem	14.7433678	0.067827108

From all the CV systems EX Hya, RU Peg and SS Aur didn't provide reliable power spectrums and more deviated orbital periods from the actual values for the Fourier analyze. The Fourier technique in the light curve analysis gives most reliable answers to the light curves which are the shapes of sine or cosine waves functions and continuous spectrums with minimum time gaps between observations. But for the light curves in Figure 01 for EX Hya, RU Peg and SS Aur have much larger observation gaps and less sine or

cosine shapes. For the other systems, it seems that there are no sine or cosine shapes in their light curves during the whole observation period. However, when analyzed over a shorter time span, the light curves partially show sine or cosine shapes with partially continuous observation scattering.

Light Curve Analysis using Lomb-Scargle Algorithm

Table 06: Highest peak values of Power spectrum using Lomb-Scargle algorithm

Name	Orbital period (days)
GK Per	2.01052904
EM Cyg	0.31936315
AH Her	0.24969318
U Gem	0.1687962
SS Cyg	0.2678389
TW Vir	0.19730737
YZ Cnc	0.08337633
IR Gem	0.07149026
SS Aur	0.19806165
EX Hya	0.05135202
RU Peg	0.37722567

Mass Transfer Rates Using Fourier Algorithm Results and Photometric Temperature Calculations

EM Cyg, RU Peg, and SS Aur are not considered in the calculations of the mass transfer rate in Table 07 because these systems did not provide reliable values for Fourier analysis.

Table 07: Mass transfer rates (M.T.R) for Fourier and photometric data

Name	log P (hrs)	photometry Tm (K)	M.T.R (Kgs^{-1})
GK Per	1.6844	5529.0612	5.6179×10^{15}
EM Cyg	0.8968	6273.8130	2.4760×10^{14}

AH Her	0.7855	7399.3421	2.8696×10^{14}
AH Her	0.7855	7096.9367	2.4285×10^{14}
U Gem	0.6022	6499.8075	7.3461×10^{13}
U Gem	0.6022	6159.3793	5.9238×10^{13}
U Gem	0.6022	6273.8130	6.3765×10^{13}
SS Cyg	0.8464	5604.8037	1.2503×10^{14}
TW Vir	0.6810	9086.8797	4.0343×10^{14}
YZ Cnc	0.3095	7289.4136	3.0195×10^{13}
YZ Cnc	0.3095	6664.1535	2.1093×10^{13}
YZ Cnc	0.3095	11776.0597	2.0566×10^{14}
IR Gem	0.2116	11776.0597	1.3098×10^{14}

Mass Transfer Rates Using Fourier Algorithm Results and H$_\gamma$ Emission Line Temperature Calculations

Table 08: Mass transfer rates for Fourier and spectroscopic Hγ emission line data

Name	Log P (hrs)	Tm by H$_\gamma$ (K)	M.T.R (Kgs^{-1})
GK Per	1.6844	7000	1.4433×10^{16}
EM Cyg	0.8968	14500	7.0650×10^{15}
EM Cyg	0.8968	7700	5.6183×10^{14}
AH Her	0.7855	6600	1.8165×10^{14}
AH Her	0.7855	5800	1.0834×10^{14}
U Gem	0.6022	5900	4.9873×10^{13}
SS Cyg	0.8464	5600	1.2461×10^{14}
SS Cyg	0.8464	5500	-
SS Cyg	0.8464	5000	7.9192×10^{13}
SS Cyg	0.8464	5000	7.9192×10^{13}
SS Cyg	0.8464	10500	1.5401×10^{15}
SS Cyg	0.8464	8000	5.1899×10^{14}
SS Cyg	0.8464	14500	5.6011×10^{15}

TW Vir	0.6810	7600	1.9741×10^{14}
TW Vir	0.6810	7200	1.5902×10^{14}
TW Vir	0.6810	5100	4.0031×10^{13}
TW Vir	0.6810	6400	9.9274×10^{13}
TW Vir	0.6810	11000	8.6634×10^{14}
YZ Cnc	0.3095	6800	2.2867×10^{13}
YZ Cnc	0.3095	5900	1.2959×10^{13}
YZ Cnc	0.3095	9100	7.3339×10^{13}
YZ Cnc	0.3095	5300	8.4386×10^{12}
IR Gem	0.2116	5300	5.3744×10^{12}
IR Gem	0.2116	11200	1.0718×10^{14}

TW Vir	0.6810	6700	1.1924×10^{14}
TW Vir	0.6810	9600	5.0258×10^{14}
YZ Cnc	0.3095	6200	1.5803×10^{13}
YZ Cnc	0.3095	5700	1.1289×10^{13}
YZ Cnc	0.3095	8700	6.1270×10^{13}
IR Gem	0.2116	5000	4.2571×10^{12}
IR Gem	0.2116	7300	1.9343×10^{13}

Mass Transfer Rates Using Lomb-Scargle Algorithm Results and Photometric Temperature Calculations

Table 10: Mass transfer rates for Lomb-Scargle and photometric data

Name	log P (hrs)	photometry Tm (K)	M.T.R (Kgs^{-1})
GK Per	1.6835	5529.0612	5.5931×10^{15}
EM Cyg	0.8844	6273.8130	2.3395×10^{14}
AH Her	0.7776	7399.3421	2.7670×10^{14}
AH Her	0.7776	7096.9367	2.3416×10^{14}
U Gem	0.6075	6499.8075	7.5292×10^{13}
U Gem	0.6075	6159.3793	6.0715×10^{13}
U Gem	0.6075	6273.8130	6.5354×10^{13}
EX Hya	0.0907	6932.7581	9.0191×10^{12}
RU Peg	0.9568	5604.8037	2.0791×10^{14}
SS Cyg	0.8080	5604.8037	1.0481×10^{14}
SS Aur	0.6770	7096.9367	1.4734×10^{14}
SS Aur	0.6770	10344.4496	6.6505×10^{14}
SS Aur	0.6770	10344.4496	6.6505×10^{14}
TW Vir	0.6753	9086.8797	3.9298×10^{14}
YZ Cnc	0.3012	7289.4136	2.9059×10^{13}
YZ Cnc	0.3012	6664.1535	2.0300×10^{13}
YZ Cnc	0.3012	11776.0597	1.9793×10^{14}

Mass Transfer Rates Using Fourier Algorithm Results and H$_\delta$ Emission Line Temperature Calculations

Table 09: Mass transfer rates for Fourier and spectroscopic H$_\delta$ emission line data

Name	Log P (hrs)	Tm by H$_\delta$ (K)	M.T.R (Kgs^{-1})
GK Per	1.6844	5000	3.7571×10^{15}
EM Cyg	0.8968	-	-
AH Her	0.7855	6500	1.7089×10^{14}
U Gem	0.6022	6400	6.9052×10^{13}
SS Cyg	0.8464	5800	1.4339×10^{14}
SS Cyg	0.8464	5150	8.9132×10^{13}
SS Cyg	0.8464	4550	5.4306×10^{13}
SS Cyg	0.8464	9000	8.3133×10^{14}
SS Cyg	0.8464	4000	3.2437×10^{13}
SS Cyg	0.8464	19500	1.8321×10^{16}
TW Vir	0.6810	6300	9.3214×10^{13}
TW Vir	0.6810	6100	8.1929×10^{13}
TW Vir	0.6810	5000	3.6983×10^{13}

IR Gem	0.2344	11776.0597	1.4552×10^{14}

Mass Transfer Rates Using Lomb-Scargle Algorithm Results and H_γ Emission Line Temperature Calculations

Table 11: Mass transfer rates for Lomb-Scargle and spectroscopic H_γ emission line data

Name	Log P (hrs)	Tm by H_γ (K)	M.T.R (Kgs^{-1})
GK Per	1.6835	7000	1.4369×10^{16}
EM Cyg	0.8844	14500	6.6752×10^{15}
EM Cyg	0.8844	7700	5.3083×10^{14}
AH Her	0.7776	6600	1.7515×10^{14}
AH Her	0.7776	5800	1.0446×10^{14}
U Gem	0.6075	5900	5.1116×10^{13}
EX Hya	0.0907	4100	1.1033×10^{12}
RU Peg	0.0907	9100	2.6773×10^{13}
RU Peg	0.0907	8000	1.5992×10^{13}
RU Peg	0.0907	16300	2.7561×10^{14}
RU Peg	0.0907	4700	1.9052×10^{12}
SS Cyg	0.8080	5600	1.0445×10^{14}
SS Cyg	0.8080	5500	9.7190×10^{13}
SS Cyg	0.8080	5000	6.6382×10^{13}
SS Cyg	0.8080	5000	6.6382×10^{13}
SS Cyg	0.8080	10500	1.2910×10^{15}
SS Cyg	0.8080	8000	4.3504×10^{14}
SS Cyg	0.8080	14500	4.6951×10^{15}
SS Aur	0.6770	4800	3.0831×10^{13}
SS Aur	0.6770	6800	1.2418×10^{14}
SS Aur	0.6770	6200	8.5820×10^{13}
SS Aur	0.6770	5900	7.0377×10^{13}
SS Aur	0.6770	6300	9.1493×10^{13}

TW Vir	0.6753	7600	1.9229×10^{14}
TW Vir	0.6753	7200	1.5490×10^{14}
TW Vir	0.6753	5100	3.8993×10^{13}
TW Vir	0.6753	6400	9.6701×10^{13}
TW Vir	0.6753	11000	8.4388×10^{14}
YZ Cnc	0.3012	6800	2.2006×10^{13}
YZ Cnc	0.3012	5900	1.2471×10^{13}
YZ Cnc	0.3012	9100	7.0579×10^{13}
YZ Cnc	0.3012	5300	8.1210×10^{12}
IR Gem	0.2344	5300	5.9706×10^{12}
IR Gem	0.2344	11200	1.1907×10^{14}

Mass Transfer Rates Using Lomb-Scargle Algorithm Results and H_δ Emission Line Temperature Calculations

Table 12: Mass transfer rates for Lomb-Scargle and spectroscopic H_δ emission line data

Name	Log P (hrs)	Tm by H_δ (K)	M.T.R (Kgs^{-1})
GK Per	1.6835	5000	3.7404×10^{15}
EM Cyg	0.8844	-	-
AH Her	0.7776	6500	1.6477×10^{14}
U Gem	0.6075	6400	7.0773×10^{13}
EX Hya	0.0907	-	-
RU Peg	0.0907	3850	8.5779×10^{11}
RU Peg	0.0907	5200	2.8546×10^{12}
RU Peg	0.0907	43000	1.3348×10^{16}
SS Cyg	0.8080	5800	1.2019×10^{14}
SS Cyg	0.8080	5150	7.4713×10^{13}
SS Cyg	0.8080	4550	4.5521×10^{13}
SS Cyg	0.8080	9000	6.9685×10^{14}
SS Cyg	0.8080	4000	2.7190×10^{13}

SS Cyg	0.8080	19500	1.5357×10^{16}
SS Aur	0.6770	4400	2.1769×10^{13}
SS Aur	0.6770	5950	7.2793×10^{13}
SS Aur	0.6770	5450	5.1240×10^{13}
SS Aur	0.6770	4750	2.9566×10^{13}
TW Vir	0.6753	6300	9.0797×10^{13}
TW Vir	0.6753	6100	7.9805×10^{13}
TW Vir	0.6753	5000	3.6024×10^{13}
TW Vir	0.6753	6700	1.1615×10^{14}
TW Vir	0.6753	9600	4.8955×10^{14}
YZ Cnc	0.3012	6200	1.5208×10^{13}
YZ Cnc	0.3012	5700	1.0864×10^{13}
YZ Cnc	0.3012	8700	5.8964×10^{13}
IR Gem	0.2344	5000	4.7293×10^{12}
IR Gem	0.2344	7300	2.1489×10^{13}

Correlation Between Mass Transfer Rate and Mean Temperature of Fourier Data with Photometric and Spectroscopic Data

Table 13: Correlations between Log (Tm/10E4) and Log (M.T.R)

Dependent Variable	Independent Variable	Correlation Coefficient	P-Value
LS_Ph_log (M.T.R)	LS_Ph_log $(Tm/10^4)$	0.159	0.530
LS_H$_\gamma$_log (M.T.R)	LS_H$_\gamma$_Log $(Tm/10^4)$	0.667	0.000
LS_H$_\delta$_log (MTR)	LS_H$_\delta$_log $(Tm/10^4)$	0.748	0.000
F_Ph_log (M.T.R)	F_Ph_log $(Tm/10^4)$	-0.044	0.887

F_H$_\gamma$_log (M.T.R)	F_H$_\gamma$_log $(Tm/10^4)$	0.694	0.000
F_H$_\delta$_log (M.T.R)	F_H$_\delta$_log $(Tm/10^4)$	0.633	0.004

LS_Ph_, LS_H$_\gamma$_, LS_H$_\delta$_, F_Ph_, F_H$_\gamma$_ and F_H$_\delta$_ are Lomb-Scargle data and Photometric data, Lomb-Scargle data and H$_\gamma$/H$_\beta$ data, Lomb-Scargle data and H$_\delta$/H$_\beta$ data, Fourier data and photometric data, Fourier data and H$_\gamma$/H$_\beta$ data, Fourier data and H$_\delta$/H$_\beta$ data respectively.

The table of correlations between the *Log(M.T.R)* and *Log(Tm/10^4)* which were calculated using photometric and spectroscopic shows that the photometric data gives no correlations in the photometric mean temperature calculations. Although the photometric data gives correlations coefficient values the P-values for both photometric data are greater than 0.05. If there should be any correlation between independent and dependent variables the P-value must be less than 0.05. But in reality, the mean temperature of the accretion disk depends on the mass transfer rate. The reason for the formation of the accretion disk is the beginning of the mass transferring process from secondary to the primary of a CV. So, the mean temperature and the mass transfer rate should have perfect correlation with each other. It is proven by both H$_\gamma$/H$_\beta$ and H$_\delta$/H$_\beta$ spectroscopic mean temperature calculations in the table 08, 09, 11, 12 and table 13. The reason for the no correlation of photometric data is the low number of observations in the Strömgren photometry. Due to that reason the normalization process for the obtaining correlation is difficult for the Strömgren photometry.

4. CONCLUSION

Although the correlation coefficient detected no correlation state between mean temperature which obtained by the Strömgren photometric, the spectroscopic analyze clearly states there are strong correlation between the variables. We suggest using a large data sample for the Strömgren photometric technique in the future works as it gives more accurate correlations between the variables.
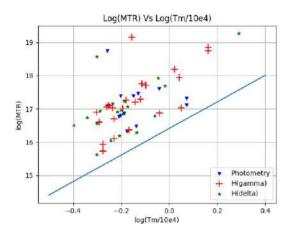
Figure 04: Log (M.T.R) Vs Log (Tm/10⁴) graph for Fourier data with photometric and spectroscopic results. Solid line represents the Equation 14 for P(h) = 1hr.
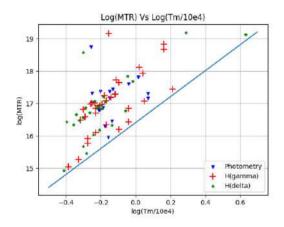
Figure 05: Log (M.T.R) Vs Log (Tm/10⁴) graph for Lomb-Scargle data with photometric and spectroscopic results. Solid line represents the Equation 14 for P(h) = 1hr.

Since the emission lines or photometric observations observed in a CV are limited to several points of the model, the observations are highly dependent on the inclination angle between the CV and the observer. Also, for future interpretations, we encourage to consider a method which uses Doppler radial velocity and the inclination angle to interpret the results for mass transfer rates.

5. ACKNOWLEDGEMENT

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NEURAL NETWORKS FOR CLASSIFICATION OF EYE CONJUNCTIVITIS IN TELEHEALTH: A CONCEPTUAL ARCHITECTURE

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ABSTRACT

Telehealth systems have developed rapidly into more conventional ways that can provide medical assistance, especially for people in remote areas. Despite rapid technological and practical developments, there are still many knowledge gaps regarding the effective use of telemedicine. Annually, nearly 1-4% of the general population might experience conjunctivitis. This study is focused on an experimental design for the classification of degrees of severity in colour medical images in telemedicine, in particular red as one of the key symptoms in the diagnosis of various pathologies. The quality of digital images is a pivotal thing in terms of telemedicine for accurate diagnosis because degraded or distorted colours can lead to errors. This study focused on the use of digital images in teleconsultation, in particular images displaying conjunctivitis (red eyes) as a case study since this pathology integrates red in its diagnosis. The deep self-organising map is suggested to be applied to classify the different severities. Moreover, U-Net, a deep learning network, is proposed to employ the segmentation of eye images for better feature extraction. Although this approach is focused on the problem of red eye image classification, it can be extended in the future to also be applied to other pathologies.

KEYWORDS: *Conjunctivitis, Deep Self-Organising Map, Neural Networks, Telehealth*

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1. INTRODUCTION

Conjunctivitis, commonly called pink eye, is a prevalent eye infection distinguished by inflammation, redness, and discharge. Conjunctivitis can be caused by different agents: viral (Muto, Imaizumi and Kamoi, 2023), bacterial (Bhat and Jhanji, 2021), or allergy (Tariq, 2024). Viral and bacterial agents are known to be highly contagious agents (A. Azari and Arabi, 2020). Therefore, it is important to diagnose them quickly to prevent the spread of disease in communal environments, especially in schools. Failure to recognise the severity level of conjunctivitis and not administering timely treatment may lead to vision impairments and corneal ulcers (Frost *et al.*, 2024). If conjunctivitis is to be diagnosed virtually, it is important to acquire distortion-free eye images. Variations in image colours may be due to multiple reasons, such as poor image quality, visual disturbances related to colour perception, interference due to lighting conditions, or reflection on the display or the viewing area.

In remote areas, people struggle to access health services quickly because of a range of challenges related to cost, time, communication, and transportation. In the recent past, telehealth systems have provided a considerable range of services for diseases like COVID-19. In 2019, a mere 1% of patients engaged with telehealth services (Hazratifard, Gebali and Mamun, 2022). However, with the COVID-19 outbreak, the rate of using telehealth has increased to more than 38% (Hazratifard, Gebali and Mamun, 2022). Telehealth involves using telecommunication technologies and Internet of Things (IoT) devices to provide healthcare services and information. Moreover, remote communities and stay-at-home patients can get quality medical services with the help of telehealth services. Furthermore, telemedicine technology is rapidly evolving and has improved its effectiveness and efficiency with the advancement of new technologies all over the world (Toritsemogba Tosanbami Omaghomi *et al.*, 2024).

In the telemedicine scenario, the specialist and the patient communicate remotely through computers. In addition to the history and data, doctors receive digital images that display different pathologies in the affected areas. Accurate colour distinction in digital images plays an important role in diagnosis. Physicians may perceive colours differently in these images for several reasons: visual disturbances related to colour perception, poor image quality or resolution, or interference due to lighting or reflection in the display or the viewing area.

This study aimed at the use of digital images in the "Store and Forward" (SAF) teleconsultation (Tensen et al., 2024). Two important critical challenges in SAF can influence the accuracy of the diagnosis when using digital images. First, image quality plays an important role in the diagnosis, which can reduce the transfer of health professionals. Second, differences in colour perception, which is an important natural cognitive process, could also affect diagnosis based on digital images. This study, which focused on the use of digital imaging and colour perception in telemedicine, is a multidisciplinary combination that integrated information systems, human factors, engineering, and health care.

There are existing systems and applications, such as EyeCareLive, ZEISS VISU360, Netra, and VSee which cater to remote diagnosis, monitoring, and treatment in the domain of ophthalmology. However, these platforms conduct remote eye exams mainly focusing on detecting vision impairments such as astigmatism and hyperopia. Also, in some of these applications, patients have to share previously taken images of their eyes for the diagnosis process.

Artificial Neural Networks (ANNs) reflect its generalisation and learning abilities through a mathematical emulation of human architecture. ANNs are used in many research domains due to their ability to model nonlinear systems. In the medical sector, ANNs are used for many tasks, such as image analysis, biochemical analysis, drug design, and diagnostic system development, among others (Shahid, Rappon and Berta, 2019).

This study reviews and proposes a methodology to classify severity levels of conjunctivitis unlike the mostly existing models focused on detecting the presence of conjunctivitis. Furthermore, it is proposed to use DSOM, a neural network architecture which

introduces an unsupervised, self-organising structure that can map non-linear relationships between image data, making it uniquely suited for classifying eye disease levels.

The rest of the paper is organised as follows. Section 2 describes the use of neural networks for medical image analysis and the conjunctivitis classification-related work, while section 3 describes the proposed solution. The expected outcomes of the proposed architecture are discussed in Section 4, and the use of proposed techniques with justifications is conveyed under Section 5. The challenges and limitations of conjunctivitis classification in telehealth are critically revealed in Section 6. Section 7 expresses the conclusion regarding the whole study.

2. RELATED WORK

Use of neural networks in medical image analysis

In the telehealth sector, medical image classification plays a pivotal role. Among the different approaches used for this purpose, neural networks can be considered as a highly effective tool used for automated identification and diagnosis of various medical conditions. This section describes the application of neural networks in image classification.

In image classification problems, to achieve a good classification, it is important to extract the features correctly. Scale-invariant feature transform (SIFT) (Sundeep *et al.*, 2023) and intensity histograms (Jayachandran and Stalin David, 2018) are feature extraction techniques commonly used in medical imaging. Support Vector Machine (SVM) (Tchito Tchapga *et al.*, 2021), logistic regression (Awad, Hamad and Alzubaidi, 2023) and Naive Bayes (Al-Aidaroo, Bakar and Othman, 2012) are common classification algorithms used to train the extracted features. Apart from that CNNs can be used for complex image classifications. CNNs derive their name from the convolutional filters that have been used to compute image features (Fathi and Maleki Shoja, 2018). When comparing CNNs with SVM, a common classification algorithm, the main drawback observed in SVM is that developing them is quite slow and its performance is far from the practical standard (Shuqi Cui *et al.*, 2017).

In lung disease classification, accurately categorising images can be particularly challenging when there is high variability within the same class and when distinct classes share a high degree of visual similarity (Zak and Krzyżak, 2020). Therefore, when classifying medical images having texture-like features, it would be advantageous to go for a customised CNN framework as there are no high-level features to be learned by the network. This will also help to overcome over-fitting problems as there are a smaller number of parameters to be learned.

Most medical data contain missing values and noise. Therefore, finding a large medical image dataset without missing values is a challenging task (Kim, Kim and Yoon, 2019). With the help of the transfer learning technique, the data scarcity problem can be solved. The TL aims to train specific features of a new task by leveraging the knowledge learned from similar tasks. Figure 1 below illustrates the architecture of transfer learning.
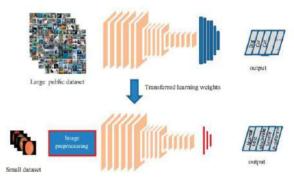
Figure 1: Transfer Learning architecture (A.M. Aslam Sujah, A. Fathima Sharfana, and Mohamed Sazni, 2022)

Table 1 below shows an overview of some model types that have been used as backbone models for TL.

Table 1: Overview of five backbone models

Model Type	Model	Released year	Parameters (all)	Dataset
Shallow and linear	LeNet5	1998	60,000	MINIST
	AlexNet	2012	62.3M	ImageNet
Deep	ResNet50	2015	25.6M	ImageNet

	InceptionV3	2016	27.2M	ImageNet
	DenseNet	2017	8.0M	ImageNet
	EfficientNet	2019	5.3M	ImageNet

According to the study by Sujah, Sharfana and Sazni (2022), the authors have created a transfer learning model to detect multiple ocular diseases in fundus images. Fundus images are the images of the back of the eye, which capture the appearance of the retina, optic nerve, and blood vessels. These images have been used to identify different fundus diseases such as diabetic retinopathy, glaucoma, cataracts, etc. In this study, the RestNet50 pre-trained model has been taken as the feature extractor since it outperformed the other CNN models such as EfficientNet-v3, Mobilet-v2, and Inception-v3. Not only single-label classification but also multi-label classification is also possible with the transfer learning technique.

Classifying severity levels of diabetic retinopathy is one of the biggest challenges faced by ophthalmologists. Enas Houby has created a model using transfer learning techniques to classify the stages (normal, mild, moderate, severe, proliferated_DR) of diabetic retinopathy (El Houby, 2021). In this study, VGG-16, a model trained using the ImageNet dataset has been used as the base model, and a dataset taken from Kaggle has been utilised to do the multi-class classification. Here, to overcome the class imbalance problem, data augmentation was performed by flipping and rotating the images by three angles.

In supervised deep learning, the accuracy of the image classification depends on the availability of annotated data. In the medical field, manual annotation is complex and requires a significant amount of time (Yadav and Jadhav, 2019). Therefore, large-scale annotated datasets are rarely to be found. Transfer learning techniques can be used to address the scarcity of annotated medical images. According to the study by Ahn et al. (2019), authors have proposed an architecture to learn features of unannotated medical images based on a model that is trained on an annotated dataset. Here, a convolutional auto-encoder (CAE), which can learn the global structures of

images is placed atop pre-trained CNN to create a hierarchical unsupervised feature extractor. This architecture was tested using the medical Subfigure Classification dataset used in the ImageCLEF 2016 competition using GoogLeNet, ResNet, and ALexNet pre-trained models. The assembly of ResNet and GoogLeNet has achieved an accuracy of 87.87%.

Existing Conjunctivitis Detection Systems

"OphthaPredict" is a web-based application proposed by Jindal and his team to detect conjunctivitis in real time using EfficientNet deep learning architecture. Moreover, this is an application developed for the Indian healthcare sector focusing on helping Auxiliary Nurse Midwives (ANMs), Accredited Social Health Activist (ASHA) workers, and Primary Care Physicians (PCPs) in the diagnosis process. Three categories, including normal, viral, and bacterial, are identified with this developed model with an accuracy of 99% (Jindal, Handa and Goel, 2024).

The research titled "Severity Based Detection of Conjunctivitis and Drug Recommendation System Using CNN" employed multi-dimensional CNN architecture for the severity level classification. This research focuses mainly on viral conjunctivitis. Based on the infection severity level, the system recommends treatment options as well (Prakash *et al.*, 2023).

Sundararajan and D (2019) presented a deep learning-based system to detect conjunctivitis. Initially, eye images were pre-processed using median and wiener filters, where the median filter was used to remove salt and pepper noises and the wiener filter to remove blurred images. The authors of this study have employed a fuzzy technique for image segmentation. Moreover, data augmentation techniques have been used to solve the fitting problems that arise when training the deep learning model. The dataset has been trained three different times by changing the size of the training dataset and in the third step, a testing accuracy of 93% has been achieved.

For Adenoviral Conjunctivitis (Ad-Cs) detection, Günay, Göçeri, and Danışman (2015) have proposed a machine learning based system. The proposed system entails multiple steps for conjunctivitis diagnosis beginning with the region of infection segmentation.

Next, the intensity of redness in the eyes and the vascularisation have been measured. For sclera segmentation, they have employed the GrabCut segmentation algorithm (Lu *et al.*, 2017), and by thresholding, the noise in the segmented area has been removed. Furthermore, vascular extraction is done through Eigen decomposition of the Hessian matrix. Figure 3 shows the sclera segmentation process used in this proposed system. For this study, 18 healthy and 12 Ad-Cs eye images have been used for the training data set to extract features. Using Bayes and Random Tree algorithms they have achieved an accuracy of 96.7%. Moreover, the authors of this study have emphasised that Grabcut with Bezier-type curves would have given more accurate sclera segmentation.
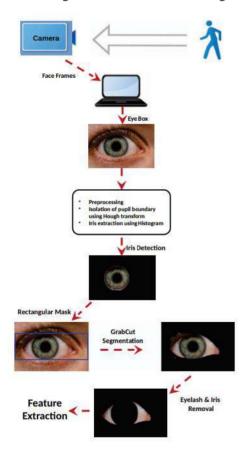
Figure 2: Sclera segmentation process (Tabuchi and Masumoto, 2020)

In the research by Tabuchi and Masumoto (2020), the authors proposed an artificial intelligence model to grade conjunctival hyperaemia severity levels as mild, moderate, and severe. The dataset used for this study consisted of 5008 slit lamp images taken at the Ophthalmology Department of Tsukazaki Hospital. Out of 5008 images, 872 images were taken for model validation and preliminary validation by graders. The Kappa coefficient was utilised to study the inter-rate agreement of the images. Based on the Japan Ocular Allergy Society's conjunctival hyperaemia severity grading system (JOAS grading), severity levels were identified by a JOAS specialist, and four (04) certified orthoptists and Kappa coefficients were calculated. Of the remaining 4008 images, 2707 images were selected as the final dataset. This dataset has been used to train six types of deep neural networks (DNNs), namely ResNet50, InceptionV3, Xception, Inception ResNet V2, VGG 19, and VGG 16. If half of the six DNN models gave the same grade as the experts, it was counted to be a correct answer. This study has shown a high correlation of 0.74 between the objective indicators and the AI grading results.

3. METHODOLOGY

The following experimental design is proposed for a precise classification of conjunctivitis into three severity levels: normal, mild, and severe.
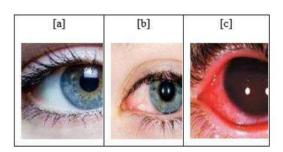
Figure 3: (a) Normal eye (b) Mild conjunctivitis infected eye (c) Severe conjunctivitis infected eye

Data Acquisition

Slit lamp images of both healthy and conjunctivitis-infected eyes need to be collected from a reliable source such as a medical institute or an eye clinic. It is preferred that all the images collected be taken from the same type of slit lamp.

Medical image collection needs to comply with ethical standards and patient privacy regulations. To ensure that, it would be required to obtain necessary medical clearances.

The complete process is illustrated in Figure 4 below.
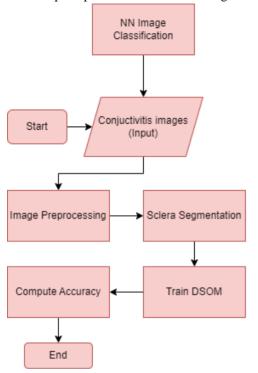
Figure 4: Image Classification Process Flow Chart

Image Preprocessing

In this phase, images will be subjected to preprocessing techniques for sharpening, smoothing, and reducing noise in the images. The collected slit lamp eye images will be sent through median and wiener filters to remove noise (Sundararajan and D., 2019). The median filter is a non-linear digital filtering technique used to remove noise while the wiener filter is a linear filtering technique used to restore the image degraded by noise.

Image Segmentation

For a better feature extraction, the sclera region of the eye covering the bulbar conjunctiva needs to be isolated. Lately, there is a higher inclination toward using deep learning techniques for the semantic segmentation of images. U-Net is one of the deep-learning networks that is designed for semantic image segmentation (Huang *et al.*, 2020). U-Net has an encoder-decoder architecture, where the encoder network is known to be the contraction path while the decoder network is called the expansion path. Here for sclera segmentation, ScleraSegNet, an attention-assisted U-Net model proposed by Wang et al. (2020) will be used.

To create a ScleraSegNet model, between the contract path and expansive path, a central bottleneck part will be introduced to enhance the separation of sclera and non-sclera pixels for learning more discriminative features. In the bottleneck part, four types of attention modules will be added. They are the spatial attention module (SAM), channel attention module (CAM), sequential channel attention and spatial attention module (CBAM), and parallel channel and spatial attention module (BAM).
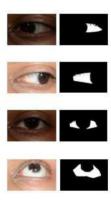
Figure 5: Sample MASD v1 eyes and corresponding segmented eyes (Wang *et al.*, 2020)

According to Wang et al. (2020), this ScleraSegNet model has achieved a precision value of 92.88% on the MASD v1 dataset. The provided Figure 5 below displays the results of sclera segmentation on sample images from the MASD v1 dataset using the ScleraSegNet model.

All the conjunctivitis-infected images will be subjected to sclera segmentation using the ScleraSegNet deep-learning model. Hyperparameters of the ScleraSegNet will be changed for better image segmentation.

Model Development

For model development, a Deep Self Organising Map (DSOM) will be employed. The Self Organising Map (SOM) uses a competitive learning technique that can detect features inherent to the problem (El Houby, 2021). In DSOM, there are mainly three layers, i.e. input, hidden, and output. The input layer is responsible for forwarding input images to the DSOM while the output layer is responsible for self-organisation. The hidden layer has two phases as SOM phase and the sampling phase.

Diagrams 6 and 7 below illustrate the two-layered DSOM architecture and the sampling layer creation in DSOM, respectively.
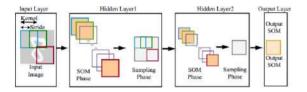
Figure 1: Two-layered DSOM architecture
(Wickramasinghe, Amarasinghe and Manic, 2019)
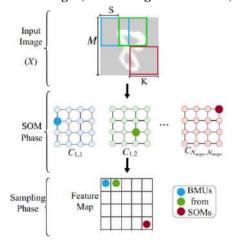
Figure 7: Sampling layer creation in DSOM
(Wickramasinghe, Amarasinghe and Manic, 2019)

In the SOM phase, each image is segmented into small local regions called patches. These patches will be sent to its own SOM and for each SOM, the Best Matching Unit (BMU) will be found. As stated in equation (1) below, BMU or the winner neuron c will be calculated by reducing the Euclidean distance between the input image local region x(t) and the centres of all neurons in the SOM lattice (Aly and Almotairi, 2020).

$$c = \arg_i \min \|(x(t) - m_i(t)\|2 \qquad (1)$$

In the sampling phase for a particular hidden layer, all the BMUs of hidden SOM units will be combined expecting a 2D grid to be generated. The generated single 2D grid acts as the feature map to the next hidden layer. A classifier will be developed depending on the trained output layer SOM to label the input records (Wickramasinghe, Amarasinghe and Manic, 2019).

Model Evaluation

Evaluation of the developed model will be done by doing a domain expert evaluation. It is valuable to involve domain experts such as ophthalmologists, in this case, to evaluate the model's results. They can provide valuable feedback on the clinical relevance and accuracy of the classifications.

4. EXPECTED OUTCOMES

Following are the expected outcomes of the proposed application aiming to classify conjunctivitis in a telehealth setting.

- Real-time analysis: To make decisions based on the conjunctivitis condition of the patient, it is required to obtain real-time images of the infected eye(s) of the patient.

- Severity Classification: Based on the captured images and the symptoms told by the patients, the proposed system should be able to accurately classify the severity level as mild, moderate, or severe.

- Enhancing diagnostic accuracy: By utilising DSOMs, the system is expected to analyse the extracted sclera region of the real-time images in a manner that provides better severity classification. Integration with telehealth platforms: For virtual consultation, integrating the developed DSOM model for seamless classification.

5. DISCUSSION

In telehealth, the accuracy of diagnosis could be affected by different factors such as the level of knowledge, experience, brain memory weaknesses, and fatigue of doctors. Another factor that may affect the diagnosis is the lighting or reflections and the set-up of the distance between the eyes and the screen.

Neural Networks can provide a standardised objective tool to support the diagnosis process and minimise any human errors that may occur during the protocol. The human eye conditions could also affect the result in cases where the doctors themselves may have colour blindness or inconsistent colour vision and weaknesses, unknowingly. A biological imperfection in the human eye causes a problem with colour perception, and this could be overcome using Artificial Neural Networks (ANN).

Table 2 below compares the existing traditional machine learning systems with DSOM under different aspects.

Table 2: Comparison between Traditional ML systems and DSOM

Aspect	Traditional ML systems	DSOM
Feature Extraction	Requires manual feature engineering and relies on domain expertise.	Automates feature extraction from raw images, learning complex patterns.
Data Requirements	Needs a large, labelled dataset and may overfit if data is limited or unrepresentative.	More robust to limited labelled data and can leverage unsupervised learning for pre-training.
Complexity Handling	May struggle with complex images and variations in severity levels.	Effectively captures high-dimensional data and complex relationships.
Performance	Performance may plateau as complexity increases and is prone to biases from feature selection.	Typically achieves higher accuracy in classifying images of varying severity levels.

In this proposed methodology, DSOM is suggested compared to traditional machine learning (ML) systems for this problem due to its power to represent a high dimensional space into a space of lower dimension. The DSOM's powerful lattice neighbourhood structure could also be utilised for the visualisation of high-dimensional data, especially health condition images.

6. CHALLENGES AND LIMITATIONS

The work only aims at grouping the images into three groups (normal, mild, and severe). In the future, more groups could be defined, such as trace, mild, and very severe, to be more precise and detailed for diagnostic decision-making.

The representativeness and the diversity of data are important to build an effective SOM model. Ensuring a well-balanced dataset that covers all three severity levels of conjunctivitis is crucial. Biased training data may lead to inaccurate classifications. Moreover, selecting optimal parameters when training the SOM is a challenge.

In the telehealth sector, patient cooperation is important to make accurate diagnoses. Capturing the conjunctivitis-infected eye(s) of a patient can be challenging. This is mainly due to variations in focus and angles. This may affect the model's capability to make correct severity assessments.

7. CONCLUSION

The neural networks serve as a powerful tool for the support of telehealth consultation by image classification. Recently, emerging methods have been

proposed by researchers to enhance the performance of the classifier by techniques such as data cleaning and transformation for better results. Despite their effectiveness and satisfactory results, neural networks still require a medical expert for monitoring and final decision after a critical evaluation of the Network's output.

This research proposes a neural network-based architecture for grouping images of patients showing conjunctivitis (pink eye) into three severity levels. Moreover, the utilisation of ScleraSegNet for accurate sclera segmentation and the implementation of unsupervised learning via deep self-organising maps will help for better classification.

Furthermore, the exploration of various neural network architectures for medical image classification and a comprehensive discussion on similar conjunctivitis classification techniques emphasise the importance of this field.

In conclusion, this study is crucial to acknowledge that the integration of neural networks into telehealth applications extends beyond conjunctivitis classification. The knowledge gained from this research can be used for further exploration into different ocular conditions and medical image analysis sectors.

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PUBLIC INTEREST OVER PRIVATE GAIN: A CRITICAL EXAMINATION OF THE ETHICAL PERSPECTIVE IN THE SRI LANKAN LEGAL PROFESSION

KA.Lavanya Lewmini Gunaratne*

ABSTRACT

The legal profession is a pillar of societal order, promoting justice and fairness. The objective of this research is to look into the fundamental concepts that characterize the legal profession as a profession primarily dedicated to societal growth rather than private gain. To do that, this paper tries to evaluate frameworks of ethics and present practices of the Legal profession in Sri Lanka using qualitative analysis and critical examination, focusing on the overall dedication to serving public interest. The research identifies a gap in understanding how closely legal practitioners in Sri Lanka emphasize ethical standards in practice. While current literature and frameworks stress upon ethical norms, there is little evidence of how these principles are prioritized above financial rewards in this sector. This research highlights that Attorneys can achieve success in their noble profession by upholding professional ethics, ensuring that the ultimate objective of the legal profession is to administer justice to the rightful individual rather than solely focusing on financial gain.

KEYWORDS: *Legal Profession, Professional Ethics, Justice, Rule of Law*

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1. INTRODUCTION

The development of justice and societal welfare is the primary focus of the legal profession, which is an essential component of society. It represents a noble effort to protect individual rights, maintain the rule of law, and promote justice and equity in society (Karnavas, 2016). Studying this area is essential because it gives insight into the significant impact that lawyers have on shaping communities, maintaining fairness, and defending the rule of law. Lawyers' job provides them with a livelihood and a sense of professional achievement, but their primary responsibility goes beyond individual profit to serve the public interest and guarantee that everyone has access to justice. This dedication frequently entails standing out for the rights of the marginalized, representing a range of interests, and upholding moral principles that put the good of the public above personal gain. Therefore, this paper analyses the importance of ethical conduct in the legal field and emphasizes how vital it is to uphold justice, integrity, and trust. It contributes new knowledge that clarifies the complexities of ethical issues in the field of law, opening the door to better professional conduct and better decision-making, and additionally, it emphasizes the relevance of ethics in the legal profession and outlines the essential principles that apply to the legal profession.

The primary research question of this research is: What are the prevailing ethical standards and laws in the legal profession mainly in Sri Lanka? The secondary question of this research is: To what extent do legal practitioners prioritize ethical considerations over financial gains? As a result of these two research questions, the research objectives of this research are: to explore and define the ethical principles and codes relevant to the legal profession mainly in Sri Lanka using case studies and laws and secondly to identify the weight given to the income of the lawyers as compared to adherence to their ethical principles.

2. METHODOLOGY

To give a multifaceted understanding of this Research topic, this research uses a qualitative approach. In the beginning, a comprehensive review of literature was conducted, which included scholarly publications, legal sources, and important international agreements. This allows for the identification of essential concepts, legal principles, rules, and precedents related to the ethical conduct of the Legal Profession. Therefore, this research uses a qualitative approach, employing secondary data such as journal articles, documents, government reports, websites, books, and international agreements, and it also uses primary data such as statutes, cases, and constitutions that relate to ethical standards and rules related to the legal profession. These sources are used to better understand this research area. This qualitative research provides a comprehensive insight into how ethical frameworks are viewed, negotiated, and used in the complex environment of the legal profession through deep examination. These findings have direct implications for improving ethical standards, professional training, and the overall quality of the legal profession.

3. RESULTS AND DISCUSSION

3.1. Professional Ethics and Legal Profession

The idea of "public interest over private gain" implies that decisions and actions should prioritize the welfare and well-being of the general public over the interests of individuals or specialized groups for personal profit or benefit. It is frequently mentioned in discussions about governance, commercial practices, and social responsibility.

Professional ethics is the cornerstone of every profession. Ethics are essential in the legal field, operating as a foundation for sustaining the rule of law and justice (Karnavas, 2016). Preserving public trust in the field of law requires professional ethics. Professional ethics means a set of rules that a potential lawyer must follow and the moral ideas that should operate as guidelines for a lawyer's behaviour (Madhavan). These rules govern the behaviour and activities of practicing lawyers, including dealings with clients, the opposing side, and the court. When lawyers act ethically, the public's trust in the system of law is strengthened. This trust is essential for the legal system to work properly. Also, Professional ethics in the field of law promotes integrity and responsibility.

In his book "Professional Ethics and Responsibilities of Lawyers," A. R. B. Amarasinghe emphasizes the responsibilities of lawyers, including their clients, the court, and other institutions. Lawyers must work with honesty, integrity, and truthfulness, fulfill court directives, and maintain client trust while demonstrating ethical conduct to the public (Amarasinghe, 1993). Also, according to Principle 12 of the UN Basic Principles on the Role of Lawyers "*Lawyers shall at all times maintain the honour and dignity of their profession as essential agents of the administration of justice*" (Basic Principles on the Role of Lawyers, 1990). Therefore, it is clear that adhering to ethical norms develops duty and accountability, which improves the overall image of the legal profession.

To begin, it is critical to understand the importance of the legal profession in maintaining justice, defending human rights, and ensuring the rule of law. However, challenges develop when personal or corporate interests outweigh these fundamental principles. According to the International Bar Association's International Principles on Conduct for the Legal Profession: "*Lawyers throughout the world are specialized professionals who place the interests of their clients above their own and strive to obtain respect for the Rule of Law. They have to combine a continuous update on legal developments with service to their clients, respect for the courts, and the legitimate aspiration to maintain a reasonable standard of living*" (IBA General Principles for the Legal Profession, 2006).

3.2. Domestic Legal Framework Governing Legal Ethics in Sri Lanka

The legal ethics of a country are generally established from domestic laws, although they may also be based on international and regional principles. According to Principle 26 of the UN Basic Principles on the Role of Lawyers "*Codes of professional conduct for lawyers shall be established by the legal profession through its appropriate organs, or by legislation, in accordance with national law and custom and recognized international standards and*

norms" (Basic Principles on the Role of Lawyers, 1990).

In Sri Lanka, as in many other nations, legal ethics refers to the norms, standards, and principles that regulate the conduct of attorneys and legal professionals. The Bar Association of Sri Lanka (BASL) is a major body that regulates legal ethics in Sri Lanka. They generally publish a code of ethics or conduct that outlines the rules that lawyers must follow in their duties as attorneys. Moreover, the Supreme Court of Sri Lanka has developed its own set of guidelines outlining the behaviour expected of lawyers in the island nation under Article 136 (1) (9) of the Constitution, and these regulations were published in the Gazette on December 7, 1988 (The Constitution of The Democratic Socialist Republic of Sri Lanka, 1978). These rules frequently address a variety of areas, such as professional standards, client representation, conflicts of interest, confidentiality, and courtroom behaviour.

According to Article 40 of the Judicature Act of Sri Lanka, if an attorney-at-law becomes a client's representative, he must have these key qualifications: Good repute, Competent knowledge, and Skills (Judicature Act, 1978). Attorneys are supposed to represent their clients with diligence, skill, and ethics. This entails giving genuine advice, keeping information private, avoiding conflicts of interest, and defending their clients' interests within the bounds of the law.

Rule 5 of the Supreme Court Rules states clearly that "*an Attorney-at-Law may not refuse to act on behalf of a party or person in any matter or proceeding before any Court, Tribunal or other Institution established for the Administration of Justice or in any professional matter at his or her Professional Fee*" (Supreme Court Rules, 1988). Also, according to the 5th rule, an attorney-at-law feels that if he represents a client, he will lose his professional independence therefore, he has the option of refusing the case without taking it. This is known as the Cab Rank Rule (Deegalla, 2019). If the client forces the attorney to provide fake documentation and evidence, or attempts

to wangle an attorney then the attorney can refuse to act as the client's representative by rules 6–13 which are exceptions to Cab Rank Rule (Deegalla, 2019).

More importantly, if a lawyer provides services to a client in an irresponsible manner, it violates their professional responsibilities. When a lawyer carries out their duties in such a manner, the legal profession needs to be disqualified. The Supreme Court was given this authority under Article 43(01) of the Judicature Act as an example of the legal profession being suppressed (Judicature Act, 1978).

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If a client chooses a lawyer to be their legal representative, then the client is required to pay the lawyer's fee and the attorney has no ethical reason for refusing that fee. When collecting fees, the attorney-at-law is supposed to follow Rules 27 to 30(b) of Supreme Court Rules including the Attorney-at-Law can waive fees due to client poverty or hardship, but cannot use client funds for specific purposes without client permission, and must respect their trust for legal advice and representation (Supreme court rules, 1988). According to Article 17 of SCR and as per the cases *In Re Aththanayake* (1987) and *In Re Brito* (1942), Lawyers must behave with complete honesty in all their interactions with clients and should not take any undue advantages from their professional responsibilities (Supreme Court Rules, 1988).

Moreover, Lawyers are required by professional ethics to offer their clients fair and impartial assistance. Lawyers guarantee that justice is not only served but also viewed as fair and unbiased by respecting ethical norms. Also, Competence and diligent representation necessitate that lawyers maintain a high level of knowledge and skill to successfully serve those they represent. By the Sixteenth Rule of the Supreme Court, attorneys-at-law must appear in court on specific days (Supreme Court Rules, 1988). Usually,

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Confidentiality is essential in ensuring that clients can provide highly sensitive information to their lawyers. Article 31-38 of Supreme Court rules and Article 126 of the Evidence Ordinance pointed out the confidentiality of information (Supreme Court Rules, 1988). According to Article 126(1), the Attorney-at-law or notary cannot disclose any communication made to them, the contents of any document they have become familiar with, or any advice given to their client without their client's express consent, during their professional employment (Evidence Ordinance, 1895). Therefore, Attorneys at law are required to maintain the confidentiality of information provided by clients. Because of this, lawyers must not reveal the details provided by the client or utilize the material for their gain.

The rules of 39-49 of Supreme Court Rules were specified about advertising and touting. The client experiences difficulties with their cases as a result of the excessive advertising and touting. Using a tout to help an attorney is a matter that goes to the heart of improper discipline and professional misconduct, which the court condemns, resulting in heavy penalties for delinquent lawyers (Supreme Court Rules, 1988). The *Re A. V. De Silva, Advocate (1934)* case states that an attorney-at-law is not permitted to use brokers to find clients.

Attorneys often find themselves in circumstances where the client's interests conflict with the lawyer's obligations to another client, previous clients, or third parties, or even against the lawyer's own personal interests due to the nature of the profession of law (Karnavas, 2016). This is referred to as a conflict of interest. The Supreme Court rule outlines some responsibilities of an attorney when there is a conflict of interest. According to Rule 58 of the Supreme Court Rules of 1988, an attorney's own interests shall

not conflict with the interests of his client, and as per Rule 57, an attorney must have no contacts or discussions with the opposing party (Supreme Court Rules, 1988). In the Indian case, *Chandra Shekhar Soni v. Bar Council of Rajasthan and Others* (1983), an attorney who was defending one party in a case shifted sides and began representing the other side and the Supreme Court held that it was not proper professional conduct.

The attorney, in his or her capacity as an Officer of Court, is bound by Rules 50 to 55 with regard to the courts. A lawyer must support the court in the proper administration of justice without undermining the Bar's independence and a lawyer is not allowed to let their client mislead or deceive the court in any way (Supreme Court Rules, 1988).

es, 1988).

Lawyers should conduct themselves with dignity and should adhere to the proper dress code when coming to court because it is crucial for a professional to show "professionalism" in their attire. It is crucial to remember that in the legal profession, appearance matters. This does not imply that a lawyer has to drive a luxurious vehicle and wear expensive suits (*Junior Bar Committee Induction Handbook for Junior Lawyers*, 2022). If an attorney is not appropriately attired, they may lose their chance to present their case before a Judge. The court attire of a Sri Lankan Attorney outlined in rule 6-8 of the Gazette of the Democratic Socialist Republic of Sri Lanka (Extraordinary) No. 1/4 dated 07.09.1978.

Furthermore, an attorney is expected to treat fellow members of the Bar fairly, courteously, and with respect in all professional engagements as a member of the profession (Supreme Court Rules, 1988). When interacting with other members of the profession, a lawyer ought to follow Rules 56 to 61 of the Supreme Court Rules. These are the main rules and regulations of Sri Lanka that an attorney should adhere to when dealing with clients, court, and other fellow members.

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that an attorney should adhere to when dealing with clients, court, and other fellow members.

Recent claims against Sri Lanka's legal profession present compelling examples of unethical activities within the legal profession. One important example is the Bar Association of Sri Lanka (BASL), where numerous office bearers, including the President and Deputy President, have been accused of misappropriating money intended for an anti-corruption effort aided by the Japan International Cooperation Agency. According to reports, around Rs. 19 million of the Rs. 21 million allocated for the work was misused. This led to calls for a thorough investigation from the legal profession, highlighting the necessity of transparency and ethical leadership to rebuild the public's trust.

3.3. Challenges to Upholding Legal Ethics in Sri Lanka and the Need for Reform

Conduct that violates ethics in the legal sector can have serious consequences. Regulatory authorities may apply disciplinary measures and professional punishments, leading to a destroyed professional image. Furthermore, ethical violations may contribute to the loss of clients, coworkers, and the trust of the public. Also, Professional misbehaviour can potentially have legal and financial effects. Therefore, to ensure compliance with legal professional ethics in Sri Lanka, several steps must be implemented. These include staying updated on ethical norms and emerging issues, as well as ensuring that attorneys complete continuing legal education and training in ethics.

One important factor to examine is the presence of corruption and unethical behaviour in the judicial system. Bribery, nepotism, and cooperation with prominent parties are some examples of how this might emerge. When attorneys put financial gain over public interest, the entire legal system's legitimacy suffers, as does public trust.

Another factor to consider is the affordability and accessibility of legal services. In Sri Lanka, like in many other nations, socioeconomic class frequently determines access to justice. Lawyers may favor profitable cases over pro bono work or affordable

legal assistance, exacerbating the disparity between the rich and the underprivileged.

To overcome these difficulties, significant reforms are required at both the institutional and individual levels. Regulatory agencies must impose strict ethical standards and hold attorneys accountable for misbehaviour. Furthermore, legal education should highlight the value of ethical behaviour and inculcate a feeling of societal responsibility in future attorneys.

Furthermore, actions aiming at increasing openness, such as publicly declaring financial interests and conflicts of interest, can assist in reducing unethical behaviour. Encouraging a culture of integrity and accountability within the legal profession is critical for protecting the public's interests while respecting the values of justice and fairness.

4. CONCLUSION

In conclusion, it is clear that being an attorney is extremely noble, and it is important for both practicing and prospective attorneys to respect the profession and maintain their dignity. As Lawyers are responsible for serving society, upholding the law, and assisting in the maintenance of the law and peace in the nation as a whole, they must carry out their responsibilities while adhering to the rules of ethics. The outcomes of the research unquestionably support the idea that ethics in the legal profession outweigh the financial benefits. A thorough examination of ethical rules, professional conduct, and the impact on clients, society, and the legal system reveals that valuing ethical practices over financial incentives is critical. Maintaining standards of ethics not only fosters trust and integrity within the field of legal practice, but also ensures that justice is carried out impartially and fairly. While financial gain may provide short-term benefits, the long-term consequences of violating ethics may reduce public trust, ruin reputations, and undermine the legal system. Every attorney can pursue success while maintaining the ideals and standards that characterize their noble profession by adhering to professional ethics. Therefore, it is clear that the goal of the legal profession is to serve the proper person with justice, not to make money.

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THE SYNERGY OF SEARCH ENGINE OPTIMIZATION AND PUBLIC RELATIONS IN THE DIGITAL AGE (AN ANALYSIS OF BEST PRACTICES IN SRI LANKA)

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ABSTRACT

In the contemporary digital landscape, the integration of Search Engine Optimisation (SEO) and Public Relations (PR) has become essential for organisations seeking to enhance their online visibility. This research investigates best practices for optimising the collaborative efforts of SEO and PR within this context. Given the rapid advancements in technology and communication, it is crucial to develop a nuanced understanding of how these two domains intersect to achieve mutual goals. Recognising the existing gaps in the literature concerning practical applications of SEO-PR strategies, this study employs a qualitative research methodology. Insights were gathered through in-depth interviews with ten experienced PR professionals, illuminating their experiences, strategies, and challenges related to SEO-PR integration. The findings indicate that a multifaceted approach to SEO and PR collaboration is vital in the digital era. A primary theme that emerged is the importance of content quality, which must be informative, engaging, and relevant to align with the objectives of both disciplines. The study also highlights the role of authentic storytelling, which resonates with the values and interests of target audiences, as a critical component of effective communication. Ethical considerations are emphasised as integral to SEO-PR integration, particularly regarding transparency, accuracy, and trustworthiness in content creation and dissemination. This research thus provides valuable insights for PR professionals and SEO experts navigating the complexities of the digital landscape.

KEYWORDS: *Digital age, Public Relations, SEO, SEO-PR Synergy*

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1. INTRODUCTION

1.1 Background of the study

The rapid evolution of digital communication has fundamentally transformed the landscape in which organisations operate. In this context, the integration of Search Engine Optimisation (SEO) and Public Relations (PR) has emerged as a crucial strategy for enhancing online visibility and fostering engagement with target audiences. As organisations strive to navigate this dynamic environment, understanding the synergy between SEO and PR becomes increasingly vital.

Search Engine Optimisation refers to the practices and strategies employed to improve a website's visibility on search engine results pages (SERPs). It encompasses a variety of techniques, including keyword optimisation, content creation, and link building, aimed at driving organic traffic to digital platforms. Given the prevalence of online information consumption, effective SEO is critical for organisations seeking to establish a robust digital presence. According to recent studies, a significant percentage of consumers rely on search engines to make informed decisions, highlighting the importance of being easily discoverable online.

Conversely, PR focuses on managing an organisation's reputation and cultivating relationships with key stakeholders, including the media, customers, and the public. Traditionally, PR strategies involved press releases, media outreach, and event management, but the advent of digital communication has expanded these practices. Today, PR professionals utilize online platforms to engage audiences, share brand narratives, and respond to public sentiment. The integration of digital tools and platforms has allowed PR to become more data-driven and responsive to audience needs.

Despite the distinct objectives of SEO and PR, their convergence presents an opportunity for organisations to amplify their messages and improve their overall effectiveness. The intertwining of these disciplines allows for a more cohesive communication strategy, where high-quality content serves as the linchpin connecting SEO and PR efforts. Content that is not only optimised for search engines but also compelling and relevant to the audience can enhance brand visibility and foster trust. For instance, informative articles, engaging blog posts, and authentic storytelling can resonate with audiences while simultaneously improving search engine rankings.

Research indicates that there is a growing recognition of the need for integrated approaches that combine the strengths of both SEO and PR. However, the existing literature reveals significant gaps in understanding the practical implementation of these strategies. Many studies focus on either SEO or PR in isolation, leaving a need for comprehensive insights into how these disciplines can effectively collaborate in the digital age.

In Sri Lanka, as in many other countries, organisations are beginning to realize the importance of this integration. The digital landscape is rapidly evolving, with an increasing number of consumers engaging with brands through online platforms. Consequently, PR professionals are challenged to adapt their strategies to leverage the advantages offered by SEO, while SEO experts must understand the nuances of effective public relations.

This study seeks to address these gaps by exploring the lived experiences of PR professionals who have actively engaged in SEO-PR collaboration. By conducting in-depth interviews, the research aims to uncover best practices, challenges, and strategies that can inform future efforts in integrating these two critical domains. Ultimately, the goal is to provide valuable insights that can guide organisations in optimising their SEO and PR efforts, enabling them to thrive in an increasingly complex digital environment.

1.2 Literature Review

 Engine Optimisation (SEO) and Public Relations (PR) has emerged as a pivotal strategy (Holiday, 2012). A review of the existing literature reveals the evolving roles of SEO and PR and their interconnectedness in the digital realm (Forbes, 2019).

The traditional view of SEO as a technical practice, focused solely on improving website rankings, has evolved (Enge, Spencer & Stricchiola, 2015). According to modern perspectives, SEO emphasises a broader approach, emphasising user experience, content quality, and brand visibility (Clarke, 2023).

This shift recognises that search engine algorithms increasingly reward high-quality, relevant content.

Simultaneously, the field of PR has expanded its scope in response to the digital age (Scott, 2020). PR, once primarily associated with media relations, now encompasses broader responsibilities, including reputation management, stakeholder engagement, and strategic communication (Holiday, 2012). As organisations increasingly interact with their audiences through digital channels, PR professionals are adapting their strategies accordingly.

The intersection of SEO and PR has become more pronounced as their functions overlap (Forbes, 2019). SEO now relies on PR to secure high-quality backlinks and leverage earned media, which contribute significantly to a website's authority (Enge, Spencer & Stricchiola, 2015). PR, in turn, depends on SEO for optimising online content to ensure it aligns with search engine algorithms, enhancing online visibility and reputation (Clarke, 2023).

Despite the growing recognition of this interdependence, the existing body of literature falls short in offering comprehensive insights into practical strategies for optimising the synergy between SEO and PR (Journal of Digital & Social Media Marketing, 2021). Little research delves into how these two domains collaborate in practice, especially in the context of the digital age, highlighting a clear knowledge gap.

A recurring theme in the limited existing literature is the significance of content quality (Journal of Search Engine Optimisation, 2020). High-quality, informative, and engaging content is central to both SEO and PR success in the digital age (Enge, Spencer & Stricchiola, 2015). Engaging content not only attracts search engine attention but also resonates with the target audience.

Furthermore, the literature emphasises the importance of authentic storytelling (Scott, 2020). The ability to craft narratives that align with the values and interests of the audience is crucial for both PR and SEO, as it facilitates effective communication (Holiday, 2012).

1.3 Research Gap

The integration of Search Engine Optimisation (SEO) and Public Relations (PR) has garnered increasing attention in the digital landscape, yet significant research gaps persist.

While existing studies often examine SEO and PR in isolation, there is a limited understanding of how these disciplines can collaboratively enhance organisational communication strategies. Specifically, the literature lacks comprehensive insights into the practical implementation of integrated SEO-PR strategies, leaving a need for exploration into effective collaboration practices.

Moreover, phenomenological approaches focusing on the lived experiences of PR professionals engaged in SEO-PR synergy remain scarce. Current research often overlooks the nuanced challenges and strategies faced by practitioners, limiting the applicability of findings to real-world scenarios. Additionally, there is insufficient attention to industry-specific dynamics, which can influence the effectiveness of SEO-PR integration.

As organizations increasingly navigate the complexities of digital communication, understanding these gaps is crucial for developing effective strategies that leverage the strengths of both SEO and PR. This study aims to address these gaps by providing empirical insights into best practices and challenges, thereby contributing to a more comprehensive understanding of SEO-PR collaboration in the digital age.

1.4 Research Problem

What are the practical challenges and strategies faced by Public Relations (PR) professionals in integrating Search Engine Optimisation (SEO) within their campaigns, and how can a deeper understanding of these experiences enhance the effectiveness of SEO-PR collaboration in the digital age?

1.5 Objectives of the study

1.To investigate the strategies and methods employed by PR professionals to effectively integrate SEO into their campaigns.

2.To examine the challenges and successes encountered by PR professionals in their SEO-PR collaborations, providing insights into their practical experiences.

3.To Identify the best practices for optimising the synergy between SEO and PR, enhancing the effectiveness of communication strategies in the digital landscape.

1.6 Significance of the study

The significance of this study lies in its contribution to understanding the evolving relationship between Search Engine Optimisation (SEO) and Public Relations (PR) in the digital age. By exploring collaborative practices and lived experiences of PR professionals, the research provides valuable insights that can inform both academic and practical approaches to SEO-PR integration. The findings aim to equip practitioners with best practices that enhance online visibility and brand reputation, ultimately contributing to more effective communication strategies. This study addresses existing gaps in the literature, fostering a deeper understanding of how these two disciplines can work synergistically to achieve organisational goals.

2. METHODOLOGY

2.1 Research Philosophy

This research adopted a constructivist philosophy, recognising that knowledge is constructed through individual experiences and interactions. This approach is particularly relevant in understanding the dynamic nature of the digital age and the collaborative efforts of Search Engine Optimisation (SEO) and Public Relations (PR) within it.

2.2 Research Method

The qualitative research method was selected to explore the intricacies of human experiences, perceptions, and practices. This method allows for a deeper understanding of how PR professionals engage in SEO-PR collaboration, capturing the complexity of their roles in the evolving digital landscape.

2.3 Phenomenological Approach

A phenomenological approach was employed, focussing on the lived experiences and perspectives of PR professionals who have actively participated in the synergy of SEO and PR (Moustakas, 1994). This approach provided rich context for exploring the nuances of their experiences and insights.

2.4 Data Collection

Data collection was conducted through semi-structured in-depth interviews, which provided flexibility to explore emerging topics while maintaining consistency in the questions asked. This approach facilitated in-depth discussions that revealed the complexities of SEO-PR integration. Key interview questions were designed to investigate specific aspects of collaboration, including strategies, challenges, and best practices, allowing the study to gather rich qualitative data from PR professionals and gain valuable insights into their experiences and perspectives.

2.5 Participant Selection

Participants were selected using purposive sampling (Palinkas *et al.*, 2015), with ten PR professionals chosen based on specific criteria: extensive experience in PR, a proven track record of SEO-PR collaboration, and representation from diverse industries and organizational sizes. This selection aimed to ensure a comprehensive understanding of the various contexts in which SEO and PR operate.

2.6 Data Analysis

Data analysis employed a thematic analysis approach (Braun & Clarke, 2006), which facilitated the identification of key themes related to SEO-PR collaboration. The findings were systematically aligned with the key interview questions, ensuring that participant responses accurately reflected these identified themes. This structured presentation allowed for a clear mapping of insights to the specific aspects of the collaboration explored in the interviews.

2.7 Qualitative Data

The primary data collected were qualitative in nature, derived from the in-depth interviews, capturing participants' narratives, experiences, insights, and perceptions related to the integration of SEO and PR in their professional roles. This qualitative approach is supported by existing research, indicating that in-depth interviews are effective for capturing nuanced experiences and best practices.

2.8 Limitations

The study's   reliance on a limited sample size of ten PR professionals might restrict the generalisability of findings. While purposive sampling aimed to select experienced professionals, the study might overlook the perspectives of a broader range of professionals or industries. As the research focused solely on the experiences and perceptions of PR professionals, there is a potential for subjectivity and bias in the data collection and interpretation. Individual viewpoints might not fully represent the entire spectrum of SEO-PR collaboration experiences. The study's time frame might limit the relevance of the findings as the digital landscape constantly evolves. Insights captured from participants within a specific period might not fully reflect ongoing changes or future developments in SEO-PR practices. The researchers' interpretations and biases might have influenced the thematic analysis. Despite efforts to maintain objectivity, the researchers' preconceptions or perspectives could have affected the identification and interpretation of themes. While in-depth interviews provided rich qualitative data, the study's focus solely on qualitative methods might have limited the depth or breadth of understanding regarding quantitative metrics or specific SEO tactics utilised within the collaboration. External factors such as industry-specific dynamics, organisational structures, or individual job roles of participants might have influenced their experiences, potentially impacting the generalisability of findings beyond the studied context.

3. RESULTS AND DISCUSSION

This research conducted in-depth interviews with ten seasoned PR professionals to explore best practices in optimising the collaborative efforts of SEO and PR in the context of the digital age. The findings reveal key insights that illuminate the multifaceted nature of SEO-PR integration.

Content quality emerges as the cornerstone.

One of the central themes that emerged from the interviews was the paramount importance of content quality. Participants uniformly emphasised the crucial role of high-quality, informative, engaging, and relevant content in both SEO and PR efforts. They viewed content as the bridge connecting these two disciplines, enabling them to achieve their respective goals. The researchers derived this theme by analysing participants' responses, which consistently highlighted content quality as a pivotal factor in their strategies.

The PR professionals stressed the need to align content strategies with the objectives of SEO and PR. Content should be crafted to serve a dual purpose: enhancing online visibility through SEO and engaging and informing the target audience through PR. The integration of content strategies was identified as a best practice, ensuring that content serves the interests of both disciplines effortlessly.

Authentic storytelling fosters connection

Authentic storytelling emerged as another fundamental concept. PR professionals recognized that effective communication in the digital age hinges on crafting narratives that resonate with the values and interests of the target audience. Authentic storytelling allows organisations to connect with their audiences on a deeper level, creating a meaningful and lasting relationship. This finding was derived from direct quotes and anecdotes shared by participants, illustrating their successful use of storytelling in their campaigns.

In addition to engaging the audience, authentic storytelling contributes to building brand trust and credibility. PR professionals highlighted that by conveying a brand's values and mission through storytelling, they could establish a stronger emotional connection with their audience. This emotional connection, in turn, supports the broader PR goals of reputation management and relationship-building.

Ethical considerations

Ethical considerations played a significant role in the integration of SEO and PR. The participants underscored the importance of transparency, accuracy, and trustworthiness in content creation and dissemination. Ensuring that the information presented is reliable and accurate was crucial not only for SEO, which relies on content for ranking, but also for PR, where credibility and reputation management are paramount. The emphasis on ethics was evident in multiple responses where participants recounted challenges they faced in balancing commercial interests with ethical considerations.

Balancing commercial interests with ethical considerations was identified as a challenge. PR professionals expressed the need to strike a delicate balance between promoting a brand and ensuring that the information shared is accurate and honestly done. The findings suggested that ethical practices are integral to maintaining a sustainable synergy between SEO and PR.

Collaborative strategies for success

Effective communication and coordination between SEO and PR teams were identified as essential for successful integration. The PR professionals emphasised the need for regular meetings, open channels of communication, and sharing of insights and strategies. Collaboration and mutual understanding between these traditionally distinct disciplines were seen as key components of their success. Participants shared specific examples of how collaboration improved their campaigns, illustrating the importance of mutual understanding between these traditionally distinct disciplines.

Furthermore, measuring the impact of their efforts was viewed as crucial. By using analytics and key performance indicators (KPIs) to assess the outcomes of their work, PR professionals were able to adapt their strategies to ensure that both SEO and PR goals were met. This data-driven approach was deemed fundamental for optimising their collaborative efforts.

Adaptability in the ever-evolving landscape

The digital age is characterised by its ever-evolving landscape. PR professionals recognised the need to stay updated with search engine algorithm changes, emerging online platforms, and digital trends. This adaptability and willingness to embrace change were seen as prerequisites for maintaining a successful SEO-PR synergy.

The participants viewed challenges not as setbacks but as opportunities for learning and growth. Whether related to algorithm updates, reputation management crises, or shifting audience preferences, they emphasised the importance of learning from setbacks. Many participants recounted specific instances where adaptability led to innovative solutions, reinforcing the significance of a resilient attitude. This resilient attitude was integral to their ability to adapt and succeed in the digital age.

Tailoring strategies to industry dynamics

The findings indicated that the synergy between SEO and PR should be tailored to suit the unique dynamics of each industry. PR professionals recognised that strategies effective in one sector might not work in another. Participants highlighted their experiences in different industries, emphasising the need for customised approaches based on industry-specific nuances and audience behaviours. Understanding industry-specific nuances, target audience behaviours, and market trends was essential for optimising their collaborative efforts effectively.

The findings from this research illuminate the intricate and dynamic nature of SEO and PR collaboration in the digital age. Content quality, authentic storytelling, and ethical considerations serve as the cornerstones for successful integration. Effective communication and coordination, combined with a data-driven approach, play a pivotal role in achieving synergy. A proactive and adaptive mind-set is vital in an environment where change is constant. These insights offer valuable guidance for PR professionals and SEO experts navigating the complex and ever-evolving landscape of the digital age and optimising the synergy between these two critical disciplines.

This research, aligning with prior studies, accentuates the pivotal role of content quality in optimising the collaborative efforts between SEO and PR (Scott, 2020). Echoing previous findings, the present study underscores content as the linchpin connecting these disciplines and enabling the achievement of their respective objectives (Enge, Spencer & Stricchiola, 2015). The emphasis placed by participants on aligning content strategies with both SEO and PR objectives aligns with the notion of integrated content approaches advocated in prior research (Clarke, 2023).

Authentic storytelling, as highlighted in this study, mirrors the emphasis seen in earlier research (Holiday, 2012). The recognition of authentic storytelling as a conduit to establish deeper connections with the audience is consistent with the emphasis on emotional

engagement and brand trust outlined in previous studies (Scott, 2020).

Ethical considerations, a key theme in this research, resonate with earlier research highlighting the importance of transparency, accuracy, and trustworthiness in content dissemination (Holiday, 2012). The balancing act between commercial interests and ethical considerations aligns with prior studies emphasising the need for ethical content creation and dissemination strategies within SEO and PR integration (Scott, 2020).

The emphasis placed on effective communication, coordination, and data-driven approaches echoes the collaborative strategies advocated in previous research (Enge, Spencer & Stricchiola, 2015). The need for adaptability in the ever-evolving digital landscape, a recurring theme in this study, aligns with prior research emphasising the need for flexibility and learning agility in SEO and PR practices (Holiday, 2012).

Furthermore, tailoring strategies to industry-specific dynamics, a finding highlighted in this research, correlates with earlier studies emphasising the importance of industry-specific approaches and audience behaviour understanding in successful SEO-PR collaborations (Scott, 2020).

The consistency between these findings and prior research underscores the enduring importance and applicability of content quality, authentic storytelling, ethical considerations, collaborative strategies, adaptability, and industry-specific tailoring in optimising the synergy between SEO and PR in the dynamic digital age (Enge, Spencer & Stricchiola, 2015).

4. CONCLUSION

The findings from this study underscore several key themes that collectively serve as a roadmap for PR professionals and SEO experts navigating the complex and dynamic digital age. The first and most central theme is the importance of content quality. High-quality content, defined by its informativeness, engagement, and relevance, emerged as the linchpin of success for both SEO and PR. This content serves as a bridge, aligning the goals of both disciplines

seamlessly. Content, it appears, is the common language spoken by SEO and PR professionals, forming the foundation of their collaboration.

Authentic storytelling emerged as another cornerstone of effective SEO-PR integration. PR professionals recognised that in the digital age, authenticity and relatability are prized by audiences. The ability to craft narratives that resonate with the values and interests of the target audience fosters a deep and lasting connection. Authentic storytelling not only engages the audience but also contributes to building trust and credibility, key objectives for both SEO and PR.

Ethical considerations are another integral aspect of the SEO-PR synergy. Transparency, accuracy, and trustworthiness in content creation and dissemination are the cornerstones of a successful digital strategy. The data-driven era demands integrity in information presentation, which is fundamental for establishing and maintaining credibility.

The findings further highlight that effective communication and coordination between SEO and PR teams are essential for a successful integration. Collaboration and mutual understanding between these traditionally distinct disciplines are key to unlocking their combined potential. Additionally, measuring the impact of their efforts through analytics and KPIs was considered crucial for optimising their collaborative strategies.

The digital age is characterized by its ever-evolving landscape, demanding adaptability, and a proactive mind-set. Challenges were not seen as setbacks but rather as opportunities for growth and learning. PR professionals recognized the need to stay updated with search engine algorithm changes, emerging online platforms, and evolving digital trends, which is vital for maintaining a successful SEO-PR synergy.

Lastly, the research highlighted the importance of tailoring strategies to the unique dynamics of different industries. One size does not fit all in the realm of SEO-PR integration, and understanding industry-specific nuances and audience behaviours is essential for optimising collaborative efforts effectively.

5. RECOMMENDATIONS

Organisations should prioritise the creation of high-quality, purposeful content aligned with both SEO and PR objectives to foster effective collaboration. Crafting narratives that resonate with audience values builds trust and connections, while transparent and credible communication ensures sustained credibility. Enhanced collaboration between SEO and PR teams is crucial for aligned efforts, adapting to digital trends, and tailoring strategies for diverse industries' dynamics and audience behaviours.

5.1 Directions for future research

Future studies should focus on conducting longitudinal analyses to track the evolving nature and long-term impact of SEO-PR collaboration. Utilizing a blend of qualitative and quantitative analyses will offer a comprehensive understanding of outcomes. Comparing SEO-PR strategies across industries and exploring global practices while considering cultural nuances and market dynamics will be essential. Additionally, investigating the integration of emerging technologies and developing ethical frameworks specific to SEO-PR collaboration will address content ethics and future-proof strategies.

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ASSESSMENT OF SETUP-ERRORS IN 3D-CONFORMAL RADIOTHERAPY FOR HEAD AND NECK CANCER PATIENTS USING AN ELECTRONIC PORTAL IMAGING DEVICE
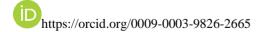
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ABSTRACT

Patient setup is crucial in radiotherapy since treatment is delivered as fractionated treatment over a period of time. Using own institutional margins by considering the setup errors will provide better radiotherapy outcome. Therefore, this study aims to assess set up errors for head and neck cancer patients using an electronic portal imaging device at Apeksha Hospital, Maharagama, Sri Lanka. A total of 101 head and neck cancer patients who were immobilized with thermoplastic mask were selected in this study. Stored data from July 2021 to July 2022 were obtained from ARIA patient management system in the Varian 2300CD Unit at Apeksha Hospital. In order to calculate systematic and random errors, translational errors in all directions were collected utilizing 303 pairs of orthogonal portal images. Moreover, three different algorithms were used to obtain the margin of clinical target volume (CTV) to planning target volume (PTV). The estimated systematic and random errors in the directions of antero-posterior, superior-inferior and medio-lateral are 0.13 cm, 0.10 cm and 0.08 cm, and 0.22 cm, 0.21 cm, and 0.19 cm respectively. Less than 0.5 cm margin were obtained by applying three different algorithms. This study indicates that using a 0.5 cm margin for head and neck cancer patients treating in 2300CD Varian Unit at Apeksha Hospital is safe. Further, this study recommends to developing institutional CTV to PTV margin for all sites of cancer to reduce unnecessary radiation to the surrounding normal healthy tissues.

KEYWORDS: *Radiotherapy, 3-Dimensional conformal radiotherapy, Electronic portal imaging device, Setup error, Clinical target volume, Planning target volume*

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1. INTRODUCTION

According to the GLOBOCAN report, 33243 new cases and 19145 deaths have been reported in 2022 in Sri Lanka (GLOBOCAN 2022). Squamous cell head and neck cancer is the 7th most common cancer worldwide, and it is the most common in men in Sri Lanka (Rupasinghe T., et al., 2021). Head and neck cancers respond to radiotherapy well. Precise delineations of tumour and critical organs are very important in radiotherapy. The International Commission on Radiation Units and Measurements (ICRU) has established different target volumes to account for the microscopic spread of the tumour and all other uncertainties (ICRU, 1999). Underestimation of the variations and uncertainties may lead to failure of tumour coverage and under or overdosage to normal healthy tissues. Image guidance plays a major role in radiotherapy treatment verification. It allows to verifying the patient position by comparing with digitally reconstructed radiograph (DRR). Electronic Portal Imaging Device (EPID) is mostly used in Radiotherapy Units since it can help to identify and fix setup errors quickly.

As setup margins have a direct impact on target volume coverage, they must be optimized to minimize the surrounding normal healthy tissue irradiation. Modern linear accelerators can be used to compare portal images and DRRs to reduce setup uncertainty and variability daily (Ramanathan V. et al., 2022). Therefore, this study aims to evaluate setup errors for head and patients treated with 3-Dimensional Conformal Radiotherapy (3D-CRT) treatment technique in the Varian 2300CD Unit at Apeksha Hospital, Maharagama, Sri Lanka.

2. MATERIALS AND METHODS

In order to assess setup errors, there are two main approaches available as random setup errors and systematic setup errors. When utilizing 3D-CRT, deviations must be assessed in 3 dimensions (Flentje, M. 1997). Portal images are compared with DRRs to identify the variation of isocenter, and the extent of inter-fractional and intra-fractional variations (Cacicedo, J. et al., 2015). References or anatomical

markers can be used to match the DRR and portal image. Three formulae are typically used (ICRU report 62, Stroom's formula, and Van Herk's formula) to determine the margins for CTV to PTV (Gupta et al., 2007 and Gizynska et al., 2020).

This descriptive quantitative study (retrospective study) was conducted with 101 head and neck patients treated with 3D-CRT in the Varian 2300CD Unit at Apeksha hospital, Maharagama, Sri Lanka. The data collection period was from July 2021 to July 2022. The age group was 18-80 years. All the data were collected from ARIA patient management system. 303 pairs of orthogonal images were selected to evaluate the transitional set up variations. All the displacements were recorded under specific codes that were assigned for each patient. Three fractions of treatment (first day, second day and randomly selected fractionation) were selected for each patient, and a total number of 606 portal images were analyzed in this study. Each portal image was compared with DRR with the aid of rigid bony anatomical landmarks to assess set up variations as shown in Figure 1 and 2. Set up variations were assessed along three directions Antero posteriorly (AP), Superior-inferiorly (SI) and Medio-laterally (ML). All the displacements were tabulated in Microsoft excel work sheet and data analysis was done by Microsoft excel 2013 version.

In radiotherapy, various error types may be taken into account. Over the course of treatment, systematic error consistently happens in the same direction and is reproducible. By using a permanent shift after a number of observations, it can be found and fixed. Otherwise, the direction and quantity of random errors fluctuate day to day. This study used DRR and portal images to measure the deviation of bony structures relative to the isocenter in order to analyze setup errors. To calculate the systematic error, the mean of the individual patient-shift along a respective axis is firstly calculated. The standard deviation of these individual systematic error values of each patient was calculated to obtain the population systematic error. The random error represents the patient's shifts from fraction to fraction and the random error blurs the dose distribution around the target. To calculate the individual random error, the standard deviation

(SD) of the individual patient shift along a respective axis was calculated. Then the mean value of individual random errors was calculated to obtain the population random error.

In this study, we used Van Herk's formula, Stroom's formula and ICRU 62 recommended formula to estimate CTV- PTV margins for head and neck cancer patients who were treated with 3DCRT technique at Varian 2300CD unit.

Figure 1: Visual comparison of bony land marks in DRR and EPI (CA Thyroid patient- AP image view).

Figure 2: Visual comparison of bony land marks in DRR and EPI (CA Thyroid patient- Lateral view).

3. RESULTS AND DISCUSSION

Figure 3 shows the displacements in all three directions, vertical, longitudinal and lateral. The individual systematic error is calculated from the mean individual deviation and the individual random error is calculated from the standard deviation of individual displacement. The population systematic error is calculated from the standard deviation of all individual systematic errors and population random error is estimated from the mean value of individual random errors. According to the graph, mostly scattered displacements can be observed in vertical direction (anterior-posterior). According to this study population, systematic errors for antero-posterior (AP), medio-lateral (ML) and superior-inferior (SI) directions were 0.13 cm, 0.08 cm and 0.1 cm respectively. In this study, population random errors for AP direction were 0.22 cm, ML direction was 0.19 cm and SI direction was 0.21 cm.

The summary of displacement in all three directions is shown in Table 1. More than 50% of displacements are less than 0.3 cm in all three directions. 0.5 cm is exceeded in less than 30% of displacements. However, greater than 0.5 cm level is higher for longitudinal direction (10.82%) rather than other two directions. Table 2 shows that measured displacements in the displacement category from all displacements, 96.48% is less than 0.7 cm. 93.08% of displacements are less than or equal to 0.5 cm in all directions. Only 0.16% of displacements exceeded 1 cm.
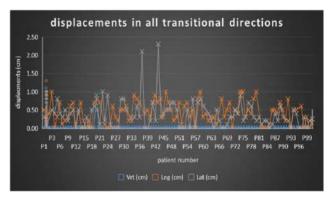

Figure 3: Displacements in all three directions, vertical, longitudinal and lateral.

Table 1: Displacement summary along each direction.

Displacement (d) Category	Vertical	Longitudinal	Lateral
d≤ 0.3 cm	86.92%	70.85%	85.67%
0.3cm<d ≤0.5 cm	8.2%	18.3%	9.3%
0.5cm<d ≤0.7 cm	2.2%	5.9%	2.1%
0.7 cm<d≤1 cm	2.4%	4.7%	2.6%
d>1 cm	0.12%	0.12%	0.24%

Table 2: Displacement summary along all directions.

Displacement (d) Category	In all directions
d≤ 0.3 cm	81.15%
0.3 cm<d≤0.5 cm	11.93%
0.5 cm<d≤0.7 cm	3.4%
0.7 cm<d≤1 cm	3.23%
d>1 cm	0.16%

A similar study was performed by Farajollahi A, et al. (2022) in Iran. The overall mean 3D displacement for head and neck cancer patients treated with 3D-CRT was reported as 0.39 cm. In addition, the maximum values of systematic error and random error were 0.39 cm and 0.27 cm respectively. The results of this study are compatible with those of the present study.

In the present study, CTV to PTV margins were 0.48 cm, 0.40 cm and 0.33 cm in the directions of Antero-posteriorly, Superio-inferiorly and Medio-laterally respectively according to the Van Herk's recipe. From Stroom's formula they were 0.41 cm, 0.35 cm, 0.29 cm, and from ICRU 62 formula they were 0.26 cm, 0.23 cm, 0.21 cm in the directions of Antero-

posteriorly, Superio-inferiorly and Medio-laterally. The comparison of CTV to PTV margins calculated from 3 different algorithms (Van Herk, Stroom and ICRU 62) is shown in figure 4. Among all 3 algorithms, ICRU 62 gives a lower margin.

Table 3 : Set-up errors and margins recipes for each direction according to three different formulae.

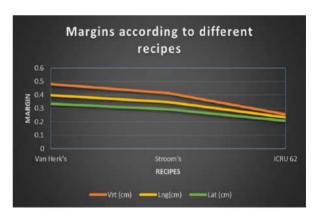|	Vertical (cm)	Longitudinal (cm)	Lateral (cm)
Population systematic error	0.13	0.10	0.08
Popolation random error	0.22	0.21	0.19
Van Herk's formula	0.48	0.40	0.33
Stroom's formula	0.41	0.35	0.29
ICRU 62	0.26	0.23	0.21

Figure 4: Comparison of margins calculated from three different algorithms.

4. CONCLUSION

It is important to evaluate setup errors in an institute to recognize the errors and to take necessary actions for better treatment delivery and fulfill the goal of

radiotherapy. In addition, it is better to evaluate the CTV-PTV margin for the institute and use the evaluated CTV to PTV margin for head and neck cancer patients who are undergoing 3DCRT technique.

The margins calculated by this study show that 0.5 cm is not exceeded in all directions from ICRU 62 recommended margins. Additionally, the setup error is well within the recommended margin for all cardinal directions. 0.26 cm, 0.23 cm and 0.21cm are the margins calculated from ICRU 62 margin recipe for Antero-posterior, Superio-inferior and Medio-lateral directions. 0.48 cm, 0.40 cm and 0.33 cm margins from Van Herk and 0.41 cm, 0.35 cm, 0.29 cm margins from Stroom's recipe for antero-posterior, superio-inferior and medio-lateral respectively. Portal images matching with DRRs using different anatomical landmarks is a useful tool for clinical practice. Immobilization devices play a major role in head and neck cancer treatment. This study recommends that the effectiveness of immobilization devices should be evaluated throughout the treatment process

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EXPLORING THE IMPACT OF FACIAL FEATURES ON APPARENT PERSONALITY TRAITS DETECTION USING DEEP LEARNING TECHNIQUES

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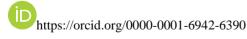Faculty of Graduate Studies, University of Sri Jayewardenepura, Nugegoda, Sri Lanka[2],

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ABSTRACT

Apparent personality detection has emerged as a prominent research area within deep learning. While numerous deep learning solutions have been developed to predict personality accurately, the lack of transparency in how these models derive predictions based on facial features undermines trust in their results. This study focuses on identifying and differentiating facial features that contribute to the Big-Five personality traits, addressing transparency in model predictions. To conduct our experiments, we utilised the ChaLearn First Impressions V2 dataset, with background removed frames ensuring models focused more on human features than background in the learning process. We began by developing Convolutional Neural Networks architectures using pre-trained VGGFace and VGG19 models. Subsequently, we employed the Grad-CAM and Guided Grad-CAM model explainable AI techniques on the test and validation datasets, utilising the trained models. Furthermore, we employed the "SelectKBest" feature selection method to analyse the outcomes of the interpretability techniques. VGG19 achieved higher accuracy (90%) compared to VGGFace (89%). Our investigation reveals that personality prediction extends beyond facial features, with XAI techniques emphasizing non-facial aspects such as background information. Statistical analysis across deep learning architectures shows no significant correlation between features identified by XAI techniques by giving different F1-scores. Despite VGG19's superior accuracy, it exhibits a stronger inclination towards non-facial data, while VGGFace prioritizes facial features, highlighting the nuanced nature of personality prediction and suggesting avenues for further research.

KEYWORDS: *Apparent Personality Detection (APD), Convolutional Neural Networks (CNN), Explainable AI (XAI), Facial Features, Select best Feature Selection*

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1. INTRODUCTION

Apparent Personality Detection (APD) has garnered significant attention in the field of deep learning research. Researchers have developed numerous deep learning solutions to predict personality traits based on facial features accurately. However, the lack of transparency regarding how these models derive their output from facial cues of-ten leads to a loss of trust in the predictions. As a result, there is a pressing need to delve deeper into identifying and differentiating facial features that influence Big-Five personality traits (Openness, Conscientiousness, Extraversion, Agreeableness, and Neuroticism) (Wiggins, 1996).

APD has emerged as a prominent computer vision application with wide-ranging implications in various fields. It finds utility in diverse domains, including human resource management (Lounsbury et al., 2008; Penney, David and Witt, 2011; Alhendi, 2019), social robotics (Lee et al., 2006; Kirby, Forlizzi and Simmons, 2010; Mileounis, Cuijpers and Barakova, 2015), criminology (Reid, 2011), game development (Zammitto, DiPaola and Arya, 2008), and the animation movie industry (Juhan and Ismail, 2016). The measurement of personality encompasses various criteria, with the Big-Five personality model (Wiggins, 1996) being widely adopted and endorsed by psychologists. This model evaluates personality based on five fundamental factors: Extraversion, Neuroticism, Agreeableness, Conscientiousness, and Openness. These factors are often abbreviated as "OCEAN" or "CANOE." To capture the nuances of each aspect, they are further delineated into sub-traits (John and Srivastava, 1999), collectively providing a comprehensive understanding of an individual's personality.

According to the literature, to measure the apparent personality, researchers developed various deep learning solutions such as Convolutional Neural Networks (CNN), Long Short-Term Memory (LSTM), and Three-Dimensional Convolutional Neural Networks (3D-CNN). The primary objective of these studies is to design and implement a model capable of measuring apparent personality. One of the main milestones of apparent personality detection is the "Looking at People ECCV Challenge First

Impression" held in 2016 (ChaLearn Looking at People - 2016 Looking at People ECCV Challenge, 2016). Researchers in this area developed different solutions to measure the personality precisely as much as possible with the ChaLearn Apparent Personality First Impressions V1 (ECCV'16) and V2 datasets (CVPR'17) (Ponce-López et al., 2016). The winners of this competition were Zhang et al. (2016), Subramaniam et al. (2016), and Güçlütürk et al. (2016). All the winners used audio and visual data to predict apparent personality. Zhang and others (2016) designed a bi-model deep regression model to predict personality from visual and audio modalities. They used CNN architectures, consisting of VGGFace (Parkhi, Vedaldi and Zisserman, 2015) pre-trained model for visual modality. These architectures are named DAN (Descriptor Aggregation Network) and DAN+. Subramaniam et al. (2016) presented a bi-model architecture with visual (background-removed) and audio features for personality judgment. They designed a 3D CNN and an LSTM to predict personality. Gucluturk et al. (2016) created bi-model deep neural network architecture with residual blocks. The maximum mean accuracies obtained by each competitor are Zhang et al. (2016) 0.9111, Subramaniam et al. (2016) 0.913355, and Güçlütürk et al. (2016) 0.912132.

After the competition, researchers developed various deep learning architectures with different modalities to predict the apparent personality with CVPR'17. Gürpınar, Kaya and Salah (2016) used visual data extracted from videos and achieved 0.9094 accuracy. Yang and Glaser (2017) proposed a Bi-model LSTM, scoring 0.9083 with L2 loss. Barezi et al. (2018) used visual, audio, and text (audio transcription) data to predict the apparent personality with tri-model deep convolutional architecture. The results concluded that the audio and text modalities are least relevant for personality detection, while visual features are more relevant, with tri-model accuracy of 0.9062. Li and others (2020) also used a multi-feature model with visual, facial, audio, and transcription data to predict the apparent personality. They proposed a deep CR-Net (classification-regression network) composed of three branches. The proposed architecture achieved 0.9188 accuracy. Mujtaba and Mahapatra (2021)

presented the multi-task deep learning approach to measure personality with visual, facial, audio, and transcription data. The proposed architecture achieved 0.9134 accuracy.

So, a significant amount of research has been done on predicting apparent personality traits, resulting in high accuracies. However, there is a noticeable dearth of studies that focus on explaining the outputs generated by these prediction models. Furthermore, the existing research in the field of explaining model outputs demonstrates varying outcomes and conclusions.

Zhang et al. (2016) used the heatmap feature visualisation XAI technique to visualise the features with the architectures ResNet, DAN, and DAN+ used in APD. According to their results, different architectures tend to focus on different image features. ResNet focused on the human body, including facial and non-facial features, while DAN/DAN+ architectures focused on human and background data. They used five random sample videos to extract this information.

Ventura et al. (2017) conducted a quantitative study with the Class Activation Map (CAM) (Zhou et al., 2015) technique and Action Unit (AU) (Ekman, Friesen and Ancoli, 1980) to gain insight into CNN-based apparent personality trait recognition. CAM was applied to find the discriminative regions in the scene data, which support personality predictions. They identified vital face regions as eyes, nose, and mouth. Then, they used the "OpenFace" library (Mahdy, Hereñú and Sumsuddin, 2019) to detect the face region and the Facial Action Coding System (Ekman, Friesen and Ancoli, 1980) to find AUs. Only 17 AUs were used in this study out of 45 AUs. These AUs were used to find the influence of emotions on personality detection. The quantitative research shows that some AUs affected personality detection. For the experiment, they selected 50 images with the highest score for personality traits.

Wei et al. (2018) used the DAN architecture initially proposed by Zhang et al. (2016) to predict the apparent personality. The results of the model interpretability techniques concluded that ResNet could identify facial regions as the primary contributors to the output. Simultaneously, DAN and

DAN+ architectures were more prone to background data than ResNet. Nevertheless, with plain background data, ResNet failed, but DAN and DAN+ could identify facial features as primary contributors. They used 12 randomly selected images to interpret the output of the model.

Yang and Glaser (2017) used the saliency map visualisation technique to find the image regions contributing to the apparent personality judgment. Furthermore, they concluded that ResNet could identify facial features as the most contributing factors to the network's output.

Li et al. (2020) used the Seaborn Python library (Waskom, 2021) to calculate heatmap on scene data to find which features mostly contribute to the apparent personality judgments. The heatmap calculation on scene data found that facial features such as the eye, nose and mouth are primarily contributing elements. Also, they concluded that non-facial data such as clothing and furnishing contribute to personality judgments. They conducted a quantitative study on the relationship between heatmap features and face key points. They used face key points as two eyes, nose, corners of the mouth, and mid-distance of the two mouth corners. According to the findings, 73.96% of the highlighted points are vital. For the experiment, they used 32 frames from each video from the test dataset of CVPR'17.

Ilmini and Fernando (2022) used Grad-CAM, Guided Backpropagation, and Guided Grad-CAM XAI techniques XAI explain the outputs of apparent personality CNN models. They also concluded that facial features such as eyes, forehead, eyebrows, nose, and mouth are mainly involved in personality detection. Further, they mentioned that the background affects personality prediction.

As found in the literature, different research works tend to interpret the output of the CNN-based APD. They have used heatmap visualisation techniques such as Class Activation Map (CAM) and saliency map visualisation to find the most contributing features. They concluded that the facial region contributes more to the APD, while background data also affects the APD. Some researchers compare the XAI technique outputs with different network architectures and

conclude that they behave differently. Also, according to the literature, interpretability techniques do not convey the difference in personality traits. The summary of the literature is given in Table 1.

Table 1 : Summary of the Literature Review

Study	Methodology	Features used	Accuracy	Key Contributions	XAI Techniques Used	XAI Outputs
Zhang et al. (2016)	Bi-modal deep regression model using CNNs with VGGFace	Combined visual and audio features	0.9111	Introduced DAN/DAN+ architectures for personality prediction using visual and audio modalities	Heatmap visualization	ResNet focused on both facial and non-facial features; DAN/DAN+ emphasized background features
Subramaniam et al. (2016)	3D CNN and LSTM with bi-modal architecture	Combined visual and audio features, background removed	0.913355	Utilized background-removed frames to enhance personality prediction	N/A	N/A
Güçlütürk et al. (2016)	Bi-modal deep neural network with residual blocks	Combined audio and visual data for better accuracy	0.9109	Developed a multi-modal architecture improving personality detection with residual networks	N/A	N/A
Gürpınar et al. (2016)	Visual data extraction using pre-trained deep learning CNN model	Focused solely on visual data for personality prediction	0.9094	Showcased the effectiveness of visual-only data for personality prediction	N/A	N/A
Yang and Glaser (2017)	Bi-modal LSTM with L1 and L2 loss	Used visual and audio data to predict personality traits	0.9083	Proposed LSTM-based personality prediction model combining visual and audio data with pre-trained deep learning models	Saliency map visualization	Identified facial features as key contributors to personality judgments
Ventura et al. (2017)	CNN with DAN, DAN+ architectures	Used visual data	0.912	Used CAM and AUs to link facial emotions to personality trait detection	CAM, Action Unit (AU) analysis	Found vital face regions (eyes, nose, mouth) as key contributors; emotions affected personality detection
Barezi et al. (2018)	Tri-modal deep convolutional architecture (visual, audio, text) with ensemble techniques	Concluded that visual features are more relevant than audio and text for personality prediction	0.9062	Highlighted the limited impact of audio and text modalities compared to visual features	N/A	N/A
Wei et al. (2018)	Deep Bi-model Regressor network	Audio and Visual Data	0.9212 with epoch fusion	Demonstrated the effect of background removal on deep learning interpretability	Feature Map	ResNet highlighted facial regions, DAN/DAN+ focused more on background
Li et al. (2020)	Deep CR-Net (Classification-Regression Network) with introduced bell-loss	Combined visual, facial, audio, and transcription data for personality analysis	0.9188	Introduced a multi-feature architecture with high accuracy for personality trait prediction	Heatmap (Seaborn library)	Identified facial features like eyes, nose, and mouth as primary contributors; non-facial data like clothing also relevant
Mujtaba and Mahapatra (2021)	Multi-task deep learning with visual, facial, audio, transcription with k-fold cross validation	Used a multi-modal approach to predict apparent personality	0.9134	Applied multi-task learning for comprehensive personality detection using multiple modalities	N/A	N/A
Ilmini & Fernando (2022)	CNN with pre-trained deep learning models	Used visual features	0.9061	Emphasized the role of background information even in background-removed datasets	Grad-CAM, Guided Backpropagation, Guided Grad-CAM	Facial features (eyes, forehead, mouth) identified, background still affects personality prediction

This study addresses this critical gap by exploring the relationship between facial features and personality traits using deep learning techniques. Our primary objective is to unravel the impact of facial cues on personality prediction and shed light on the interpretability of these deep learning models. Understanding how these models make projections can enhance their transparency and build trust in their results. We leverage the CVPR'17 dataset to conduct our experiments, curated explicitly for analysing apparent personality. To minimise the potential bias arising from contextual factors, such as background information, we remove the background frames from the dataset. This approach ensures that our focus remains solely on facial features and their influence on personality prediction.

The rest of the paper is organised as follows. Section Two discusses materials and methods, Section Three includes the results, and Section Four contains the discussion and conclusion.

2. METHODOLOGY

In this section, we outline the methodology employed in this study to identify the significant facial features that influence the assessment of the Big-Five personality traits.

Figure 1 depicts the comprehensive research methodology utilised to identify the prominent facial features that impact the Big-Five personality traits.
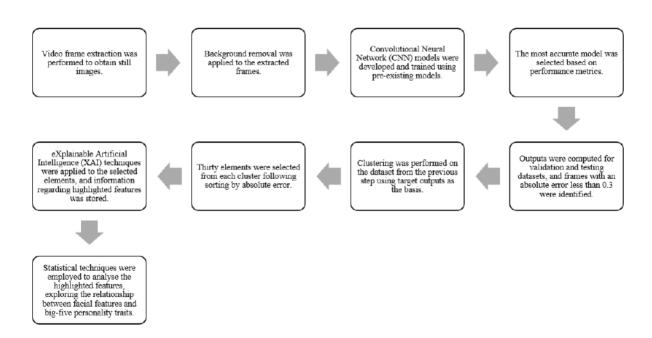
Figure 1: Methodology

Dataset and Pre-processing

The CVPR'17 dataset was employed for this study, comprising videos featuring individuals from diverse nationalities, age groups, and ethnic backgrounds. The dataset is composed of 10,000 video clips extracted from 3,000 unique videos. Among these, 6,000 video clips were assigned to the training dataset, while the validation and test datasets consisted of 2,000 video clips each. Each video clip in the dataset is associated with ground truth values representing the Big-Five personality traits, ranging from 0 to 1.

After extracting 20 frames from each video, the image dataset sizes are as follows:

- Training dataset: 6,000 X 20 = 120,000 images

- Validation dataset: 2,000 X 20 = 40,000 images

- Test dataset: 2,000 X 20 = 40,000 images

The background of each image was removed and replaced with black colour during the preprocessing stage to mitigate potential bias introduced by background details. This step was undertaken to ensure a focus on identifying significant facial features that influence personality traits in current research. The Rembg Python library (Gatis, 2022) was utilised to remove the background.

Network Architecture

This study developed the CNN models using the VGGFace (Parkhi, Vedaldi and Zisserman, 2015) and VGG19 (Simonyan and Zisserman, 2014) pre-trained deep learning models. Specifically, for the VGGFace-based CNN architecture, the DAN (Deep Aggregation Network) architecture, initially introduced by Zhang et al. (Zhang et al., 2016), was utilised. As for the VGG19-based CNN architecture, the classifier layer was removed, and two fully connected layers with output sizes of 512 and 5 were added, followed by a final sigmoid layer. These modifications were made to adapt the VGG19 model for the task of personality trait prediction.

Hyper-parameters of the network are as follows:

- Batch-size:16

- Learning rate: $1 \times e^{-5}$

- Maximum number of epochs: 200

- Early stop counter: 20

- Optimiser: RAdam=$1 \times e^{-6}$

Several test runs were conducted to determine the optimal hyperparameters mentioned above. Then, each network was trained ten times using the finalised parameters and evaluated using the test dataset. The model that achieved the highest accuracy on the test dataset was selected and saved for further analysis, specifically for feature visualisation purposes.

Prepare the Dataset for the Visualisation

The highest accuracy model was employed to evaluate the validation and test datasets. Subsequently, the images that obtained an absolute error (as defined by Equation 1) less than 0.3 were selected for further

analysis. Approximately 90% of the videos from both the test and validation datasets exhibited an absolute error below this threshold.

Next, the prepared dataset was partitioned into groups based on the ground truth value (target) as outlined below:

Cluster 1:   Target ≥ 0.8

Cluster 2: $0.8 >$Target ≥ 0.6

Cluster 3: $0.6 >$ Target ≥ 0.4

Cluster 4: $0.4 >$ Target ≥ 0.2

Cluster 5:   Target ≤ 0.2

Absolute Error =|target - output| (1)

The target is the ground truth value, and the output is the network output.

In general, Cluster 5 tends to contain a smaller amount of data for all traits. Consequently, when selecting data, Cluster 5 is often disregarded. Each cluster is sorted in ascending order based on the absolute error (Equation 1), which is the difference between the target and the error. From each group, 30 subjects were chosen for the feature visualisation stage. As a result, 120 images with considerably lower absolute errors were utilised to interpret the network's output for each trait.

Feature Visualisation Techniques Used

Deep learning interpretability techniques have witnessed significant advancements, surpassing the limitations of earlier methods. To explain the inner process of deep learning models, a range of approaches have been developed. These techniques, commonly known as post hoc interpretability techniques, aim to interpret already trained deep learning models. While these techniques offer valuable insights, it is essential to acknowledge that they possess their own set of advantages, disadvantages, and limitations. Furthermore, interpretability techniques can be classified into model-specific and model-agnostic methods. Model-specific methods are tailored for specific models, providing explanations for their particular internal structure and operations. On the other hand, model-agnostic techniques are more generalised, applicable

across different models, and offer broader insights into model behaviour. These model-agnostic techniques enable interpretability regardless of the specific deep learning architecture employed.

Class Activation Map (CAM), GRADient-weighted CAM (Grad-CAM), and Guided Grad-CAM are widely recognised explainable artificial intelligence (XAI) techniques designed explicitly for interpreting CNN models. CAM and Grad-CAM are model-specific techniques employed to analyse CNN models concerning a specific target class. CAM requires a particular network structure in the final layer and is utilised for interpreting the last convolutional layer. On the other hand, Grad-CAM applies to any network structure, offering a generalisation of CAM. In contrast, Guided Grad-CAM stands out by its ability to generate high-resolution class discriminative visualisations, providing detailed insights into the model's decision-making process. The review study conducted by Linardatos et al. (2020) concluded that regarding CNN XAI techniques, Grad-CAM is the most influential technique according to citations per year. Hence, we used Grad-CAM and Guided Grad-CAM XAI techniques in this study.

Grad-CAM generalises the CAM for various convolutional neural network architectures (Selvaraju et al., 2020). Grad-CAM calculates a class discriminative map by taking the gradient of the score for category c y^c concerning the convolutional layer's feature map activation A^k, $\frac{\partial y^c}{\partial A^k}$. These gradients are globally averaged and pooled to obtain neuron importance (α_k^c) over width and height dimensions. Finally, to obtain the Grad-CAM, they performed a weighted combination of forward activation maps followed by the ReLU activation.

Guided Grad-CAM

Grad-CAM cannot highlight the fine-grained regions as Guided Backpropagation and Deconvolutional techniques. Because of that, the authors have obtained element-wise multiplication of Grad-CAM and Guided Backpropagation outputs. Grad-CAM's coarse map highlights the image regions, while Guided Grad-CAM identifies the object's edges (Selvaraju et al., 2020). Grad-CAM and Guided Grad-CAM techniques were employed to recognise the features that contribute positively to the output. Furthermore, additional processing was conducted on the original image and the heatmap to enhance the clarity of the visualisation output. Initially, the heatmap was utilised to identify the contours associated with it. Subsequently, these contours were used to draw polygons on the original image, allowing for the identification of the specific areas covered by the heatmap. The following pseudocode (Algorithm 1) illustrates the processing of the original image and heatmap to visualise the feature map.

```
grey_img = cv2.cvtColor(heatmap, cv2.COLOR_BGR2GRAY)
ret, thresh = cv2.threshold(grey_img, 50, 255,
cv2.THRESH_BINARY)
contours, hierarchy = cv2.findContours(thresh, 1, 2)
for item in range(len(contours)):
        cnt = contours[item]
                if len(cnt)>20:
                poly_coords = [cnt]
                cv2.polylines(img, poly_coords, True, (0,0,1), 2)
```

Algorithm 1: Pseudocode for processing the original image and heatmap to obtain a clear visualisation of the feature map.

As described earlier, the dataset consisting of 120 images was subjected to the model as mentioned earlier interpretability techniques. Building upon the methodology outlined in the original paper (Selvaraju et al., 2020), we visualised the final convolutional layer of both the VGGFace and VGG19 models.

Feature Identification

In the process of feature visualisation, a total of 11 facial features and six non-facial features were considered. The facial features encompassed the forehead, brow, eyebrow, bridge of the nose, eye, cheek, nose, nasolabial angle, mouth, mental fold, and chin. On the other hand, the non-facial features comprised the hair, neck, ear, dress/jewellery/hand gestures, and the presence of spectacles or a beard (specifically for males), as indicated by the visualisation techniques employed.

Subsequently, the dataset generated in the previous step was analysed to determine the presence of the 17 features mentioned above within each feature map. A binary approach was adopted, where a value of 1 was assigned if the visualisation techniques used highlighted a specific area or part of an area corresponding to a feature, and a value of 0 was set otherwise.

Consequently, a new dataset encompassing the target values, the network's output, and the highlighted features was curated. This process was iterated for all five traits using the VGGFace and VGG19-based models, resulting in 10 distinct datasets. Subsequently, the Python sci-kit-learn library's 'SelectKBest' module ('scikit-learn/scikit-learn', 2022) was applied to these datasets to determine the statistical relationship between the highlighted features and the network's output. The 'SelectKBest' algorithm, coupled with the f_regression score function ('sklearn. feature_selection.f_regression', 2022), was employed, which yields both an F-statistic and a P-value. A higher F-statistic signifies a significant contribution to the model's predictive ability.

3. RESULTS

This section provides a comprehensive analysis and presentation of the findings derived from the exploration of facial features and their influence on Big-Five personality traits using deep learning techniques. This section presents the outcomes of the conducted study, highlighting the key insights and observations obtained through the analysis of the collected data.

Model Accuracy

Table 2 summarises the mean accuracies achieved by each model. According to the results, the VGG19-based CNN model outperforms the VGGFace-based CNN model. Both models scored the lowest accuracy for the Neuroticism trait.

Table 2: Mean Accuracy values scored on the test dataset.

Trait	VGGFace	VGG19
Extraversion	0.9001	0.9079
Neuroticism	0.8946	0.9027
Agreeableness	0.9013	0.9087
Conscientiousness	0.9013	0.9121
Openness	0.9006	0.9074

1 Cell values represent the accuracy of each model for the personality traits on the test dataset. The Overall accuracy was calculated using Equation 2

$$Mean\ Accuracy = 1 - \frac{1}{N*M}\sum_{j=1}^{M}\sum_{i=1}^{N}|target_{ij} - output_{ij}| \quad (2)$$

N=number of videos, M = 5 (Big Five Personality Traits), target = ground truth value and output = network output.

Visualisation Techniques

VGGFace

Figure 2 displays sample outputs for various traits representing a selected instance. The analysis revealed that both facial and non-facial features, along with the background, were identified as the most influential factors. The heatmap predominantly emphasises the human body, encompassing facial and non-facial attributes. Notably, in the case of Extraversion, Neuroticism, and Agreeableness, non-facial characteristics such as dress were found to carry more

significance than facial data for the given instance. Ground truth values of the selected sample are as follows: E: 0.89719623, N: 0.8854167, A: 0.7692308, C:0.7669903, and O: 0.8333333.

VGG19

Figure 2 illustrates sample outputs obtained for the Big-Five personality traits using the VGG19-based CNN model. In these samples, both facial and non-facial features were identified as significant contributors to the predictions. However, in certain instances, the model exhibited a stronger emphasis on the background rather than the facial and non-facial features (Figure 2).
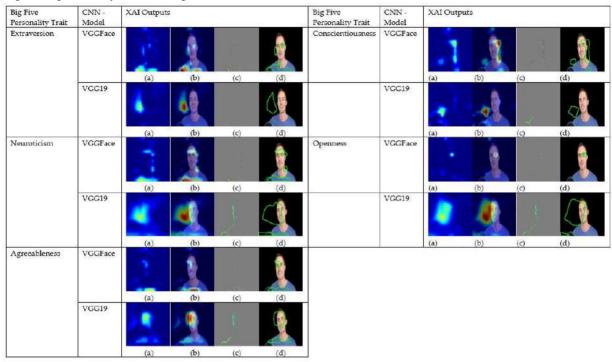

Figure 2: Visualisation Techniques output for VGGFace and VGG19 ((a) – Heatmap, (b) – Grad-CAM, (c) – Guided Grad-CAM, and (d) – Most Contributing Features)

Interpretability vs Faithfulness of CNN-based APD

Gaining insights into the performance of CNN-based APD models is crucial in understanding their underlying mechanisms. The faithfulness of a model refers to its capacity to provide accurate explanations of its internal processes. However, achieving faithfulness often involves a trade-off with interpretability, where faithful visualisations can be less straightforward to interpret and vice versa. Moreover, a trade-off exists between interpretability and the overall performance of the machine learning model (Linardatos et al., 2020). As a result, researchers have introduced various machine learning interpretability techniques to address the limitations of existing methods and strike a balance between faithfulness and interpretability.

The F-statistic values obtained from the statistical tests conducted on the ten datasets are summarised in Figure 3. The highest seven F-score values for each model (corresponding to one network with one trait) are highlighted in bold. Precisely, the first column displays the F-score values obtained by each feature for the Extraversion trait using the VGGFace model, while the second column represents the Extraversion trait with the VGG19 model.

The scores demonstrate that facial features play a significant role in determining the network output

using the VGGFace CNN model. Additionally, non-Jewellery, and Hand gestures) are identified as prominent features.

facial features like hair, neck, and feature 15 (Dress,
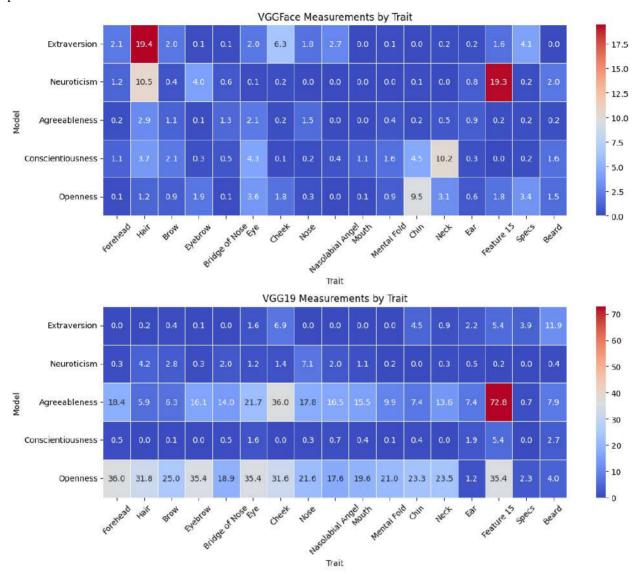
Figure 3: F-Score values which were obtained by each feature from the 'SelectKBest' technique.

The VGGFace model highlights the following features as necessary for calculating personality traits.

- Extraversion: hair, cheek, specs, nasolabial angle, forehead, brow, and eye

- Neuroticism: feature 15, hair, eyebrow, beard, forehead, ear, and bridge of the nose

- Agreeableness: hair, eye, nose, bridge of nose, brow, ear, and neck

- Conscientiousness: neck, chin, eye, hair, brow, chin, and beard

- Openness: chin, eye, specs, neck, eyebrow, cheek, and feature 15

Except for the Neuroticism trait, the eye factor is selected as one of the most contributing features for all other characteristics.

According to Figure 3, the VGG19 model emphasises non-facial features, particularly Feature 15, as indicated by its high F-statistic score. The VGG19 model identifies the following features as crucial for determining personality traits.

- Extraversion: beard, cheek, feature 15, chin, specs, ear, and eye

- Neuroticism: nose, hair, brow, bridge of the nose, nasolabial angle, cheek, and eye

- Agreeableness: feature 15, cheek, eye, forehead, nose, and nasolabial angle

- Conscientiousness: neck, chin, eye, hair, brow, mental fold, and beard features

- Openness: forehead, eyebrow, eye, feature 15, hair, cheek, and brow

In the VGG19 model for the Extraversion trait, some facial features obtained an F-score of "nan," indicating that they were not consistently highlighted across all sample elements. Additionally, the test results for the open-ness trait significantly differed from the other traits, with higher F-statistic values observed for most features. Notably, except for the Neuroticism trait with the VGGFace model, the Eye feature emerged as the main contributing feature for all traits across both architectures. Some models also showed that wearing specs and having a beard were contributing features, but this observation is dependent on the specific sample selection, where subjects need to wear specs or be male with a beard.

The two models' activation of different image regions resulted in distinct contributing features for the same trait, as reflected in Figure 3.

Sensitivity to Noise

To assess the robustness of the interpretability techniques, we introduced Gaussian noise to a sample image (Figure 4) and observed the highlighted features (Figure 5). The VGGFace model displayed minimal differences be-tween the original image and the noise-added image regarding highlighted features. However, when comparing the original image and the noise-added image, the VGG19 model exhibited noticeable variations in the highlighted features for the same trait. Moreover, the outputs of the two models showed relatively consistent results between the original image and the noise-added image (Figure 5, first row).
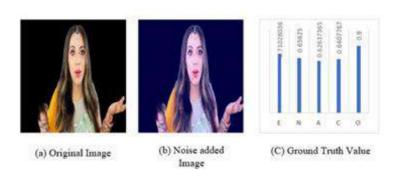

(a) Original Image   (b) Noise added Image   (C) Ground Truth Value

Figure 4: Sample instance used to check the sensitivity to noise.

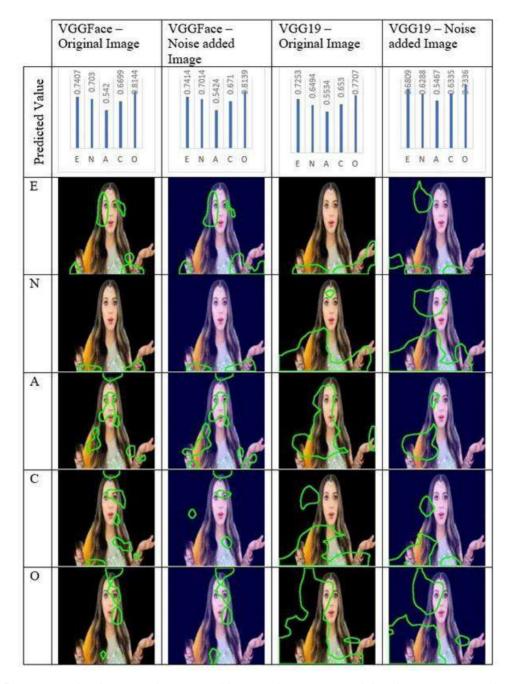| Predicted Value	VGGFace – Original Image	VGGFace – Noise added Image	VGG19 – Original Image	VGG19 – Noise added Image
	0.7407, 0.703, 0.542, 0.6699, 0.8144 (E N A C O)	0.7414, 0.7014, 0.5424, 0.671, 0.8139 (E N A C O)	0.7253, 0.6494, 0.5534, 0.653, 0.7707 (E N A C O)	0.6809, 0.6288, 0.5467, 0.6335, 0.7336 (E N A C O)
E				
N				
A				
C				
O				

Figure 5: Features highlighted by interpretability techniques on the original image and the noise-added image.

4. DISCUSSION AND CONCLUSION

The results of this study underscore the influence of both facial and non-facial features in CNN-based apparent personality detection (APD), as highlighted by model interpretability techniques. While the VGGFace and VGG19 models identified different contributing features, it is difficult to pinpoint specific personality traits based solely on facial features. This aligns with the findings of Ventura et al. (2017), who also noted that models focused on facial regions, such

as the eyes and mouth, but found it challenging to differentiate these regions in terms of personality traits.

One of the critical gaps in the current literature is the lack of transparency in how APD models make predictions. While previous works (e.g., Wei et al., 2018) have noted that models such as ResNet, DAN, and DAN+ use different image regions for personality prediction, our study adds to this by demonstrating how models like VGGFace prioritize facial features, whereas VGG19 places more emphasis on non-facial features, including background data. This highlights the need for further investigation into how background information affects APD predictions, especially given that even with background removal, some models continue to highlight non-facial regions (Figure 2).

Our study applied Grad-CAM and Guided Grad-CAM techniques to interpret the predictions, and while the VGGFace model showed a clear focus on facial data (excluding Neuroticism), VGG19 appeared more prone to rely on non-facial elements like dress, hand gestures, and jewellery, as reflected in the F-statistic values (Figure 3). This suggests that non-facial features play a significant role in personality prediction, which is an area not sufficiently explored in previous studies. The statistical assessments, particularly the F-statistic values, further emphasize the need to account for these non-facial elements in future APD models.

Despite VGG19 outperforming VGGFace in accuracy (90% vs. 89%), our findings indicate that accuracy alone does not guarantee a more facially interpretable model. The reliance on background information rather than facial features suggests that higher accuracy models may not necessarily offer better insight into the facial cues contributing to personality detection. This opens up a discussion on the trade-offs between model accuracy and explainability.

The findings contribute to filling the gap in the literature by providing a nuanced understanding of the role of non-facial data in personality detection and by demonstrating the limitations of current XAI techniques when applied to APD models. While Grad-CAM and similar techniques are widely used in image classification, their effectiveness in explaining APD

outputs may be constrained by dataset biases, as noted in the ECCV challenge dataset used in this study.

In summary, this study highlights the complexity of personality detection models and suggests that future research should focus on enhancing model transparency and explainability, particularly by exploring how non-facial features contribute to predictions. Moreover, benchmarking datasets with greater diversity and more sophisticated interpretability techniques could further advance the field and provide more robust conclusions.

5. ACKNOWLEDGEMENTS:

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THE NEED FOR INTEGRATING CLOUD-BASED PROJECT MANAGEMENT TOOLS IN IT CURRICULA: INSIGHTS FROM SRI LANKA'S SOFTWARE INDUSTRY

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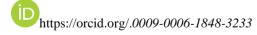Department of Information Technology, Faculty of Management Studies and Commerce, University of Sri Jayewardenepura, Sri Lanka[3]

ABSTRACT

Cloud-based project management software is heavily used in the software development industry, with cloud computing advancements. As such software usage is becoming popular in the industry, empirical evidence suggests that investigating the efficient integration of cloud-based project management software into Information Technology degree programmes is crucial in bridging the gap between university education and industry requirements. Therefore, this mixed-method study was carried out in Sri Lanka, where the software development industry is a significant player in the service sector. To analyse the current uptake of such software, 102 firms were given a closed-ended questionnaire. The fact that 93% of respondents are using these tools and that they specified that their use is crucial for project success suggests that they should be integrated into the academic curricula of IT degrees. Thirteen interviews were also done with industry professionals. The thematic analysis showed that professionals who had studied using cloud-based project management software in their degrees found it easier to adopt them in the workplace than those who had not, suggesting the need for integrating them into academic curricula. Effective integration strategies included offering cloud-based project management tools as practical components required for use in projects, industry-led workshops, and online courses as assignments. These results can help higher education establishments improve their curricula, including the latest industry practices, to bridge the gap between academic and industry requirements.

KEYWORDS: *Cloud-based software, project management, cloud-based project management software, academic curricula, industry requirements*

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1. INTRODUCTION

With the latest advancements in cloud computing, Project Management (PM) software has also started to be delivered as a cloud-based or Software-as-a-service (SaaS) application. A survey conducted by Capterra Inc. (2019) in the United States revealed that 60% of 400 project management professionals shifted towards cloud-based software adoption due to their advantages. Cloud-based PM software can benefit project teams in terms of cost saving, accessibility, the latest version updates, and avoiding licensing issues (Bajwa and Deichmann, 2018).

A study has been conducted in Sri Lanka to analyse the level of cloud computing adoption considering all three models, namely Infrastructure-as-a-Service (IaaS), Platform-as-a-Service (PaaS), and Software-as-a-Service (SaaS) during COVID-19. They have identified that 87.7% of companies adopt cloud-enabled services, and their use has increased with COVID-19 as an innovative solution to the new normal (Athambawa *et al*., 2023). Furthermore, Bala, a cloud services consultant, has elaborated that there is a growing trend in adopting cloud applications by various sectors in Sri Lanka that will continue in the coming years as well. He predicts that many businesses of scale from small to large scale will adopt such software because of the positive aspects of cost-saving, scalability, and flexibility (Bala, 2023).

With this rising adoption of the latest technologies in the software development industry, it has become mandatory for recent graduates to have knowledge and skills in using the latest software when they enter the industry for career upliftment. Further, it has become the responsibility of higher education institutes to review and develop their academic curricula frequently to match the industry demands.

One of the owners of a software development firm in Sri Lanka has mentioned in a LinkedIn article that the inability to cover the up-to-date industry practices and tools being used in the industry is a major concern where a lot of early careers lack the needed skills demanded by the industry. In the same article, he highlights the need for universities to keep in touch with industry and regularly update their curricula with

the help of industry, which is essential in bridging such skill gaps. In his article, the skill of working with cloud technology was also mentioned as a highly demanded skill expected from IT degree graduates by the industry (Kalhara, 2023).

Some studies have been carried out to identify how academic curricula should be updated along with the latest technologies in the industry, such as cloud computing, agile methodologies, and DevOps technologies (Al-Mousa, 2022; Demchenko *et al*., 2019; Foster *et al*., 2018; Neyem *et al*., 2018; Patrikeos *et al*., 2023). However, they highlight that various other technologies should focus on effectively integrating into the Information Technology (IT) related degree programmes to bridge the gap between academic curricula and industry demands. Further, through a review of the literature, it was evident that similar studies have rarely been undertaken to study the need for integrating cloud-based PM software into the academic curricula of IT degree programmes.

Therefore, this research was undertaken to accomplish the objectives below and fill the gaps in identifying how cloud-based PM tools can be better incorporated to enhance IT degree programmes.

1. *To identify the requirement for integrating cloud-based PM tools into the academic curricula of IT degree programmes.*

2. *To explore how to integrate cloud-based PM tools into the academic curricula of IT degree programmes effectively.*

While adding value to the theoretical arena, which has a gap in studying how effectively cloud-based PM tools can be amalgamated to enhance IT degree programmes, this study provides valuable findings to be applied by higher education institutes when reviewing and updating their academic curricula to match industry demands.

Related Works

The process of designing, creating, deploying, and maintaining computer programmes to meet client requirements or as an automated software solution for performing regular tasks is known as software development (IBM, 2021). Project management has

evolved as a vital phase in the process of developing software as its success is constrained by scope, time, money, and quality (Schwalbe, 2015). Project management refers to "the application of knowledge, skills, tools, and techniques to project activities to meet project requirements", as defined by the Project Management Institute (2017).

Similar literature has shown that project performance and project management tools such as Gantt charts, Work Breakdown Structures (WBS), and Network Diagrams have a significant relationship (Jugdev *et al*., 2013). One such tool is project management software, which provides several integrated project management capabilities in a single software package. It may be used to support a range of project management tasks that contribute to the success of projects, including organising, carrying out, monitoring, recording, and communicating within project teams (Bajwa & Deichmann, 2018).

With the development of networking and internet technologies, cloud computing revolutionised the way that IT resources are digitally provided via the internet without the need for any physical infrastructures (Calheiros *et al*., 2009; Munguti & Opiyo, 2018). According to Ahmad and Waheed (2015) and Palos-Sanchez *et al*. (2017), three primary cloud computing models are Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS).

PM software started to be provided as a cloud-based software solution as a result of the development and acceptance of the Software as a Service (SaaS) paradigm of cloud computing (Assalaarachchi *et al*., 2022; Bajwa & Deichmann, 2018). Thereby PM software is available via the internet with usage-based pricing that eliminates the need for downloads and installations.

Several well-known cloud-based PM software platforms include Jira, Zoho Projects, Wrike, and Monday.com (FinancesOnline, 2022). Due to its advantages, including cost savings, ease of collaboration, automatic software updates and maintenance, avoidance of licensing issues, and scalability, this type of software has grown in popularity among project management professionals (Assalaarachchi *et al*., 2022; Bajwa & Deichmann, 2018).

The majority of higher education institutions offer IT degree programmes to cater to the employability needs of the rapidly growing software development industry. Such degree programmes offer courses on various domains such as software engineering, database management, systems analysis, IT project management, programming, networking, etc., which are essential in shaping graduates who are well-qualified to work in the software development industry. However, due to technology advancing so quickly, IT degree programmes must constantly update their curricula to reflect the latest developments in the industry to bridge the skill gap (Foster *et al*., 2018). By doing so, IT degree programmes can offer students more updated practical exposure to the latest technologies and industry standards, enhancing degree quality and making an industry-ready workforce.

Previous literature emphasising the need to review and revise academic curricula has shown that degree programmes in IT, in particular, need to be updated frequently to incorporate new technologies and industry practices to create graduates competent to the requirements expected by industry. One such study found that although cloud technologies have advanced significantly, the curriculum development for IT-related degree programmes has not kept up at the same pace (Foster *et al*., 2018). Furthermore, software development professionals have commented in their articles that cloud-based technologies are in rising demand in industry and that graduates lack skills in better use of such technologies as degree programmes have not been updated to match such requirements in the industry (Bala, 2023; Kalhara, 2023).

Few studies have been conducted to analyse how course modules in IT degree programmes, including software engineering and project management, need to be updated along with the latest technologies like cloud computing and DevOps. The majority of those studies have identified having up-to-date practical content, hands-on projects, presentations, certification courses, and workshops as strategies to incorporate the latest technologies and practices into degree

programmes effectively (Al-Mousa, 2022; Demchenko *et al.*, 2019; Foster *et al.*, 2018; Neyem *et al.*, 2018; Patrikeos *et al.*, 2023).

The results of the analysis of the literature highlight the need for continued investigation into new technical advancements and their integration into educational initiatives. Although there is widespread agreement about the significance of tailoring IT education with industry requirements, surprisingly, few studies concentrate on integrating cloud-based PM software into IT-related degree programmes. This discrepancy is noteworthy because software of this type is widely used in the software development sector, where it is essential for effectively and cooperatively managing projects. Similarly, there is very little knowledge in the literature about the need for integrating and effective strategies for integrating cloud-based PM software into IT courses. This research attempts to determine the requirement of integrating cloud-based PM software into IT degree programmes and to investigate effective strategies for integration to bridge the gap between industry requirements and academic offerings. The research aims to close this gap in literature and improve the relevance and application of IT education so that graduates are equipped to handle the requirements of the modern workforce.

2. METHODOLOGY

A mixed method approach was followed in this research to achieve the objectives as follows by selecting the software development industry of Sri Lanka as the case. Sri Lanka was chosen based on its prominence for software development around the world and accounts for 29% of the export income of the country.

Objective 01: To identify the requirement for integrating cloud-based PM tools into the academic curricula of IT degree programmes.

Mixed-method approach was utilized to achieve the objective of identifying the need to integrate cloud-based PM software into academic curricula of the IT degree programmes. A quantitative survey was conducted to collect data on the current nature of cloud-based PM software utilisation in managing the projects of software development firms in Sri Lanka. This survey aided the researcher in identifying whether such software are trending in the industry and then in emphasising the importance of incorporating them in an academic curriculum. A Google Form was developed and shared among a sample of software development firms in Sri Lanka via E-mail, LinkedIn, and personal contacts. One hundred and two (102) valid responses were obtained in total via convenience sampling technique. They were then subjected to descriptive statistics in Statistical Package for the Social Sciences (SPSS23) to obtain valuable insights on the current nature of cloud-based PM software adoption in the industry and identify the requirement for integrating them into IT degree programmes.

To obtain further insights on the requirement for incorporating such tools into IT degree programmes, interview data was analysed using thematic analysis where software development professionals commented on the need for having cloud-based PM software integrated into academic curricula of IT degrees. This data was obtained through the same interviews carried out to achieve Objective 02 as explained below.

Objective 02: To explore how to integrate cloud-based PM tools into the academic curricula of IT degree programmes effectively.

Concerning the second objective achievement, qualitative semi-structured interviews were carried out with IT professionals in software development firms in Sri Lanka who have experience in using cloud-based PM tools. A total of 13 interviews were undertaken with IT professionals from various fields of software development using the snowball sampling technique where one professional recommended the other from their professional network. The interviews were stopped once the data reached the minimum saturation point where no novel findings were revealed in the last interviews. The transcripts of those interviews were analysed using the thematic analysis process with the aid of NVivo 14 software to derive effective strategies for integrating cloud-based PM tools into IT degree programmes. A specific code was assigned to each IT professional as "Rn", where n indicates the number of interviews held to ensure the anonymity and confidentiality of the respondents.

Some of the demographic details of the respondents are available in Table 1.

Table 1: Summary of Respondent Details of Qualitative Interviews

Respondent	Job Role	Company Scale	Adopted Cloud-based PM Software
R1	Project Manager	Large Scale	Jira
R2	Project Manager	Large Scale	Jira
R3	Business Analyst	Large Scale	Azure DevOps
R4	Software Engineer	Large Scale	Jira
R5	Quality Assurance Engineer	Large Scale	Azure DevOps
R6	Project Manager	Medium Scale	Jira
R7	Project Manager	Medium Scale	Jira
R8	Business Analyst	Medium Scale	Jira
R9	Software Engineer	Medium Scale	Jira
R10	Quality Assurance Engineer	Medium Scale	Jira
R11	Project Manager/Business Analyst	Small Scale	Asana
R12	Software Engineer	Small Scale	Trello
R13	Quality Assurance Engineer	Small Scale	Trello

3. RESULTS

To support the achievement of objective one, a survey study was conducted to analyse the current situation of cloud-based PM tool adoption in the software development industry of Sri Lanka. The findings were used to get insights on the usage of such software in the industry and highlight the importance of integrating them into curricula of IT degree programmes. One hundred two (102) responses were received with voluntary participation from companies offering various software solutions such as Enterprise applications, web applications, mobile applications, customised software solutions, and industry-specific

software solutions. Also, responses were a mix of large-scale, medium-scale, and small-scale companies. Out of those responses, only 102 were used for analysis after treating any missing values available and unengaged responses.

In alignment with identifying the current situation of Cloud-based PM software adoption among software development firms in Sri Lanka, it was found that 94 companies out of 102 (92.16%) have adopted Cloud-based PM software adoption compared with the company scale given in Table 2.

Table 2: Cloud-based PM Software Adoption based on Company Scale

		Cloud-based PM Software Adoption	
		Count	Percentage (%)
Company Scale	Large Scale	34	36
	Medium Scale	43	46
	Small Scale	17	18
Total		94	100

Out of the cloud-based PM software solutions adopted, Jira can be identified as the most popular software, with 68.9% adoption Figure 1.
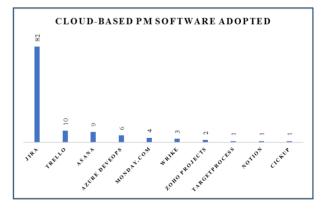

Figure 1: Cloud-based PM Software Adopted

All the firms (100%) who have adopted cloud-based PM software stated that it affects the success of their software development projects, and they would recommend this software to others. However, only

95.7% of companies have stated that they will continuously use this software in the future, while 1.1% stated that they are not sure, and 3.2% stated that they will not continue to use this in the future.

The above findings indicated that most software development firms adopt cloud-based PM software to manage their projects and thereby emphasise that it is necessary for graduates entering the industry to have prior knowledge or skills to adapt to industry trends.

The same was further validated during the in-depth interviews conducted with software development professionals as they all emphasised the fact that graduates coming to the industry with prior knowledge or skills in using cloud-based PM tools find it easier to get used to such tools in the industry than those who are not aware of such tools during their degree programme. Therefore, they recommend universities to update their curricula to match with such industry standards.

> *"I had gone through cloud-based PM technologies and educated myself about those during university, and I believe it became easier when I came to the industry." (R1)*

> *"I quickly adapted to work with Jira during the internship as I have been introduced to it through university degree as a trend in project management software." (R6)*

> *"As the industry is [more] using cloud-based PM software, I suggest universities review their degree programmes and use these tools in practical components of subjects like Project Management or Software Engineering." (R13)*

"I highly recommend giving some good understanding to university students about practical examples like Jira, how JIRA works, how confluence works, how we can collaborate with teams, how we can create tickets just to give them practical knowledge on how these tools work in the industry is a must." (R10)

Therefore, it became evident that there is a crucial need for higher education institutes to incorporate cloud-based PM software into IT degree programmes.

Objective 02: To explore how to integrate cloud-based PM tools into the academic curricula of IT degree programmes effectively

As the first objective shed light on the need for higher education institutes to incorporate cloud-based PM software into IT degree programmes, 13 interviews were held with software development professionals who use that software to explore how they can be integrated effectively into degree programmes.

Thematic analysis revealed four main modes of effectively integrating cloud-based PM software into IT degree programmes as follows.

A. Introducing a practical component of cloud-based PM tools in subjects

The majority of project managers highly recommended that incorporating a practical component of cloud-based PM tools has become a necessity with their growing use in the industry. They further suggested that this can be effectively added to subjects like Project Management or Software Engineering when teaching them the concepts of software development project management tools.

"I highly recommend giving some good understanding to university students about practical examples like Jira, how JIRA works, how confluence works, how we can collaborate with teams, how we can create tickets just to give them practical knowledge on how these tools work in the industry is a must." (R10)

"One of the best ways to integrate cloud-based PM tools into degree programmes by offering a practical component in modules such as Project Management or Software Engineering." (R13)

Based on those findings, introducing a practical component of cloud-based PM tools in subjects of IT degree programmes was themed as one way of effectively integrating such technologies into degree programmes.

B. Requesting students to follow an online course on cloud-based PM software as an assignment

During the interviews, it was requested by several project managers to introduce online courses on cloud-based PM tools as a part of continuous assessments in

subjects of IT degree programmes. As there are many short online courses with free certificates, lecturers can easily mandate students to undertake such courses and submit the completion certificate to evaluate them as a continuous assessment of subjects like project management.

"Lecturers can easily incorporate these by asking students to undertake online courses that are freely available on cloud-based PM tools and grade it as a part of their evaluation on course." (R5)

"I heard of these when I was in the university and did a few courses like Agile project management with Jira, which helped me get used to them when entering the industry. I recommend lecturers make it a mandate to follow such certificate courses as a part of the assignment in their course." (R11)

Therefore, requesting students to follow an online course on cloud-based PM tools as an assignment of the course emerged as another way to effectively integrate those new technologies into IT degree programmes.

C. Workshops on cloud-based PM tools through industry resource persons

Another set of project managers suggested carrying out workshops with the aid of resource persons from the industry as they have updated experience in using the latest technologies like cloud-based PM software. This can also be introduced as a part of evaluation in courses like Project Management, where students are given a few marks for attending mandatory workshops. This can be used as an effective way to update the practical knowledge of lecturers on how these tools are being used in industry and can facilitate train-the-trainer sessions for lecturers as well without limiting them to students.

"Universities can allocate some of the industrial resources to teach students or give some good understanding about these cloud-based PM platforms in their courses." (R7)

"I recommend providing train-the-trainer sessions on cloud-based PM tools to lecturers of subjects like project management so that they can update their knowledge to disseminate with students." (R9)

Therefore, through the analysis, conducting workshops on cloud-based PM tools with industry resource persons was identified as another effective way to incorporate these tools into IT degree programmes.

D. Making it mandatory to be used during their undergraduate development projects

Some project managers elaborated on their own experience that some degree programmes require students to use a cloud-based PM tool when they undertake development projects by groups and assign a mark for proper use in evaluation. They emphasise the fact that the experience students gain by using that can be applied easily to real-world projects of the industry, and they can quickly adapt to the latest software in practice.

"During my time at university, we were introduced to a project management tool called Trello, which we used with the team in our final year project. I would say it supported me in that aspect to have prior knowledge of a tool, and introducing those tools to be used by students in their projects will give them practice on how it works in the industry." (R8)

Therefore, making it mandatory to use cloud-based PM software during their undergraduate development projects was also analysed as another practical approach to integrating cloud-based PM tools into IT degree programmes.

As a summary of findings, it was validated through both surveys and interviews that there is a crucial need to update the IT degree programmes with the introduction of cloud-based PM tools as the industry is heavily using such tools. Introducing a practical component of cloud-based PM tools in subjects, requesting students to follow an online course on cloud-based PM software as an assignment, and workshops on cloud-based PM tools through industry resource persons, making it mandatory to be used during their undergraduate development projects were identified as means of effectively integrating it to IT degree programmes as in Figure 2.
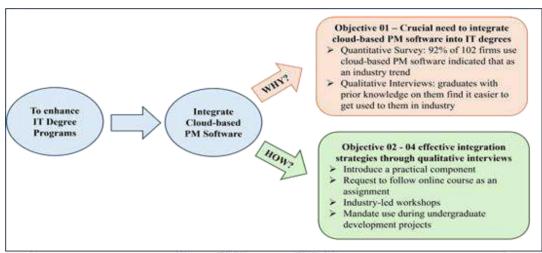
Figure 2: Summary of Findings

4. DISCUSSION

The results of this study also showed that the use of cloud-based PM software is trending, which is aligned with other similar research carried out in the Sri Lankan context and evidences from industry professionals (Assalaarachchi *et al*., 2022; Athambawa *et al*., 2023; Bala, 2023). Study revealed that cloud-based PM tools are heavily used in the industry and professionals recommend that IT degree programmes are to be reviewed to integrate these PM tools to make graduates skilful in such latest technologies when they enter the industry.

The findings from the thematic analysis of this study revealed that there is a need to integrate cloud-based PM software into IT degree programmes. Four effective integration strategies were suggested: introducing it as a practical component within relevant subjects, requiring students to complete online courses on the topic as part of their assignments, conducting workshops led by industry professionals, and making its use mandatory for undergraduate development projects.' Some strategies identified aligned with those of previous studies such as workshops, certificate courses, having updated technical content with a practical module when integrating similar technologies like cloud computing and DevOps into degree programmes (Al-Mousa, 2022; Demchenko *et al*., 2019; Foster et al., 2018; Neyem *et al*., 2018; Patrikeos *et al*., 2023). However, as a novel finding of

this study, another approach for effectively integrating cloud-based PM tools was identified that mandates students to practically experience such tools in their undergraduate development projects. Thereby this study added a novel finding to the literature on effective integration of latest technologies into academic curriculum to bridge the gap between academia and industry.

Implications for Research and Practice

This work has significant implications for theoretical and practical fields. Theoretically, by emphasising the need to incorporate new technologies like cloud-based PM software into degree programmes, it advances the relatively unexplored field of academic curriculum creation. The addition broadens the theoretical landscape by offering empirical insights into how new technology tools might improve the efficacy and relevance of curricula.

From a practical standpoint, the results provide useful suggestions for higher education institutions. By adding cloud-based PM software to their curricula, these educational programmes can enhance their students' employability and prepare them for the modern workforce by providing them with modern skills that meet industry requirements. Therefore, curriculum designers who want to close the gap between academic preparation and professional ractice will find this study to be an invaluable resource.

Limitations and Future Research Directions

Universities may have difficulties integrating cloud-based PM tools due to factors such as financial constraints, lack of experience in real-world implementations, and technological needs. However, this study concentrated on the viewpoints of industrial requirements, and thus, future studies should examine these difficulties and their successful solutions by working with lecturers and students to integrate these technologies into degree programmes.

5. CONCLUSION

As evident from the previous statistical and empirical findings, cloud-based PM software has become popular among professionals of software development firms in managing their projects successfully. However, previous studies have elaborated that more studies are needed to explore effective strategies for how cloud-based PM software can be integrated into IT degree programmes by bridging the skill gap between industry requirements and academic offerings. As a result, this study was undertaken with the objectives of identifying the need to integrate cloud-based PM tools into the academic curricula of IT degree programmes and exploring effective integration strategies.

Utilising a mixed method approach, a quantitative survey was shared to analyse the requirement for integrating cloud-based PM tools into the academic curricula of IT degree programmes and further qualitative interviews to explore effective strategies to integrate cloud-based PM software into academic programmes in IT. Data analysed from both quantitative surveys and qualitative interviews revealed that the majority of firms adopt such software, and Jira seems to be the most popular service vendor. Therefore, there exists a crucial need to review and update the academic curricula of IT degree programmes to incorporate these tools effectively. Further from thematic analysis, introducing a practical component of cloud-based PM tools in subjects, requesting students to follow an online course on cloud-based PM software as an assignment, and workshops on cloud-based PM tools through industry resource persons, making it mandatory to be used during their undergraduate development projects were identified as means of effectively integrating it to IT degree programmes.

These effective strategies evolved as the major contribution of this study, which adds significant value in both theoretical and practical aspects. While filling the gap in the literature, the findings of this study shed light on curriculum review and the development of IT degree programmes incorporating cloud-based PM software as a most sought-after requirement in the industry. Academic institutes can adopt the strategies easily when they plan for updates in academic programmes to match industry expectations. However, future research needs to be carried out to explore challenges and provide recommendations to overcome such challenges that universities might face when incorporating the latest technology into their degree programmes to facilitate successful integration.

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A COMPARATIVE STUDY ON THE ANTIOXIDANT POTENTIALS OF HYBRID AND GENERIC PAPAYAS AVAILABLE IN JAFFNA, SRI LANKA

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ABSTRACT

Generic papaya is a tropical plant abundant in Sri Lanka. Traditionally, it has been used therapeutically as it is a good source of polyphenols, carotenoids and an excellent source of vitamins that are powerful antioxidants. Specially, unripe fruit and leaf of papaya are recognized as a remedy for cancer and heart diseases due to their high antioxidant content. Recently, consumption of hybrid papaya fruits has increased as they are readily available in the local markets. However, the phytochemical constituents and quantity of these hybrid papaya varieties may differ from those available in the generic plant and hence their antioxidant potentials may also vary. Meanwhile there is concern within the community whether hybrid papaya has the same nutritional values as generic papaya. However, there have been no investigation done on the antioxidant activity of hybrid papaya available in Jaffna. Therefore, this study focused on investigating the in-vitro antioxidant potential of leaf and unripe fruit of generic and selected hybrid papaya varieties using 1,1-diphenyl-2-picrylhydrazyl (DPPH) assay. The unripe fruits and leaves of generic and selected hybrid (Red lady, Maradona, Tanin and Vega F1) varieties were collected from the Agricultural Research and Training Centre in Jaffna, Sri Lanka. The unripe fruit was sliced after removing the skin and seeds. The sliced unripe fruit and leaves were shade dried and powdered. The powdered plant materials were macerated with methanol and ethyl acetate separately for 48 hours at room temperature. The DPPH assay was carried out on the methanol and ethyl acetate extracts of the individual plant materials by employing ascorbic acid as the standard. The obtained data were analyzed using one-way ANOVA at 5% significance level and a significant difference between the antioxidant activities of the standard (IC$_{50}$ value = 12.394 µg/mL) and the selected papaya extracts (IC$_{50}$ values vary from 430.641 – 6,652.267 µg/mL) was found. Further, the selected hybrid papayas exhibited better antioxidant properties than the generic one; but, did not show a common trend within them. The leaf extracts were found to possess more antioxidant potential than the unripe fruit extracts of the same papaya variety. With respect to the solvents employed in extraction, methanolic extracts of the selected papayas showed better antioxidant activity than the corresponding ethyl acetate extracts. Preliminary phytochemical screening of the leaf and unripe fruit extracts of hybrid papayas revealed the presence of alkaloids, flavonoids, polyphenols and glycosides, which could be responsible for their antioxidant activity. The finding of the study revealed that hybrid papaya could be used as a raw material for functional food as generic papaya. However, there is a need to evaluate the other nutritional values to confirm it further.

KEYWORDS: *Antioxidant potential*, DPPH *assay, Generic papaya, Hybrid papaya, Leaf, Unripe fruit*

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1. INTRODUCTION

Papaya is a tropical plant found in Sri Lanka and widely available in all parts of the country. The fruit, peel, flower, seed, and leaf of the plant possess medicinal value as phytochemicals like enzymes (in latex), carotenoids (in fruits and seeds), alkaloids (in leaves), phenolic compounds (in fruits, leaves, and shoots), and glucosinolates (in fruits, leaves, and shoots) are found in the papaya plant (Zuhair *et al.*, 2013). Major groups of phytochemicals responsible for the antioxidant activity of papaya include polyphenols, carotenoids, and vitamins such as vitamin C & E (Foyzun and Aktar, 2017). As papaya is a highly consumed natural source, hybridization techniques are employed to increase its productivity.

Hybridization is the process of combining two genetically different parents to create new crop varieties (hybrid plants) with properties such as rapid growth, high yield, great disease resistance and longevity. Such hybrid plants might possess different phytochemical constituents compared to the generic plants. As such, the pharmacological activities of such hybrid varieties may vary (Addai, Abdullah and Mutalib, 2013).

Oxygen is essential for life to exist, but in certain instances it has serious deleterious impacts on the human body. Under normal physiological conditions, oxidative metabolism causes the production of free radicals like reactive oxygen species (ROS) (Chanda & Dave, 2009). They become harmful to humans, when they are not eliminated from the body by endogenous protective systems. Such imbalance between the generation of free radicals and endogenous protective mechanism leads to oxidative stress (Koju *et al.*, 2019).

Long-term accumulation of these free radicals in the human body can damage important biological molecules such as DNA, proteins, carbohydrates & lipids and result in a homeostatic disruption (Sivasankari, Poongothai, and Sudha, 2019). These cell damages cause numerous diseases and disorders like cancer, cardiovascular disease, neural disorder, Alzheimer's disease, cognitive impairment, alcohol

induced liver disease, ageing, atherosclerosis, *etc.* (Patel *et al.*, 2010).

The compounds which can prevent these cell damages are known as antioxidants. They can terminate the radical-based chain reactions by removing the free radical intermediates and inhibiting other oxidation reactions when present at low concentrations compared to that of the oxidizable substrate. Generally, the antioxidants serve as reducing agents and neutralize free radicals by oxidizing themselves. Several molecules play a role in antioxidant defence; they are either endogenous (internally synthesized) such as glutathione, α-lipoic acid, and coenzyme Q or exogenous (consumed) such as vitamin C, vitamin E, retinol, and phenols (Somogyi *et al.*, 2007).

Antioxidants are prevalent in regularly consumed food products because they are either naturally occurring concurrent chemicals or synthetic antioxidants that are added during processing. Fruits, vegetables, tea, and other dietary sources contain various kinds of antioxidants.

Natural antioxidants are preferred because of their cost effectiveness, compatibility with food, and fewer adverse effects on the human body (Ahmed *et al.*, 2019). Also, it has been reported that they provide numerous health benefits including reduction of plaque development in the arteries and prevention of chronic diseases like cancer and heart disease (Dwivedi *et al.*, 2020). Meanwhile, consumers' desire for natural antioxidant sources has increased due to toxicity and carcinogenic nature of some synthetic antioxidants (Patel *et al.*, 2010).

Currently, the consumption of hybrid papaya has increased in the country as they are readily available in the market. Also, cultivation of hybrid papaya is preferred over the generic variety as the hybrid plants are shorter in size and give higher yields. However, their phytochemical compositions and quantity may differ from the generic one as they are produced by cross pollination. Meanwhile the local community is concerned whether hybrid papaya possesses the same nutritional values as generic papaya. However, there have been no investigation done on the antioxidant activity of hybrid papaya available in Jaffna. Therefore, this study focused on investigating the *in-*

vitro antioxidant activity of leaf and unripe fruit of the selected hybrid (Red lady, Maradona, Tanin & Vega F1) and generic varieties by employing DPPH free radical scavenging assay to establish the antioxidant capacity of hybrid papaya in comparison with generic papaya. This study will provide a framework for the future antioxidant studies and to understand the nutritional values of the hybrid papaya.

2. METHODOLOGY

A. Determination of antioxidant activity and phytochemical analysis of leaf and unripe fruit extracts of generic and hybrid papayas

1. Sample preparation

Leaves, and unripe fruits of generic and selected hybrid (Red lady, Maradona, Tanin, and Vega F1) papayas were collected from the Agricultural Research and Training Centrer in Jaffna, Sri Lanka and their authenticity were checked at the Department of Plant & Molecular Biology, University of Kelaniya, Sri Lanka. All raw plant materials were cleaned thoroughly with tap water followed by distilled water two to three times. The leaves were allowed to dry in the shade for a week. The unripe fruits were peeled off and seeds were removed, and the flesh was shredded into small thin pieces. The unripe fruit flesh slices were dried completely in the hot air oven at 50ºC for 2 days until a constant weight was attained. The dried leaves and unripe fruit flesh slices were milled separately, and the respective homogenous powders were obtained. The powdered samples were stored at 4ºC in airtight containers.

2. Preparation of extracts from samples

The powdered samples, 10 g each, were macerated separately with 200 mL of ethyl acetate and 200 mL of methanol at room temperature for 48 hours. Then, the macerated mixtures were filtered separately using Whatman No.1 filter papers with pore size 11.0 μm. The solvents were evaporated using rotatory evaporator (R3001, China) at 45ºC under reduced pressure and the resulting crude extracts were stored at 4ºC in the refrigerator.

3. Preparation of DPPH solution

The DPPH reagent (4 mg) was dissolved in 100 mL of methanol to prepare 0.004% (w/v) deep violet coloured DPPH solution which was stored in the dark at room temperature.

4. Determination of antioxidant activity by 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging assay

Antioxidant activity of the crude extract was determined by adopting a slightly modified procedure of DPPH radical scavenging assay (Ahmed *et al.*, 2019) due to limited resources.

An amount of 3 mL of freshly prepared DPPH solution (0.04%) in methanol was added separately to 1 mL standard ascorbic acid solutions at different concentrations (3.125, 6.25, 12.5, 25, 50, and 100 µg/mL). The resulting mixtures were allowed to stand for 30 minutes in the dark. Absorbances of the said mixtures were recorded at 517 nm wavelength using a UV-Visible spectrophotometer (Spectro SC) and the standard curve for DPPH assay for ascorbic acid was plotted using the recorded data. Similarly, 1 mL solutions of each crude extract at different concentrations (50, 100, 200, 400 and 800 µg/mL) were added separately to 3 mL of freshly prepared DPPH solution (0.04%) in methanol, the resulting mixtures were allowed to stand for 30 minutes in the dark and absorbances were recorded at 517 nm wavelength. The same procedure was repeated with the mixture containing 1 mL of methanol and 3 mL of DPPH solution in methanol which was considered as the control. All experiments were carried out in triplicate. The degree of discoloration of the reaction mixture is proportional to the free radical scavenging efficiency of the crude extract. The following equation was employed to calculate the DPPH free radical scavenging activity (percentage of inhibition):

Percentage of inhibition = [(A$_{control}$ − A$_{sample}$) / A$_{control}$] *100

A$_{control}$ = Absorbance of Control

A$_{sample}$ = Absorbance of Sample

The percentage of scavenged DPPH was plotted against the concentration of each crude extract and the IC_{50} value of the respective crude extract was calculated.

5. *Phytochemical analysis*

The laboratory-based experiments to determine the presence/absence of phytochemicals (alkaloids, saponins, flavonoids, tannins, glycosides, polyphenols, gum & mucilage) were performed on the twenty crude extracts of hybrid papayas using standard protocols (Ahmed *et al.*, 2019).

B. Data analysis

All experiments were carried out in triplicate and the recorded data were presented as mean ± standard deviation. The antioxidant activity was expressed as IC_{50} value. The statistical significance was evaluated by the analysis of variance (ANOVA) followed by Paired Sample T Test. Difference between the mean values was considered significant when p-value is less than 0.05 ($p < 0.05$).

3. RESULTS AND DISCUSSION

Yield percentages of crude extracts

10 g of dried and powdered leaf and unripe fruit flesh samples of generic and four different hybrid papaya varieties were separately extracted in methanol and ethyl acetate solvents by maceration. Though many extraction techniques are available, maceration process was chosen for the current study in order to extract the heat-sensitive phytochemicals along with others that may enrich the papaya extracts with more antioxidants. Moreover, heating may affect the extractability characteristics of the solvent (Ghori, 2013).

Table 1 shows the yield percentages of the corresponding crude extracts.

Table 1: Yield percentages of crude extracts of leaf and unripe fruit of generic and hybrid papayas in methanol and ethyl acetate.

Variety of Papaya	Plant part	Yield percentage of crude extract	
		Methanolic extract	Ethyl acetate extract
Generic	Leaf	12.0%	10.5%
	Unripe fruit	9.5%	7.0%
Red lady	Leaf	11.5%	11.0%
	Unripe fruit	8.5%	7.5%
Maradona	Leaf	6.0%	4.3%
	Unripe fruit	5.2%	3.8%
Tanin	Leaf	6.5%	4.5%
	Unripe fruit	4.8%	2.5%
Vega F1	Leaf	8.8%	5.3%
	Unripe fruit	6.8%	3.4%

Higher yields were obtained for leaf extracts than unripe fruit extracts. The highest yield (12.0%) was obtained for the leaf powder of generic papaya extracted in methanol. Meanwhile the lowest yield in percentage was observed for unripe fruit powder of Tanin papaya extracted in ethyl acetate with the value of 2.5%. In general, extraction was found to be more efficient in methanol than ethyl acetate which shows that polarity of the solvent employed for extraction influences yield percentage of the extract (Addai *et al.*, 2013). Further, the phytochemical compositions of plants vary according to the cultivar type and part of the plant, the yields of the corresponding crude extracts also differ.

In-vitro antioxidant activities of crude extracts

In this study, DPPH free radical scavenging assay was used to determine the antioxidant activity as it is a simple and rapid method and gives reliable information concerning the antioxidant ability of the tested plant material (Amira, 2013). When a DPPH free radical becomes paired with hydrogen from a free radical scavenging antioxidant, a DPPH-H species forms and the purple colour of DPPH fades rapidly to yellow. The degree of discoloration indicates the free radical scavenging potential of the antioxidant compound.
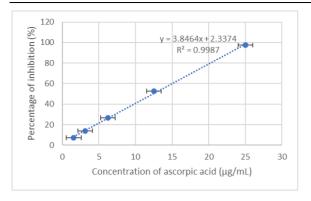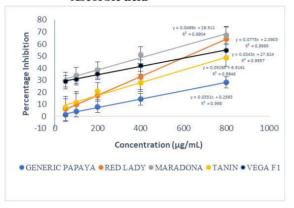
Figure 1: Standard curve for DPPH assay for Ascorbic acid

Figure 2: Percentage of Inhibition *vs* Concentration plots for Leaf extracts of Generic and Hybrid Papayas in Methanol
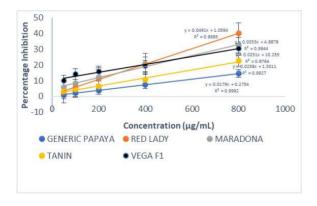

Figure 3: Percentage of Inhibition *vs* Concentration plots for Leaf extracts of Generic and Hybrid Papayas in Ethyl acetate
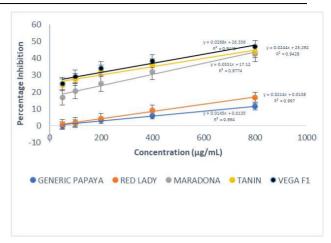

Figure 4: Percentage of Inhibition *vs* Concentration plots for Unripe fruit extracts of Generic and Hybrid Papayas in Methanol
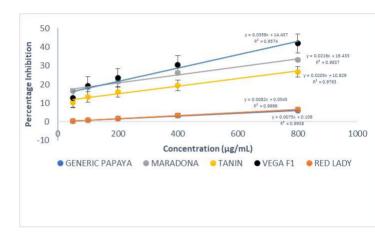

Figure 5: Percentage of Inhibition *vs* Concentration plots for Unripe fruit extracts of Generic and Hybrid Papayas in Ethyl acetate

Figure 1 shows the standard curve for DPPH assay for ascorbic acid. The DPPH free radical scavenging potentials (in percentage) of leaf extracts of generic and selected hybrid papayas in methanol and ethyl acetate solvents are depicted in Figures 2 and 3 respectively. Figures 4 and 5 illustrate the DPPH free radical scavenging activities (in percentage) of unripe fruit extracts of generic and selected hybrid papayas in methanol and ethyl acetate respectively.

The concentration of the plant extract required to reduce the initial DPPH concentration by 50% is known as the IC_{50} value of the respective plant extract. The IC_{50} values of all 20 crude extracts of papaya, determined from the regression analysis of the plots in Figures 2-5, are listed in Table 2.

Table 2: IC_{50} values of crude extracts of leaf and unripe fruit of generic and hybrid papayas in methanol and ethyl acetate

Crude Extract of Papaya			IC_{50} Value (μg/mL)
Solvent	Plant Part	Variety	
Methanol	Leaf	Generic	$1407.11 \pm 16.67^{e,f,g}$
		Red lady	$619.79 \pm 5.21^{g,h,i}$
		Maradona	$430.64 \pm 18.02^{h,i}$
		Tanin	$819.09 \pm 47.37^{f,g,h}$
		Vega F1	$652.36 \pm 20.24^{g,h,i}$
	Unripe fruit	Generic	3447.35 ± 197.90^{b}
		Red lady	$2335.80 \pm 322.20^{c,d}$
		Maradona	$993.35 \pm 62.76^{f,g,h}$
		Tanin	$1012.62 \pm 17.49^{f,g,h}$
		Vega F1	$882.99 \pm 38.58^{f,g,h}$
Ethyl acetate	Leaf	Generic	$2777.91 \pm 182.27^{b,c}$
		Red lady	$996.75 \pm 41.22^{f,g,h}$
		Maradona	$1277.97 \pm 76.98^{e,f,g}$
		Tanin	$1879.80 \pm 233.78^{d,e}$
		Vega F1	$1583.47 \pm 78.21^{d,e,f}$
	Unripe fruit	Generic	6652.27 ± 373.37^{a}
		Red lady	6090.92 ± 1006.37^{a}
		Maradona	$1554.03 \pm 127.93^{d,e,f}$
		Tanin	$1910.78 \pm 121.70^{d,e}$
		Vega F1	$990.61 \pm 21.47^{f,g,h}$

IC_{50} value of ascorbic acid is 12.39 ± 0.15^{j} μg/mL

Triplicate values are represented as mean ± SD; Values with different superscripts ($^{a-h}$) in the same column differ significantly (P<0.05)

The IC_{50} value of a plant extract is inversely related to its antioxidant activity. A low IC_{50} value indicates a high antioxidant activity of the plant extract and in turn a high percentage of inhibition of DPPH radicals.

In the present study, the IC_{50} value of the standard (ascorbic acid) was found to be 12.394 μg/mL whereas the IC_{50} values of the leaf and unripe fruit extracts of generic and selected hybrid papayas in methanol and ethyl acetate solvents varied from 430.641 – 6,652.267 μg/mL. Leaf powder of Maradona hybrid papaya extracted in methanol showed the highest IC_{50} value of 430.641 μg/mL, meanwhile unripe fruit powder of generic papaya extracted in ethyl acetate exhibited the lowest IC_{50} value of 6,652.267 μg/mL. A one-way ANOVA followed by Paired Sample T Test performed on the recorded data revealed a significant difference (p>0.05) between the antioxidant activities of ascorbic acid (standard) and the papaya extracts as well as between each and other extracts.

Based on the DPPH assay of the papaya varieties, the selected hybrid papayas exhibited better antioxidant properties than the generic one. However, a common trend could not be observed within the hybrid varieties.

When considering the plant parts, the leaf extracts were found to possess more antioxidant potential than the unripe fruit extracts of the same papaya variety selected for this study. A similar observation has been reported by Amira *et al.* (2013) where the analysis of antioxidant activities of different parts of the Carica papaya plant revealed that young leaves possess the highest antioxidant property followed by unripe fruit, ripen fruit, and finally seeds based on the type and quantitative availability of phenolic constituents.

This study further demonstrates that the polarity of the solvent used for extraction influences the extraction efficiency as well as antioxidant activity of the resulting extract. A separate study on the effect of solvents in the extraction of phenols responsible for antioxidant property of two papaya cultivars revealed high phenolic content in the cultivar extracted with 50% methanol (Addai *et al.*, 2013). The findings of the current study were on a par with the literature where methanolic extracts showed better antioxidant activity than the corresponding ethyl acetate extracts (Foyzun & Aktar, 2017).

Phytochemical Analysis

In the current study, the phytochemical constituents of the leaf and unripe fruit extracts of the selected hybrid papayas were analyzed by adopting standard procedures (Ahmed *et al.*, 2019) and the results are shown in Tables 3 and 4. However, quantitative determination of the identified phytochemicals

responsible for the antioxidant activity could not be performed due to lack of facilities in the host institution.

Table 3: **Phytochemical analysis of leaf extracts of selected hybrid papayas**

Phytochemicals	RLM	RLEA	MLM	MLEA	TLM	TLEA	VLM	VLEA
Alkaloids	+	+	+	+	+	+	+	+
Saponins	-	-	-	-	-	-	-	-
Flavonoids	+	-	+	-	+	-	+	-
Tannins	-	-	-	-	+	-	+	-
Glycosides	+	+	+	+	+	+	+	+
Polyphenols	+	+	+	+	+	+	+	+
Gum & mucilage	-	-	-	-	-	-	-	-
Sterols	+	+	+	+	+	+	+	+

RLM = Red lady leaf methanolic extract; **RLEA** = Red lady leaf ethyl acetate extract; **MLM** = Maradona leaf methanolic extract; **MLEA** = Maradona leaf ethyl acetate extract; **TLM** = Tanin leaf methanolic extract; **TLEA** = Tanin leaf ethyl acetate extract; **VLM** = Vega F1 leaf methanolic extract; **VLEA** = Vega F1 leaf ethyl acetate extract
(+) indicates presence and (-) indicates absence

From the phytochemical screening of the leaf extracts of the selected hybrid papayas in methanol and ethyl acetate, it was found that all the crude extracts contain alkaloids, glycosides, polyphenols and sterols. While the presence of flavonoids was observed in the methanolic extracts of all hybrid papayas, those of Tanin and Vega F1 possess tannins additionally. The presence of flavonoids and tannins along with other antioxidants might have contributed to the enhanced i*n-vitro* antioxidant activities demonstrated by the methanolic extracts of leaf of the selected hybrid papayas. But none of the extracts exhibited the presence of saponins, gum and mucilage (Table 3). A phytochemical screening carried out by Aboobacker *et al* (2020) on the leaf extract of caccia papaya in methanol has revealed the presence of alkaloids, glycosides, flavonoids, saponins, tannins and carbohydrates. This observation is comparable to the present study.

Table 4: **Phytochemical analysis of unripe fruit extracts of selected hybrid papayas.**

Phytochemicals	RFM	RFEA	MFM	MFEA	TFM	TFEA	VFM	VFEA
Alkaloids	+	+	+	+	+	+	+	+
Saponins	-	-	-	-	-	-	-	-
Flavonoids	+	+	+	+	+	+	+	+
Tannins	-	-	-	-	-	-	-	-
Glycosides	+	+	+	+	+	+	+	+
Polyphenols	+	+	+	+	+	+	+	+
Gum & mucilage	-	-	-	-	-	-	-	-
Sterols	+	+	+	+	+	+	+	+

RFM = Red lady unripe fruit methanolic extract; **RFEA** = Red lady unripe fruit ethyl acetate extract; **MFM** = Maradona unripe fruit methanolic extract; **MFEA** = Maradona unripe fruit ethyl acetate extract; **TFM** = Tanin unripe fruit methanolic extract; **TFEA** = Tanin unripe fruit ethyl acetate extract; **VFM** = Vega F1 unripe fruit methanolic extract; **VFEA** = Vega F1 unripe fruit ethyl acetate extract

While the unripe fruit extracts of the selected hybrid papayas in methanol and ethyl acetate were found to possess almost similar phytochemical compositions as those of the leaf extracts, a few exceptions were noted (Table 4). All the unripe fruit extracts contain flavonoids in addition to alkaloids, glycosides, polyphenols and sterols. Also, absence of tannins along with saponins, gum and mucilage were noted in all the unripe fruit extracts. It should be noted that not only the availability but also the quantity and extractability (extraction process and solvent) of available antioxidants determine the extent of antioxidant potential of the plant material. Further, quantity of phytochemicals in a plant material may vary according to the age of plant, time of collection, and the environmental conditions (Koffi *et al.*, 2020). As such, lesser antioxidant activities of the unripe fruit extracts compared to the leaf extracts of papayas in the current study may be attributed to one or more of the above factors. The finding of the present study revealed that hybrid papaya could be used as a raw material for functional food as generic papaya.

4. CONCLUSION

This study has demonstrated a significant difference between the antioxidant activities of the standard and the selected papaya varieties based on statistical analysis. The selected hybrid papayas exhibited better antioxidant properties than the generic one but did not show a common trend within them. The leaf extracts were found to possess more antioxidant potential than the unripe fruit extracts of the same papaya variety. Methanolic extracts of the selected papayas showed better antioxidant activity than the corresponding ethyl acetate extracts. The presence of phytochemicals, such as alkaloids, flavonoids, polyphenols and glycosides, could be attributed to the antioxidant property of the papaya extracts. Overall, this study confirms that the antioxidant level of hybrid papaya is better than that of the generic papaya based on the DPPH assay, and hybrid papaya could be used for daily consumption as generic papaya. However, further studies are needed to understand the nutritional values of hybrid papaya.

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STRESS AND COPING STRATEGIES ASSESSMENT WITH PSS-10 SCALE AND THE BRIEF COPE SCALE AMONG CANCER PATIENTS IN A HOSPITAL, BANKE, NEPAL

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ABSTRACT

Cancer patients often experience significant psychological distress throughout their diagnosis, treatment, and recovery phases. This study conducted at Sushil Koirala Prakhar Cancer Hospital in Khajura, Banke, Nepal, aimed to explore stress levels and coping strategies among cancer patients undergoing chemotherapy. A hospital-based cross-sectional design was employed, and data were collected using semi-structured questionnaires including the Perceived Stress Scale (PSS-10) and the Brief COPE scale. A total of 384 cancer patients participated in the study. Results indicated that a majority of patients reported moderate stress levels, with significant associations found between stress levels and marital status, place of residence, and occupation. Approach coping strategies were predominantly utilised by patients, highlighting active coping mechanisms such as emotional support, positive reframing, and humour. The findings underscore the need for tailored psychosocial interventions to mitigate stress and enhance coping strategies among cancer patients in similar settings.

KEYWORDS: *Cancer patients, Perceived stress, Coping strategies, Chemotherapy*

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1. INTRODUCTION

Uncontrolled proliferation and spread of aberrant cells is a hallmark of a category of disorders known as cancer (American cancer society, n. d.). Poorly built, loosely shaped, and unorganised cells are characteristics of cancer (Williams & Hopper, 2008). For most people, a cancer diagnosis is deadly. Many people believe that there is no treatment for cancer, only excruciating suffering. This is an oversimplified and too broad picture of cancer, despite its widespread popularity. Without doubt, cancer is a dangerous condition that might be fatal (Evert *et al*., 2010).

About eighty percent of patients have some degree of physical, psychological, or emotional suffering during the early phases of their cancer treatment, which can be a significant emotional and psychological burden. Cancer patients now have a higher chance of survival because of medical improvements, but they must put up with uncomfortable side effects for longer than in the past (Puri *et al*., 2010).

Even when the disease has long since passed, stress is thought to be a significant psychological trigger for cancer patients, contributing to problems from diagnosis through prognosis and treatment. The ambiguity surrounding the disease, its severity, physical challenges, medical treatments, psychological effects, and familial concerns all cause stress for cancer patients. A comprehensive strategy is required due to the several detrimental effects of stress on cancer patients, including the exacerbation of mental health conditions including anxiety, depression, and posttraumatic stress disorder, as well as the decline in their quality of life (QoL) (Barre *et al*., 2018).

Kabra, Verma, and Verma (2022) conducted a cross-sectional study to evaluate perceived stress levels and coping strategies among cancer patients using the Perceived Stress Scale (PSS-10) and the Brief COPE scale. The study was conducted in a clinical setting and involved a diverse sample of cancer patients undergoing treatment. The results revealed that a significant number of patients experienced moderate to high levels of stress, with factors such as the type and stage of cancer, treatment modality, and patient support systems influencing stress levels. The study also highlighted that active coping strategies, such as problem-solving and emotional support-seeking, were positively associated with lower stress levels, while maladaptive coping strategies, such as denial and self-blame, were linked to higher stress. The findings underscore the importance of psychological support and targeted interventions to help patients manage stress more effectively during cancer treatment.

Sharma, Singh, and Koirala (2021) conducted a hospital-based study to assess the stress levels and coping mechanisms of cancer patients receiving chemotherapy in a Nepalese hospital. Using the PSS-10 scale to measure perceived stress and the Brief COPE scale to evaluate coping mechanisms, the researchers found that a majority of patients reported significant stress, particularly related to uncertainty about their prognosis and the side effects of chemotherapy. The study identified that patients who employed problem-focused coping strategies, such as planning and positive reframing, exhibited better emotional well-being compared to those who relied on avoidant coping mechanisms like behavioural disengagement and substance use. The authors concluded that implementing stress management programmes tailored to the needs of cancer patients could improve their coping capacity and overall quality of life during treatment.

The majority of the stresses related to diagnosis, disease, and treatment are experienced by cancer patients. These pressures might lead to coping mechanisms that have an impact on mental health. Patients' and their families' lives are impacted by cancer in a variety of ways. A significant degree of psychological stress is linked to cancer diagnosis and treatment, which alters a patient's personal life routes, daily activities, employment, relationships, and family duties (Karabulutlu *et al*., 2010).

Over the years, a variety of behavioural and psychological therapies have been employed to help cancer patients cope with their symptoms and lessen their severe side effects. Encouraging our natural

ability to heal will enable us to get the most out of any therapy we select; on the other hand, undervaluing it will probably make it harder for any treatment to be effective. Cancer patients can benefit from learning how to cope with stress, anxiety, and everyday demands as it can help them make decisions about their priorities and course of action (Wazqar, 2018).

Despite extensive research on stress and coping mechanisms among cancer patients, significant gaps remain in understanding the nuanced psychological and emotional experiences specific to different cultural and geographical contexts. Current studies, such as those by Kabra *et al.* (2022) and Sharma *et al.* (2021), provide valuable insights into the stress levels and coping strategies of cancer patients, but their findings are often limited to hospital-based or clinical settings in specific regions. There is a lack of research that comprehensively examines the psychological burden of cancer in rural or underserved populations, particularly in low-income countries like Nepal. Furthermore, while the PSS-10 and Brief COPE scales are widely used, the variability in stress levels and coping mechanisms among different cancer types, stages, and demographic groups remains underexplored. Addressing this gap is crucial to developing culturally sensitive, personalised interventions that enhance coping strategies and improve the overall quality of life for cancer patients. More research is needed to assess how socio-economic factors, cultural beliefs, and access to healthcare influence the stress and coping processes in cancer patients, particularly in settings like Banke, Nepal.

Rationale for the Study

Unchecked cell development, or cancer, is one of the leading causes of mortality worldwide (Shewach & Kuchta, 2009). The International Agency for Research on Cancer estimates that by 2040, there would be 27.5 million new instances of cancer globally, compared to the 17 million cases that were diagnosed in 2018. According to Mao (2019), there will likely be a significant increase in the worldwide cancer burden as a result of aging populations, growing risk factors, and population growth.

A complex unpleasant emotional experience of a psychological (cognitive, behavioural, emotional), social, or spiritual origin, psychological distress can make it difficult for patients to manage their illness. Distress may range from everyday emotions like fear and grief to incapacitating illnesses like social isolation, depression, anxiety, panic attacks, and even existential and spiritual crises. According to El Kheir and Ibharim (2019), the prevalence of long-term psychological disturbance varies from 20% to 66%. There is evidence that individuals with cancer typically have high levels of stress, which can lead to unfavourable symptoms like dread, worry, or sadness. As a matter of fact, it might be a painful event for some, endangering their bodily and mental health (Macia *et al.*, 2020).

A Korean study found that compared to other groups, women and cancer patients in the third stage experienced more stress but less coping. There was a negative correlation found between stress and emotion- and problem-focused coping strategies. Relative to problem-focused coping techniques, emotion-focused coping was more common among Korean cancer patients (Kin *et al.*, 2002).

A study done in Sudan reveals that 25% of chemotherapy patients had psychological anguish. The study suggests that a comprehensive approach to the care of cancer patients is necessary, including psychological examination to identify individuals at risk, since psychological distress has a role in both cancer recurrence and recovery (El Kheir & Ibharim, 2019).

Research has shown that some coping mechanisms are more flexible and often employed than others, resulting in more positive, proactive, and productive coping processes. In actuality, the degree of cancer, the amount of time after diagnosis, the course of medical therapy, etc., can all affect how well a person copes. According to some writers, coping mechanisms including acceptance, constructive self-talk, and

reaching out for social support are linked to improved quality of life, well-being, and adaptability in cancer patients. Conversely, poorer mental health outcomes are linked to maladaptive coping mechanisms such as self-blame, avoidance, and negation (Macia, 2020).

Objectives of the Study

- To determine coping mechanisms and stress levels in hospitalised cancer patients.

- To gauge how stressed out cancer sufferers are

- To determine the extent to which cancer patients employ coping mechanisms.

- To determine whether there is a relationship between a person's stress level and particular sociodemographic factors.

- To ascertain if certain sociodemographic characteristics and level of coping mechanisms are related.

Significance of the Study

This study might provide baseline data of stress and coping strategies among cancer patient. Health care professional can incorporate study finding in patient centred care and promote effective coping mechanism to improve quality of life of cancer patient.

Variables of the study

Independent Variables

Socio demographic variables and Clinical characteristics are independent variables.

Dependent Variable

Stress and Coping Strategies among Cancer patients

Hypothesis

H1: There will be a significant relationship between the level of stress and selected demographic variables among cancer patients who are receiving Chemotherapy.

H2: There will be a significant association between the level of Coping strategies and the selected demographic variables among cancer patients who are receiving Chemotherapy.

2. METHODOLOGY

Research Design

The study employed a cross-sectional research methodology centred on hospitals to determine the prevalence of stress and coping strategies among cancer patients in a specific hospital in Banke, Nepal.

Study Area

The study setting was Sushil Koirala Prakhar cancer Hospital of Khajura Rural Municipality, Banke district, Province 5. It was established at 2075 B.S which is 10km away from Nepalgunj Nursing Campus. It is only one specialised government cancer hospital where a huge number of the population from the mid and far Western Region receive the services at any given space of time. This hospital provides the day care services for the chemotherapy treatment, minor surgery, OPD services for prevention, treatment and research on cancer.

Research population

The study population was all cancer Patient who are receiving chemotherapy at Sushil koirala Prakhar cancer hospital of Khajura VDC, Banke District, Province 5.

Research Instrumentation

The instruments consisted of the following parts:

Part I:

A semi-structured questionnaire related to socio-demographic variables

A semi-structured questionnaire related to clinical characteristics

Part II

A modified Perceived Stress Scale (PSS-10 items) to measures level of stress

Part III

A Brief COPE scale (28 item) to measure coping strategies.

Sampling Method

Nonprobability purposive method was used for data collection

Sample size

The sample size was 384

Inclusion criteria

- 18 years and above
- Patients receiving Chemotherapy

Exclusion Criteria

- Mental illness
- Neurological disorder

Validity and Reliability

A thorough literature review, discussions with a research adviser, subject matter experts, and statisticians were used to determine the content validity of the study.

Data collection Procedure

The researcher obtained permission from the concerned authority of Sushil Koirala Prakhar Cancer Hospital Khajura Rural Municipality, Banke district.

The purpose of the study was explained to each respondent.

Informed consent was taken from the samples before administering questionnaires.

Confidentiality and anonymity was strictly maintained.

Semi-structure questionnaire and Perceived Stress Scale-10 and A Brief COPE scale (28 item) was used for data collection.

Data were collected within 3 months

A pre-test was done to a 10% sample group.

Table 1: Socio-demographic variables

Variables	Frequency	percentage
Age		
<51	173	45.05
More than and equal to 51	211	54.95
Sex		
Female	244	63.54
Male	140	36.46
Educational status		
Illiterate	128	33.33
Informal	62	16.15
Primary level	99	25.78
Higher secondary	86	22.40
Above higher secondary	9	2.34
Marital status		
Unmarried	27	7.03
Married	289	75.26
Divorced	20	5.21
Widow/widower	48	12.50
Occupation		
Business	65	16.93
Farming	176	45.83
Housemaker	8	2.08
Service/job	122	31.77
Students	13	3.39
Income		
Enough for 6 months	44	11.46
Enough for 12 months	309	80.47
Surplus for 12 months	31	8.07
Place of residence		
Province 5	119	30.99
Province 6	171	44.53
Province 7	96	24.48
Type of family		
Nuclear family	130	33.85
Joint family	254	66.15

Data management and analysis

Following data collection, each day's data were carefully examined to ensure that it was accurate, consistent, and full. After that, data were coded and updated. Information was added to epi-data. Prior to analysis, the data were verified for correctness and completeness. Data were evaluated using both inferential (chi square) and descriptive (mean, standard deviation) statistics in accordance with the study's aims. SPSS 21 was used for the analysis.

Ethical consideration

Approval from Ethical Review Board (ERB) of NHRC was taken. An official letter from NHRC was submitted to the concerned authority of Sushil Koirala Prakhar Cancer Hospital Khajura VDC, Banke district. The purpose of the study was explained to the respondents. Prior instruction was provided before collecting information. Written informed consent from the respondents was taken. Each respondent was assured for privacy and confidentiality of information given from them. Data was collected in a conducive environment without any bias.

3. RESULTS AND DISCUSSION

The demographic data presents a comprehensive overview of the study's participants, highlighting various socio-demographic variables among cancer patients. The age distribution indicates that a slightly higher proportion of patients are aged 51 years and above (54.95%), compared to those below 51 years (45.05%). This suggests a relatively older sample population, which is not uncommon in cancer studies given the higher incidence of cancer in older age groups (Table 1).

Gender distribution reveals a significant predominance of female patients, who constitute 63.54% of the sample, whereas males represent 36.46%. This disparity might reflect higher healthcare-seeking behaviour among women or specific cancer types that are more prevalent in females within the studied region.

Educational status among the patients varies considerably. A significant portion of the sample is

illiterate (33.33%), and another substantial group has only informal education (16.15%). Patients with primary level education constitute 25.78%, while those with higher secondary education represent 22.40%. Only a small fraction of the patients (2.34%) have education beyond the higher secondary level. This distribution indicates a relatively low overall educational attainment, which could impact patients' understanding and management of their condition.

Marital status data shows that a majority of the patients are married (75.26%), while smaller proportions are unmarried (7.03%), divorced (5.21%), or widowed (12.50%). The high percentage of married individuals might imply the presence of familial support systems, which are crucial in coping with chronic illnesses like cancer.

In terms of occupation, nearly half of the patients are engaged in farming (45.83%), followed by those in service or job roles (31.77%). A smaller number are involved in business (16.93%), house keeping (2.08%), or are students (3.39%). This occupational distribution highlights the rural and agrarian background of a significant portion of the sample.

Regarding income, the majority of the patients (80.47%) report having enough income for 12 months, indicating a relatively stable financial condition for most of the sample. However, 11.46% have income sufficient only for 6 months, and 8.07% have a surplus for 12 months, suggesting some financial variability within the group.

The place of residence data shows that most patients are from Province 6 (44.53%), followed by Province 5 (30.99%) and Province 7 (24.48%). This regional distribution can provide insights into the geographic spread and potentially the availability of healthcare services in these areas.

Finally, the type of family data indicates that a majority of the patients (66.15%) live in joint families, while 33.85% live in nuclear families. The prevalence of joint family systems might provide stronger social support networks, which are essential for coping with

the emotional and practical challenges posed by cancer.

Overall, the demographic analysis provides a detailed understanding of the patient population, highlighting key areas that could influence stress levels and coping strategies among cancer patients (Table 2).

Table 2: Perceived Stress Scale

PPS	Frequency	Percentage
Low stress	18	4.69
Moderate stress	340	88.54
High stress	26	6.77
Mean(SD) – 20.13 (3.74)		

The data on perceived stress levels among cancer patients reveals a distribution where the majority experience moderate stress. Specifically, out of the total sample, 340 patients, representing 88.54%, report moderate stress levels. This predominant moderate stress category highlights a significant emotional burden that many cancer patients endure, possibly linked to the uncertainties and challenges associated with their illness and treatment.

In contrast, a smaller segment of the population, consisting of 26 patients or 6.77%, experiences high stress. Although this is a minority, the presence of high stress in this group is critical as it indicates the need for targeted interventions to address severe psychological distress.

Additionally, the data shows that only 18 patients, making up 4.69% of the sample, report low stress levels. This relatively small proportion suggests that very few cancer patients in the study cope well enough to maintain low stress levels.

The overall distribution underscores the necessity for comprehensive psychosocial support systems within healthcare settings to mitigate stress and enhance coping mechanisms among cancer patients.

Addressing these stress levels is vital for improving patients' overall well-being and potentially influencing their treatment outcomes.

Table 3: Association between PSS and socio-demographic variables (PSS score was not normally distributed in shapiro wilk test)

Socio-demographic variables	PSS			x^2	P value
	low	moderate	high		
Age					
<51	8	152	13	0.2763	0.871
More than equal to 51	10	188	13		
Sex					
Female	10	215	19	1.52	0.465
Male	8	125	7		
Educational status					
Illiterate	9	110	9	4.52	0.81
Informal	1	58	3		
Primary level	4	87	8		
Higher secondary	4	77	5		
Above higher secondary	0	8	1		
Marital status					
Unmarried 1	2	22	3	22.31	0.001*
Married 2	15	261	13		
Divorced 3	0	14	6		
Widow/widower 4	1	43	4		
Occupation					
Business	3	54	8	15.58	0.084
Farming	6	161	9		
Housewife	0	1	7		
Service/job	6	7	109		
Student	3	9	1		
Monthly income					
Enough for 6 months	15	274	20	0.59	0.96
Enough for 12 months	2	4	38		
Surplus for 12 months	1	2	28		
Place of residence					
Province 5	5	99	15	10.28	0.03*
Province 6	8	154	9		
Province 7	5	87	2		
Types of family					
Nuclear family	6	117	7	0.60	0.73
Joint family	12	223	19		

The analysis of the association between Perceived Stress Scale (PSS) scores and various socio-demographic variables provides valuable insights into how different factors correlate with stress levels

among cancer patients. Given that the PSS scores were not normally distributed according to the Shapiro-Wilk test, chi-square (χ2) tests were used to evaluate these associations (Table 3).

Age: The age groups (<51 and ≥51) show no significant association with PSS scores, as indicated by a χ2 value of 0.2763 and a p-value of 0.871. Both age categories exhibit similar distributions of low, moderate, and high stress levels, suggesting that age alone does not significantly influence stress levels among the patients in this study.

Sex: Similarly, the sex of the patients (female and male) does not show a significant association with PSS scores, with a χ2 value of 1.52 and a p-value of 0.465. Both females and males exhibit comparable stress distributions, indicating that gender does not significantly impact the perceived stress levels in this sample.

Educational Status: Educational status also does not show a significant association with PSS scores (χ2 = 4.52, p = 0.81). Patients across different educational levels (illiterate, informal, primary level, higher secondary, and above higher secondary) display similar stress distributions. This suggests that educational attainment does not markedly influence stress levels among the cancer patients in this study.

Marital Status: Marital status, however, shows a significant association with PSS scores (χ2 = 22.31, p = 0.001). The unmarried and widowed/widower groups have higher proportions of high stress compared to the married group, indicating that marital status significantly impacts stress levels. Married patients tend to have lower stress, possibly due to the support system provided by a spouse.

Occupation: The occupation variable approaches significance (χ2 = 15.58, p = 0.084). Different occupations (business, farming, housewife, service/job, and student) show varying stress levels, with housewives and students having higher proportions of high stress, while those in service/jobs predominantly report moderate stress. This variation suggests that occupation might influence stress levels, although the association is not statistically significant in this study.

Monthly Income: Monthly income does not show a significant association with PSS scores (χ2 = 0.59, p = 0.96). Patients' stress levels are similarly distributed regardless of whether their income is enough for 6 months, enough for 12 months, or surplus for 12 months. This finding indicates that income level does not significantly impact perceived stress among these patients.

Place of Residence: The place of residence shows a significant association with PSS scores (χ2 = 10.28, p = 0.03). Patients from Province 5 exhibit higher stress levels compared to those from Provinces 6 and 7. This suggests that geographic location may influence stress levels, possibly due to differences in healthcare access, social support, or environmental factors.

Type of Family: Finally, the type of family (nuclear vs. joint) does not show a significant association with PSS scores (χ2 = 0.60, p = 0.73). Both nuclear and joint family types exhibit similar stress distributions, indicating that family structure does not significantly impact perceived stress levels among the patients in this study.

Table 4: Brief Cope Score

	Mean	SD
Avoidance coping	**23.66**	**3.29**
Self-distraction	4.69	1.11
Denial	4.96	1.29
Substance use	4.51	1.25
Behavioural disengagement	4.53	1.26
Self-blame	4.96	1.14
Approach coping	**44.59**	**4.59**
Active coping	5.09	1.15
Use of emotional support	5.01	1.24
Religion	4.90	1.23
Positive reframing	5.04	1.10
Acceptance	4.96	1.30
Planning	4.64	1.26
Humour	5.13	1.33
Venting	4.93	1.21
Use of instrumental support	4.86	1.14

In short, marital status and place of residence are the only socio-demographic variables significantly associated with perceived stress levels among cancer patients. These findings underscore the importance of considering marital support and geographic factors when addressing stress in this population. Other

Table 5: Association table (applying t-test)				
Coping Strategy	**Variable**	**Mean (SD)**	**t-test**	**p-value**
Avoidance Coping	Place of Residence	5.93 (0.74)		< 0.001
Mean (SD) = 23.66 (3.29)	Marital Status	2.23 (0.75)		< 0.001
Approach Coping	Place of Residence	5.93 (0.74)		< 0.001
Mean (SD) = 44.59 (4.59)	Marital Status	2.23 (0.75)		< 0.005

variables such as age, sex, educational status, occupation, monthly income, and type of family do not show significant associations with stress levels, suggesting that these factors may not independently influence the perceived stress among the patients studied.

The analysis of the Brief COPE inventory scores reveals that cancer patients predominantly use approach coping strategies over avoidance coping strategies (Table 4). The overall mean score for approach coping is 44.59 (SD = 4.59), significantly higher than the mean score for avoidance coping, which is 23.66 (SD = 3.29). Within approach coping, strategies such as active coping (mean = 5.09, SD = 1.15), use of emotional support (mean = 5.01, SD = 1.24), positive reframing (mean = 5.04, SD = 1.10), and humour (mean = 5.13, SD = 1.33) are frequently employed by patients. Conversely, within avoidance coping, denial (mean = 4.96, SD = 1.29) and self-blame (mean = 4.96, SD = 1.14) are the more commonly used strategies. This pattern indicates that while patients do engage in avoidance coping to some extent, they more often rely on proactive and positive strategies to manage their stress and illness.

Association table (applying t-test)

Table 5 shows the association between coping strategies (avoidance and approach coping) and socio-demographic variables (place of residence and marital status) with corresponding t-test results:
This table summarises the association between avoidance and approach coping strategies and the socio-demographic variables of place of residence and marital status. The significant p-values (<0.001 and <0.005) indicate strong associations in these comparisons. Association between brief cope score and socio-demographic variables (none of the variable were significantly associated with each other).

The research reveals significant findings regarding stress levels and coping mechanisms among cancer patients, but a critical comparison with existing literature exposes certain gaps and implications. For instance, the predominance of moderate stress levels among cancer patients in this study aligns with Kabra *et al.* (2022), who found similar stress levels using the PSS-10 scale. However, unlike Kabra *et al.*'s study, which emphasised the influence of treatment modality on stress, the current study does not reveal significant associations between stress levels and socio-demographic factors such as age, sex, and education. This divergence suggests that stress among cancer patients in Banke, Nepal may be more influenced by other contextual factors, such as cultural or environmental stressors, that were not examined in Kabra's work. Moreover, while Sharma et al. (2021) found that patients employing problem-focused coping strategies showed improved emotional well-being, the present study's emphasis on approach coping mechanisms (e.g., active coping, emotional support) reinforces this, but it also reveals a significant use of avoidance coping strategies (e.g., denial and self-blame). This suggests that while patients may generally attempt to adopt positive coping mechanisms, a notable subset still struggles with maladaptive responses, a finding that may reflect broader social or psychological challenges unique to the region.

The study's implications also diverge from existing literature in terms of the association between socio-demographic factors and coping strategies. While previous studies like those of Wazqar (2018) highlighted the role of education and financial status in shaping patients' coping strategies, this research shows no significant relationship between these variables and stress or coping mechanisms, except for marital status and place of residence. These findings suggest that the support systems provided by marriage and geographical healthcare disparities may play a more central role in how patients cope with their illness in this context. Additionally, the significant associations between coping strategies and place of residence in this study point to regional differences in stress management, a variable often underexplored in cancer research but critical in areas with varying healthcare access and social support.

These findings underscore the importance of culturally and geographically tailored interventions for stress management in cancer care, particularly in rural and underserved regions. They suggest that existing psychosocial support systems may not adequately address the needs of cancer patients in Nepal, highlighting a gap in both local healthcare practices and global cancer care research.

The demographic data presents a comprehensive overview of the study's participants, highlighting various socio-demographic variables among cancer patients. The age distribution indicates that a slightly higher proportion of patients are aged 51 years and above (54.95%), compared to those below 51 years (45.05%). This suggests a relatively older sample population, which is not uncommon in cancer studies given the higher incidence of cancer in older age groups.

4. CONCLUSION

The findings from this study underscore the pervasive stress experienced by cancer patients at Sushil Koirala Prakhar Cancer Hospital, Khajura, Banke, Nepal. The majority of patients reported moderate to high levels

of stress, significantly influenced by marital status and place of residence. Interestingly, socio-demographic factors such as age, sex, educational status, occupation, monthly income, and family structure did not show significant associations with stress levels, highlighting the universal nature of psychological distress in this context.

Moreover, the coping strategies employed by patients predominantly leaned towards approach coping mechanisms, with significant reliance on active coping, emotional support, positive reframing, and humour. Avoidance coping strategies, although present, were less frequently utilised. The strong association between coping strategies and socio-demographic variables further elucidates the complex interplay between individual circumstances and psychological responses to cancer.

These insights emphasise the critical need for comprehensive, patient-centred care that integrates psychosocial support tailored to individual demographic backgrounds. Healthcare professionals should prioritise the development and implementation of holistic intervention programmes that address both emotional and practical challenges faced by cancer patients. By fostering effective coping mechanisms and reducing stress, such initiatives can significantly enhance the overall quality of life and potentially improve clinical outcomes for cancer patients.

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THE IMPACT OF EMPLOYEE APPRECIATION APPROACHES ON JOB SATISFACTION: EMPIRICAL EVIDENCE FROM AIR TRAFFIC CONTROLLERS OF SRI LANKA TO ENHANCE HUMAN PERFORMANCE
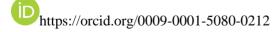
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ABSTRACT

Understanding the dynamics of job satisfaction among Air Traffic Controllers (ATCs) is imperative for ensuring the human performance, productivity, efficiency and safety of aviation operations. This study investigates the impact of various employee appreciation methods on the job satisfaction levels to enhance the performance of ATCs in Sri Lanka. Drawing upon existing literature and analysis of the data collected from the current employees, the research is aimed at filling a critical knowledge gap regarding the relationship between employee appreciation and job satisfaction within the ATC sector. The research problem centres on the need to comprehend how different forms of appreciation, ranging from verbal acknowledgements to tangible rewards, influence ATCs' job satisfaction. Through a structured survey utilizing a Likert scale, the study measured the effects of seven appreciation methods on job satisfaction, namely verbal expressions in one-on-one and public settings, electronic notes, written communications, tangible items, monetary bonuses, and the absence of gratitude. Key research questions addressed the specific impacts of each appreciation method on the job satisfaction of ATCs'. By analysing responses from ATCs in Sri Lanka, the study aimed to provide insights for supervisors and managers to tailor appreciation strategies effectively. The findings hold significance in enhancing the work environment, retaining talent, and promoting organisational productivity within the aviation industry. Acknowledging potential limitations such as participant biases and organisational policies, the research adopts measures to ensure data integrity and confidentiality. By leveraging a comprehensive approach to data collection and analysis, it enhanced the reliability and credibility of the findings of the study.

KEYWORDS: *Air Traffic Controllers, Employee Appreciation, Human Performance, Job Satisfaction*

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1. INTRODUCTION

Employee performance and job satisfaction are critical in today's competitive environment in order for firms to achieve their goals. Previously, material items were regarded as more valuable than any other in the eyes of an organization. However, presently, organizations have realized that human resources are more valuable than other assets. They now focus on human resources to improve performance due to high global competition and the dynamic business environment. Organizations can attain social sustainability with a positive working relationship with employees. A competent and motivated worker is a resource that is extremely scarce and not readily available in the market. Because of this, modern businesses seek to use sustainable human resources to gain competitive advantages. Examining job satisfaction is a method of measuring how well an organisation creates a positive work environment for its employees (Che Nawi et al., 2016). Companies that aim to foster job satisfaction can boost productivity by keeping their workforce engaged (Che Nawi et al., 2016). The behaviour of managers within the organisation plays a role in establishing an atmosphere, which in turn leads to higher levels of job satisfaction among employees (Fabio et al., 2017). Locke (1969) provides the definition of job satisfaction describing it as an emotional state influenced by an individual's values regarding their work and resulting in feelings of delight or dissatisfaction. Assessing job satisfaction often focuses on the factors that determine an individual's inclination or aversion toward their job. These factors are dependent on socio elements like age, work experience, job characteristics, supervision, support, communication, fairness, career growth opportunities, and the overall work atmosphere (Chen et al., 2019; Spector, 1997). Competent employees are assets to an organisation as they have the motivation to complete their tasks and align with the organisation's objectives. This alignment directly affects intentions to leave the job, absenteeism rates, work culture, and overall work productivity (Miller et al., 2009).

Air Traffic Controllers (ATCs), who include aerodrome controllers, area controllers and approach controllers working in control towers, have roles within a work environment that involve limited human interaction. The dynamics of this environment depend on the type and volume of air traffic at the airport. Due to a shortage of well-trained ATCs (E & Zhang 2017), a high rate of turnover can result in negative consequences such as reduced air traffic flow, increased passenger delays, and added workload on the remaining ATCs. Job dissatisfaction is a predictor of employees leaving their organisations (Jou et al., 2013). Therefore, it becomes crucial to understand the range of factors that contribute to this situation in order to enhance safety in the aviation industry.

ATCs play a major role in securing aviation safety in Sri Lanka, and currently Airport and Aviation Services Sri Lanka (Private) Limited ('AASL') and Sri Lanka Air Force ('SLAF') are the sole organisations in Sri Lanka which recruit and train civil and military ATCs. There are approximately 800 civil and military ATCs currently working in the industry, but a significant reduction in the workforce can be noted in the industry due to premature resignations by the controllers. This is mainly due to the inadequacy of current monetary and non-monetary benefits received by the ATCs coupled with the rising cost of living caused by the severe economic crisis faced by Sri Lanka in the year 2022. This caused many ATCs to prefer to seek foreign employment for better benefits and better living standards. This has created a shortage in the industry causing a possible standstill of air traffic control services offered by Sri Lanka. Thus, it is important to retain the existing ATCs and also attract new talent into the sector by ensuring the job satisfaction of the staff involved in the ATC industry.

To ensure that employees in an organisation are satisfied with their jobs, it is essential for employers to understand the relationship between forms of showing appreciation to employees and how it affects their job satisfaction, allowing employers to tailor their strategies accordingly. By analyzing existing literature, Naim and Lenka (2018) discovered that the way appreciation is shown impacts how employees perceive their job satisfaction. Other factors such as work location, employee generation and leadership style also play a role. Furthermore, research conducted

by Fabio et al. (2017) further supports the notion that employer gratitude towards employees in forms has implications for job satisfaction and employee morale. The researchers emphasize that gratitude fosters relationships between employees and employers, creating an environment that benefits both parties within the organisational and societal context. This study conducted an analysis to measure the importance of methods used by employers to motivate support staff and how these methods directly impact their job satisfaction. Gevrek et al. (2017) also conducted a study examining the effects of employee appreciation and gratitude on employee morale and job satisfaction where it was found that monetary factors contribute to job satisfaction while other variables such as job rank and title also play a role. In light of the above findings, it is viable for the ATC sector to explore on the impact of various employee appreciation methods on the job satisfaction levels and also implement such methods systematically to retain and attract more ATCs to the industry to fill the shortage of staff facing currently.

2. LITERATURE REVIEW

Employee job satisfaction plays a major role, in determining the success or failure of an organisation and also provides the foundation for an organization's accomplishments. (Stankovska et al., 2017, Mahajan & Kumar 2018). Creating a conducive work environment is essential for attracting talent and retaining highly productive employees, which should be a priority for employers (Jalilianhasanpour et al., 2021). Employees who receive motivation from their employers and satisfaction demonstrate a deep commitment to driving the organisation's success (Varma, 2017). The growth and expansion of an organisation are closely tied to recognising the significance of employee job satisfaction (Sittisom, 2020). When employees feel valued in their workplace, their motivation and their enthusiasm for work increase (Hamrick & White 2020).

Building a relationship and ensuring job satisfaction can be achieved through supportive approaches such as providing constructive feedback and guidance, recognising and appreciating contributions, and maintaining effective communication where

expressing gratitude, and acknowledging employees' efforts not only boosts performance but also prevents demoralisation and thoughts of leaving (Mahadi et al., 2020).

Employee perspectives towards work are inevitably shaped by job stress which impacts experiences such as engagement. Consequently, it influences both job satisfaction and intentions to leave the job (Allisey et al., 2014; Bowling et al., 2015; Kazemi et al., 2015; Yoon et al., 2021). Job satisfaction plays a role in influencing employee performance while aiding in achieving organisational goals. It also enhances group effectiveness by reducing employees' inclination, towards aversive behaviours (Chen, 2018).

The intention of employees to leave their organisation, known as turnover intention, is closely connected to how satisfied employees are, with their jobs. When job satisfaction decreases it often leads to an increase in turnover intention, which acts as a mediator for employee turnover (Chung et al., 2017; Mobley, 1977; Steel & Ovalle 1984).

While many studies delve into general workforce job satisfaction, limited attention has been given to the job satisfaction of Air Traffic Controllers. This quantitative study aims to examine how seven specific methods of employee appreciation affect the job satisfaction of ATCs in Sri Lanka given the unique nature of the job carried out by the ATCs.

Methods of employee appreciation

Within the domain, there are many ways to show appreciation, to both groups and individuals. Employers are faced with the task of understanding and appreciating the sources of motivation for individual employees in order to foster positive job satisfaction (Noor & Zainordin 2018). De Gieter and Hofmans (2015) suggest that while financial incentives play a major role in motivating employees, there is a growing trend towards embracing financial rewards as a form of appreciation.

Achmad et al. (2020) explore the realm of employee motivation, highlighting that it arises from factors including employers' gestures, such as showing appreciation, which plays a role in shaping job

satisfaction. A complex relationship emerges, connecting how employers value their employees with increased engagement, higher retention rates, and enhanced job satisfaction compared to those who feel undervalued (White, 2016).

In their research, Hamrick and White (2020) provide an analysis of the ten methods of employee appreciation that have the most positive impact. These methods align with what they call the five languages of appreciation, which include affirmations, acts of service, tangible tokens, and physical touch (Hamrick & White 2020). By conducting a survey, they found that affirmation stands out as a preferred method of appreciating employees.

Similarly, Stankovska et al. (2017) conducted two types of surveys to explore appreciation methods. The Job Satisfaction Survey (JSS), originally developed by Paul Specter in 1985 included 36 questions covering nine aspects of job satisfaction. The Job Motivation Questionnaire (JMQ) helped them gain insight into the factors that influence job satisfaction, among educators (Stankovska et al., 2017).

The study conducted by Norman (2005) sought participants' perspectives on methods of appreciation used in the medical field, which revealed that methods such as acknowledgement, recognition, and thoughtful gestures lead to positive outcomes.

In the field of education, it is important to show appreciation financially. These financial methods involve providing opportunities for career growth, supporting education and training during work hours, recognizing job performance and promoting and encouraging communication (Haider et al., 2015). According to Jensen et al. (2005), as cited in Haider et al. (2015) organisations that incorporate rewards tend to have engaged employees and establish themselves as top employers who value their workforce (Haider et al., 2015).

Scholars have extensively studied job satisfaction over the years using Locke's influential definition which he presented in 1969 as a reference point. Within this framework, job satisfaction is seen as a combination of emotions where individuals experience either delight or discontent based on their values related to

their jobs. This complex landscape is measured through factors that individuals use to assess their liking or disliking towards their roles. Throughout the evaluation process various socio-demographic factors such as age, work experience, job characteristics, supervision dynamics, support systems, communication effectiveness, fairness considerations, career trajectory and the overall work environment all play a role (Chen et al., 2019; Spector, 1997).

The employee motivation aligns with the goals of the organisation and impacts factors like turnover intention, absenteeism rates, work culture and overall productivity (Miller et al., 2009). This interaction not only fosters a positive relationship that leads to employee satisfaction but also shapes long-term outcomes. The responsibility lies with the organisation to create a healthy work environment which is essential for job satisfaction.

In the landscape of attitudes and work conditions, job stress emerges as a factor that impacts employee engagement and emotional experiences. It casts its influence on job satisfaction and turnover intention (Allisey et al., 2014; Bowling et al., 2015; Kazemi et al., 2015; Yoon et al., 2021).

Air Traffic Controllers

There are three types of ATCs namely Aerodrome, Area, and Approach controllers. Each with their role coordinates their tasks within an environment where human interaction is minimal. The coordination required for this role is like a ballet performance that adapts to the type and amount of air traffic flowing through the airport (E & Zhang, 2017). The increased turnover of ATCs leads to the lack of experienced and skilled ATCs in the aviation industry and this leads to negative consequences such as disrupted air traffic flow, passenger delays, and heavier workloads for existing controllers. At the heart of this equation lies job dissatisfaction as a factor that predicts one's inclination to sever ties with the organisation (Jou et al., 2013). As the importance of employee job satisfaction intertwines with safety in the aviation sector, there is a need to explore and comprehend factors affecting job satisfaction. It is not just

necessary but crucial to strengthen the industry's resilience and ensure its continued growth.

Despite the research on employee job satisfaction, there is a lack of in-depth literature reviews specifically focusing on the job satisfaction of ATCs. This absence highlights the need for an exploration that can bridge the understanding of this profession. The lack of inquiry presents a chance to delve into the complexities of ATCs's job satisfaction and how it is impacted by appreciation approaches of the management in order to provide valuable insights for a wide range of stakeholders.

Job satisfaction

Job satisfaction is influenced by employees' internal perceptions and the external motivators they encounter (Parlalis, 2011). Employee satisfaction is a combination of opinions, emotions, and experiences related to their job and the employer (Vorina et al., 2017). In essence, job satisfaction can be measured based on an employee's sense of achievement and recognition received from their employers (Parlalis, 2011). As aptly stated by More & Padmanabhan (2017), "A positive attitude towards the job leads to levels of job satisfaction while negative attitudes indicate dissatisfaction." Satisfied employees exude inspiration, innovation, and optimism in contrast to their counterparts (Rast & Tourani, 2012; Windon, 2019). Job satisfaction is a response that individuals have towards their job conditions, and it encompasses ideas and perspectives formed within their work environment (Stankovska et al., 2017).

By expressing appreciation towards their workforce employers create a work environment where employees feel valued. This sense of value enhances productivity and loyalty among employees (Jalilianhasanpour et al., 2021). On the other hand, employers who underestimate the importance of employee job satisfaction risk productivity and decreased morale among their workforce (Sittisom, 2020). The absence of satisfaction is evident through disinterest and detachment from the goals of the organisation. Thus, it is worth noting that employer actions or lack thereof have an impact on job satisfaction (Noor & Zainordin, 2018).

Noor and Zainordin (2018) defined job satisfaction as a combination of an individual's feelings towards both their job and the organisation. Luthans and Sommer (2005) advised employers to be highly aware of factors that can either foster or undermine employee job satisfaction.

The importance of job satisfaction goes beyond being a feeling where it guides companies to improve productivity (Stankovska et al., 2017). Job satisfaction is also viewed as an employee's connection, with their job, which is closely linked to their experience within the organisation (Olen, 2017). Hoppock (1935) provided one of the definitions describing job satisfaction as a combination of psychological, and environmental factors that contribute to an individual's liking for their job. Olen further explored this concept acknowledging its ambiguity, and he found that positive and negative aspects of job satisfaction have reaching effects throughout an organisation influencing productivity and the overall work environment (Olen, 2017). Che Nawi et al. (2016) aligned their definition with experts in the field by considering job satisfaction as a measure of success—a characteristic that enhances not only the reputation but also motivation and productivity, across all employees. Thus, it is evident that the concept of job satisfaction is challenging to define due to the factors that contribute to its meaning, and it is a realm that is difficult to capture accurately (Che Nawi et al. 2016).

Employee appreciation and job satisfaction

Existing literature emphasizes the importance of investigating how methods of appreciation relate to levels of job satisfaction. Recognizing employees offers advantages such, as boosting job satisfaction increasing workplace engagement enhancing work quality and fostering a sense of value within the organisation (Jalilianhasanpour et al., 2021). Motivation can be nurtured through methods like incentives, acknowledgment or tangible rewards which contribute to a perception of one's job and drive productivity (Ana & Ardita, 2021). Researchers can utilise these insights to develop resources that

employers can implement to enhance employee job satisfaction and cultivate work environments.

Pathak's study in 2014 holds a special place in this discussion as it highlights the importance of gratitude in workplaces and distinguishes it from financial compensation, where he challenges the idea that challenging goals are the driving force behind employee productivity emphasizing that appreciation can be a powerful motivator for excellence (Pathak, 2014). Further, leadership practices such as enhancing employees' skills involving them in decision-making, and fostering a work environment serve as a blueprint for increasing job satisfaction (Pathak, 2014). Thus, direct communication emerges as a way of showing appreciation and nurturing job satisfaction.

Theoretical foundation

The theoretical framework of this research encompasses four pillars.
- o Abraham Maslow's theory on motivation (1943)
- o Victor Vroom's expectancy theory (1964)
- o Frederick Herzberg's motivation-hygiene theory (1959)
- o Arne L. Kalleberg's' theory of job satisfaction (1977)

Abraham Maslow's theory on motivation (1943)

Abraham Maslow's theory on motivation played a role in the framework of this study. According to Maslow's work in 1943, individuals have five levels of needs, which include security, social needs, self-esteem, and self-actualisation, the desire to achieve one's highest potential (Maslow, 1943). One key aspect of Maslow's theory suggests that people prioritise addressing their significant unmet needs first (Alajmi & Alasousi, 2019). In this research, author relied on Maslow's theory as a foundation to understand different types of unmet needs in the work environment and explore how employer-applied methods of appreciation impact job satisfaction among ATCs.

Victor Vroom's expectancy theory (1964)

Victor Vroom's expectancy theory (Vroom, 1964) examines how employees perceive the actions required to attain organisational rewards as a driving force behind their motivation.

Vrooms' theory consists of three components; Expectancy, which refers to the belief that actions will lead to desired outcomes; Instrumentality, which focuses on the connection between job performance and expected results; and Valence, which pertains to the value individuals assign to expected outcomes (Vroom, 1964). In the context of this study, Vroom's theory helps to understand how ATCs experience job satisfaction based on their perception of the appreciation methods provided by their employers.

Frederick Herzberg's motivation-hygiene theory (1959)

Frederick Herzberg's motivation-hygiene theory (1959) differentiates between factors that can demotivate individuals, such as pay and job security (external factors) and factors that can motivate them such as recognition and responsibility (related to the nature of work itself).

Arne l. Kalleberg's theory of job satisfaction (1977)

Another component of the framework is Kalleberg's theory of job satisfaction (1977) which emphasised that six aspects of work influence an employee's level of satisfaction, i.e. intrinsic facet, convenience facet, financial facet, extrinsic facet related to relationships with co-workers, extrinsic facet related to long-term career prospects within one institution and resource adequacy. Each of these elements plays a role in determining job satisfaction in the relationship between employees and employers.

3. METHODOLOGY

Research Philosophy and Approach

This study is guided by a positivist research philosophy, which emphasizes objectivity, reproducibility, and the use of measurable variables. Positivism is well-suited for data analysis as it allows for the exploration of relationships and patterns, facilitating credible and reliable findings that can be validated. The study employs a deductive research approach, enabling the testing of well-defined hypotheses within a controlled framework. This approach acknowledges the importance of established concepts and previous research findings, promoting precision in data collection and analysis.

Research Strategy

A quantitative research strategy was adopted to systematically measure and analyze variables, allowing for the examination of causal relationships between employee appreciation and job satisfaction. This strategy enhances the accuracy of findings and enables hypothesis testing through statistical analysis.

Sampling Strategy

The study utilized a purposive sampling method to select Air Traffic Controllers (ATCs) based on criteria such as experience level and work environment, ensuring the homogeneity and comparability of the sample. Participants were drawn from both Airport and Aviation Services Sri Lanka (Private) Limited (AASL) and the Sri Lanka Air Force (SLAF), reflecting the characteristics of the population. Simple random sampling was then used to administer the questionnaire, avoiding biases associated with non-probability sampling methods. The distribution of the sample was based on the proportion of ATCs within each organization, ensuring representation across different positions.

To determine the appropriate sample size, Yamane's formula was applied, setting a significance level of 0.05, a precision level of ±5%, and a confidence level of 95%, as recommended by Uakarn et al. (2021). This calculation indicated a minimum requirement of 242 participants. Accordingly, a sample size of 257 participants was deemed sufficient to ensure precise and reliable results while minimizing the likelihood of abnormal data distribution. The identification of variables and the conceptual framework of the study are as depicted below.

Data Collection

Data collection was conducted using an online questionnaire, developed through a rigorous multi-step process. Comprehensive research informed the creation of the questions, and a draft version was reviewed by five experts using the Item Objective Congruence (IOC) index, which requires a minimum score of 0.50 for acceptance (Kraiwanit et al., 2023; Thetlek et al., 2023). The questionnaire achieved IOC values between 0.80 and 1.00, ensuring relevance and clarity in terms of content, language, and structure.

The finalized questionnaire was disseminated via various online platforms. Respondents provided explicit consent to use their responses for research purposes, with an option to opt-out if they did not wish to participate.

Table 1. Identification of the variables

Dependent Variable	DV	Job Satisfaction
Independent Variables	IV1	**Verbal (one, on one)** Having a conversation between a supervisor and employee to privately acknowledge their efforts and build a connection in the workplace
	IV2	**Verbal (in public)** Publicly recognizing an employee's accomplishments boosts visibility and morale by acknowledging their contributions in front of the team.
	IV3	**Electronic note (media, email, LinkedIn)** Using platforms like social media, email, or LinkedIn to express recognition and celebrate achievements in the virtual space.
	IV4	**Written/ Typed (letters, cards)** Showing appreciation through letters or typed cards adds a touch and conveys lasting sentiments that acknowledge an employee's dedication.
	IV5	**Tangible items (gift card token of appreciation)** Offering rewards such as gift cards or tokens as symbols of recognition that employees can enjoy for their hard work.
	IV6	**Monetary bonus** Providing compensation as a reward for exceptional job performance, demonstrating the organization's commitment to valuing outstanding contributions.
	IV7	**No expression of gratitude** When there is no acknowledgment or appreciation given.
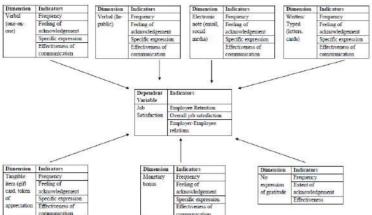
Figure 1. Conceptual Framework

Data analysis

IBM SPSS was used to calculate the Cronbach's Alpha for internal consistency. For all the instruments, Cronbach's Alpha was above 0.7 with a significance of P<0.005. So the internal consistency was good for all the variables. Hence, the research tools were identified as reliable and they would provide credible results. Thereafter, the data were tested for normality and it was identified that all the variables were normally distributed. Subsequently, the data collected were then analyzed in detail by the use of descriptive statistics and the Analysis of Variance (ANOVA). Since the study employed an ex-post research design, the first step in analyzing the data was descriptive statistics, which entailed the use of percentages and means so as to get a general feel of the appearance of the commencement as well as to get an awareness of the inherent tendencies of the identified variables in the study. This approach uses Analysis of Variance (ANOVA) to study the relationships between the multiple dependent variables and ensure the correlations and dependencies between the variables. This approach was more helpful in the analysis, as it provided insights into the patterns of data that helped to expound on the results of the study by providing a detailed assessment of the dataset.

4. RESULTS

The main objective of this study was to investigate how various employee appreciation methods impact job satisfaction of ATCs. Understanding how this segment of operational staff perceives these methods and whether they directly influence their job satisfaction can provide insights for supervisors, managers and leaders. The findings of this study offer information that institutional leaders and managers can utilise to foster a work environment for all employees, which Buil et al. (2018) emphasised for those in operational roles who play a major part in organisational workflow (Chambliss, 2017).

A total of 257 (Male- 211, Female-46) responses were collected from participants. All those 257 respondents met the criteria for inclusion and were considered usable as they were comprehensively completed by respondents. The majority of participants were individuals within the age range of 30 to 39 years, from Sri Lanka. They had either been employed by AASL (205) or by SLAF (52) as ATCs.

In order to analyse each appreciation method, one sample t test was conducted on all seven methods. Hypothesis of the study and the results of the one sample t test is depicted in the table below. All the hypotheses were accepted with the relationships as depicted on the Table 2.

Based on the methods of appreciation, there was a statistical impact, on job satisfaction (p<.001) which led to the rejection of the null hypothesis suggesting a significant effect on job satisfaction. However, due to multicollinearity detected in the four variables namely Verbal (in public), Written/ Typed (letters, cards), Tangible items (gift card, token of appreciation) and Monetary bonus, hypotheses pertaining to aforementioned variables were not considered for this study. The results of the multiple regression are shown in Tables 5, 6 and 7.

Table 3. Inter correlation matrix for multicollinearity statistics

An inter-correlation matrix for multicollinearity statistics displays the correlation coefficients between multiple variables, highlighting the degree of linear

Table 2. Hypothesis of the research and one sample T test results

		Hypothesis	Pearson's Correlation	Significance	Conclusion	Relationship
H1	H01	The method of appreciating employees in one one-on-one (verbal), setting holds a significant influence on job satisfaction among Air Traffic Controllers.	0.581	<0.001	Accepted	Moderately Positive
	H_a1	The approach of appreciating employees in one-on-one (verbal), interactions does not have a statistically significant effect on job satisfaction within the Air Traffic Controllers.			Rejected	
H2	H02	The act of verbalizing (public) employee appreciation exerts a significant effect on job satisfaction among Air Traffic Controllers.	0.377	<0.001	Accepted	Weakly Positive
	H_a2	Verbalizing (Public) employee appreciation does not result in a statistically significant impact on job satisfaction among Air Traffic Controllers.			Rejected	
H3	H03	The method of employee appreciation involving notes holds a significant influence on job satisfaction, among Air Traffic Controllers	0.606	<0.001	Accepted	Strongly Positive
	H_a3	Utilizing electronic notes (media, email, LinkedIn) as a means of employee appreciation does not demonstrate a significant influence on job satisfaction among Air Traffic Controllers.			Rejected	
H4	H04	Using written or typed items like letters and cards to show employee appreciation has an influence on job satisfaction among Air Traffic Controllers.	0.514	<0.001	Accepted	Moderately Positive
	H_a4	Using written or typed items like letters and cards to show employee appreciation does not have an impact on job satisfaction among Air Traffic Controllers.			Rejected	
H5	H05	Using items such as gift cards and tokens of appreciation has a significant impact on job satisfaction, among Air Traffic Controllers.	0.142	0.023	Accepted	Very Weakly Positive
	H_a5	Using items such as gift cards and tokens of appreciation does not have a significant effect on job satisfaction among Air Traffic Controllers.			Rejected	
H6	H06	Offering bonuses to appreciate employees has a significant influence on the job satisfaction of Air Traffic Controllers	0.367	<0.001	Accepted	Weakly Positive
	H_a6	The method of appreciating employees through bonuses does not show any significant effect on the job satisfaction of Air Traffic Controllers			Rejected	
H7	H07	The absence of expressing gratitude holds an influence on the job satisfaction of Air Traffic Controllers.	-0.739	<0.001	Accepted	Strongly Negative
	H_a7	Not expressing gratitude does not have an impact on the job satisfaction of Air Traffic Controllers			Rejected	

relationship among them. It aids in identifying multicollinearity issues in regression models, where high correlations suggest potential redundancies. This matrix is essential for ensuring model accuracy and interpretability in statistical analyses. Table 3 provides the intercorrelation matrix for this study.

Table 3. Inter correlation matrix for Multicollinearity Statistics

		Verbal One-on-one Appreciation	Verbal In-person Appreciation	Electronic Note appreciation	Typed Letters and cards	Gift Cards and Token of Appreciation	Bonuses as Rewards	No Expression of Gratitude
Correlations								
Verbal One-on-one Appreciation	Pearson Correlation	1	.632**	.511**	.808**	.266**	.003	-.331**
	Sig. (2-tailed)		<.001	<.001	<.001	<.001	.960	<.001
	N	257	257	257	257	257	257	257
Verbal In-public Appreciation	Pearson Correlation	.632**	1	.468**	.803**	.360**	.036	-.216**
	Sig. (2-tailed)	<.001		<.001	<.001	<.001	.564	<.001
	N	257	257	257	257	257	257	257
Electronic Note appreciation	Pearson Correlation	.511**	.468**	1	.574**	.199**	.330**	-.449**
	Sig. (2-tailed)	<.001	<.001		<.001	.001	<.001	<.001
	N	257	257	257	257	257	257	257
Typed Letters and cards	Pearson Correlation	.808**	.803**	.574**	1	.466**	.061	-.277**
	Sig. (2-tailed)	<.001	<.001	<.001		<.001	.328	<.001
	N	257	257	257	257	257	257	257
Gift Cards and Token of Appreciation	Pearson Correlation	.266**	.360**	.199**	.466**	1	-.335**	.102
	Sig. (2-tailed)	<.001	<.001	.001	<.001		<.001	.104
	N	257	257	257	257	257	257	257
Bonuses as Rewards	Pearson Correlation	.003	.036	.330**	.061	-.335**	1	-.558**
	Sig. (2-tailed)	.960	.564	<.001	.328	<.001		<.001
	N	257	257	257	257	257	257	257
No Expression of Gratitude	Pearson Correlation	-.331**	-.216**	-.449**	-.277**	.102	-.558**	1
	Sig. (2-tailed)	<.001	<.001	<.001	<.001	.104	<.001	
	N	257	257	257	257	257	257	257

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

multicollinearity statistics

Variance Inflation Factor (VIF) and tolerance values are essential metrics for diagnosing multicollinearity in regression analysis. VIF quantifies the extent of multicollinearity, with values above 5 indicating potential issues. Tolerance, the reciprocal of VIF, should exceed 0.2. Adhering to these standards ensures model stability and reliable results.

Table 4. Tolerance and VIF values for multicollinearity statistics

		Collinearity Statistics	
Coefficients[a]			
Model		Tolerance	VIF
1	Verbal One-on-one Appreciation	.290	3.448
	Verbal In-person Appreciation	.353	2.831
	Electronic Note appreciation	.547	1.828
	Typed Letters and cards	.158	6.320
	Gift Cards and Token of Appreciation	.594	1.684
	Bonuses as Rewards	.519	1.926
	No Expression of Gratitude	.559	1.789

a. Dependent Variable: Employee Satisfaction

Source: Author, Generated using IBM SPSS 26

Due to the multicollinearity identified through above tests, 4 independent variables were deemed unfit for the model. Verbal in public appreciation, Gift cards or tokens of appreciation, Bonuses and rewards and Written, typed letters or cards were deemed unfit.

Table 5. Multiple Regression Analysis- Model Summary of the sample

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change	Durbin-Watson
Model Summary[b]					Change Statistics					
1	.838[a]	.702	.698	.66602	.702	198.614	3	253	<.001	1.636

a. Predictors: (Constant), No Expression of Gratitude, Verbal One-on-one Appreciation , Electronic Note appreciation

b. Dependent Variable: Employee Satisfaction

Source: Author, Generated using IBM SPSS 26

As per the Table 5, multiple regression model summary provides essential metrics for evaluating model performance. An R-squared value above 0.7 is generally considered strong, while adjusted R-squared accounts for model complexity. The F-statistic p-value should be below 0.05 for overall significance. Coefficients' p-values should also be below 0.05 to denote individual predictor significance.

Table 6. Multiple Regression Analysis- ANOVA table

Model		Sum of Squares	df	Mean Square	F	Sig.
ANOVA[a]						
1	Regression	264.303	3	88.101	198.614	<.001[b]
	Residual	112.226	253	.444		
	Total	376.529	256			

a. Dependent Variable: Employee Satisaction

b. Predictors: (Constant), No Expression of Gratitude, Verbal One-on-one Appreciation , Electronic Note appreciation

Source: Author, Generated using IBM SPSS 26

A Multiple Regression Analysis ANOVA table evaluates model significance. The F-statistic compares model fit to a null model, with p-values below 0.05 indicating significance. Sum of Squares (Regression and Residual) assess explained and unexplained variance, respectively. Mean Squares, derived by dividing Sum of Squares by degrees of freedom, facilitate comparison and model assessment.

Table 7. Multiple Regression Analysis- Coefficients table					
Coefficients[a]					
	Unstandardized Coefficients		Standardized Coefficients		
Model	B	Std. Error	Beta	t	Sig.
1 (Constant)	2.439	.176		13.851	<.001
Verbal One-on-one Appreciation	.257	.035	.292	7.253	<.001
Electronic Note appreciation	.195	.039	.211	4.965	<.001
No Expression of Gratitude	-.365	.026	-.547	-14.120	<.001
a. Dependent Variable: Employee Satisfaction					
Source: Author, Generated using IBM SPSS 26					

Table 7. Multiple Regression Analysis- Coefficients table

Multiple Regression Analysis assesses the relationship between multiple independent variables and a dependent variable. The coefficients table presents the impact of each independent variable on the dependent variable, with generally accepted values indicating the strength and direction of influence. Accepted values vary depending on the field but typically range from -1 to 1, representing weak to strong relationships.

Study limitations

This study aimed to examine how seven employee appreciation methods affect the job satisfaction of ATCs. After completing the study, it is crucial to review the data collection process for improvements in future research endeavours. While this study yielded results with dependent variables such as one on one communication, electronic note (social media, email, LinkedIn), verbal (in public), written/ typed (letters, cards), tangible items (gift card, token of appreciation) and monetary bonus which were identified as effective methods, there are limitations that future researchers should address and minimise.

One limitation worth noting is that this study only considered seven employee appreciation methods.

Some companies may offer ways to show appreciation to their employees, which are not covered in the seven methods mentioned in this study. These unique methods, tailored to each organisation can have an even greater impact, on employees compared to the seven mentioned methods.

Further, this study specifically focuses on a region and may be influenced by cultural and organisational factors unique, to Sri Lanka. Therefore, it is needed to concern these findings before applying them to other contexts. Further research is necessary for generalisability.

5. DISCUSSION

Organisational leaders and managers often face the challenge of finding ways to appreciate their employees, which can positively affect outcomes such as job satisfaction (Aguenza & Som 2012). However, there is no information on how employee appreciation methods specifically influence the job satisfaction of operational staff (Bradler & Neckermann 2019; Haider et al., 2015). This quantitative study helped to fill this gap by examining the impact of employee appreciation methods on ATCs' job satisfaction and these methods can be adopted by employers to further the job satisfaction of their employees.

The statistical analysis of the regression analysis provides a comprehensive understanding of how various employee appreciation approaches influence job satisfaction; the model summary found an R-value of .838 indicating a strong correlation between observed and predicted values. An R Square of .702 shows that 70.2% of the variance in economic outcomes is explained by the model. Significant Predictors found: Verbal one-on-one appreciation and Electronic Note appreciation. Negative Predictor found: Absence of gratitude to the employee. Implications of these insights highlight the complex interplay of psychological, behavioural, and technological factors in shaping the job satisfaction of Air Traffic Controllers. Based on the statistical analysis, the following recommendations could be drawn.

Enhance personalized verbal appreciation

One significant finding from this study is the connection between verbal appreciation and job satisfaction among ATCs in Sri Lanka. This underscores the importance of fostering personal communication between supervisors and ATCs. In order to further improve on this aspect employers are able to carry out the following,

Training in Communication Skills; Develop and implement training programs that focus on equipping supervisors and team leads with the skills to deliver constructive feedback effectively.

Encourage Open Communication Channels; Foster an environment where ATCs feel comfortable approaching their superiors with any concerns or feedback they may have. This approach promotes a culture of trust and transparency.

Embrace electronic appreciation notes

The study indicates a positive relationship between electronic appreciation notes and job satisfaction. In today's age, electronic communication plays a major role in workplace dynamics. In order to harness its benefits, it is important to:

Implement Dedicated Electronic Platforms; Consider implementing platforms solely dedicated to expressing appreciation and acknowledgment varying from email recognitions to more advanced tools designed specifically for peer-to-peer recognition.

Provide training on the use of Electronic Communication; Provide ATCs with training, on how to use electronic communication to express gratitude.

This involves creating messages and using technology to facilitate genuine acknowledgments.

Dealing with a lack of gratitude

The negative correlation with the lack of gratitude emphasizes the negative impact it has, on job satisfaction. In order to confront this issue, it is important to:

Promote Awareness Programmes; Promote the value of showing appreciation at work by organising initiatives such as workshops, seminars and communication campaigns. These activities can effectively emphasise the impact of acknowledgment on employee morale and job satisfaction.

Cultivate a Culture of Gratitude; Foster an environment where gratitude is valued within the organisation by incorporating practices that promote appreciation into activities and encouraging supervisors and team members to acknowledge and recognise each other's efforts.

Continuous monitoring and adaptation

To ensure that these methods remain sustainable and effective, it is vital to establish a strategy for regular monitoring and adaptation;

Implement Feedback Mechanisms; Create avenues for feedback from ATCs regarding the implemented recommendations. This could involve surveys, focus groups or even anonymous suggestion boxes to gather constructive input.

Data Driven Decision Making: Utilise data analytics to assess the impact of implemented strategies on job satisfaction, continuously monitor trends over time and make informed adjustments based on evolving workforce needs and preferences.

Mechanism, for gathering employee feedback

It is crucial to empower ATCs to participate in the improvement of appreciation practices through the means given below.

Structured Feedback Mechanism; Create a well-organized and confidential system where ATCs can freely express their opinions and suggestions. This can be done through feedback sessions, anonymous surveys or a dedicated feedback portal.

Incorporating Feedback in Decision Making; Integrate the feedback received into decision making processes. By demonstrating a commitment to listening and addressing employee concerns, trust can be strengthened, leading to appreciation initiatives.

In addition to the above, further research should be conducted to explore the implications of employee appreciation methods across organisations beyond institutions providing Air Traffic Services. By using a research model with adjustments, to requirements and

including additional employee appreciation methods, a wider range of data can be collected for analysis.

It would be valuable to conduct research, on how different methods of appreciating employees impact the job satisfaction of operational staff in institutions, such as financial, sales, legal, medical and educational organisations. Additionally, it would be interesting to expand these studies to Air Traffic Service providers and consider how cultural factors might influence the preferred methods of appreciation. By including operational staff from countries and institutions in the research, it is possible to gain a comprehensive understanding. It is recommended that leaders and managers within organisations review the findings from this study and other similar studies to recognize the significance of establishing relationships with employees who feel valued (Hamrick & White, 2020).

The implications of this study have both internal and external impacts. Within an organisation, leaders who fully grasp the impact of employee appreciation methods can foster job satisfaction, loyalty and positive morale among employees. Understanding which methods of appreciation lead to job satisfaction is crucial as it influences employee's motivation to stay in their job. A positive work environment not only boosts productivity, but also attracts individuals to be a part of the organisation ultimately shaping a favourable perception of the organisation in society beyond its boundaries.

6. CONCLUSION

In conclusion this quantitative study aimed to examine the impact of seven employee appreciation strategies on the job satisfaction of ATCs. Building upon Becks 2016 study, data was collected from 257 participants who met the criteria of being ATC staff members of AASL or SLAF. The results revealed that all seven methods had an influence on the job satisfaction of ATCs with one-on-one communication, electronic notes (social media, email, LinkedIn), verbal (in public) communication, written/ typed (letters, cards) communication, tangible items (gift card, token of appreciation) and monetary bonus as the effective methods of appreciation.

Thus, this study offers insights into the factors that influence job satisfaction among ATCs in Sri Lanka. The comprehensive nature of appreciation strategies as revealed by regression analysis highlights the importance of adopting an approach to enhance satisfaction.

In conclusion, the below model can be instrumented by employers and other stakeholders of ATC in identifying and quantifying job satisfaction of ATCs all around the world. It also suggests best suiting appreciation techniques to increase job satisfaction of ATCs.

Job Satisfaction= 2.439 + 0.257 (Verbal One-on-one Appreciation) + 0.195 (Electronic Note Appreciation) - 0.365 (No expression of Gratitude)

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INVESTIGATING THE DETERMINANTS OF FINANCIAL INCLUSION AMONG URBAN YOUTH: EVIDENCE FROM SRI LANKA

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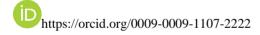
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ABSTRACT

Financial inclusion, defined as equitable access and use of affordable financial services is crucial for fostering economic growth. This study investigates the determinants of financial inclusion in urban youth in Sri Lanka, addressing the critical gap in the literature. Utilising the data from 384 respondents across selected urban areas, the research employs a web-based questionnaire and applied Partial Least Square- Structural Equation Modelling (PLS-SEM) to assess the relationships between financial inclusion and key determinants such as Peer Influence, Government Policies, Mobile Banking Usage, Telecommunication Network Quality and Financial Literacy. The findings identify Financial Literacy as the most significant determinant of financial inclusion followed by positive correlations with other variables. The study offers practical insights for financial institutions and policymakers to improve financial literacy and design targeted strategies for enhancing financial inclusion among urban youth. However, the study's focus on urban youth limits its generalisation to rural population where access and inclusion may differ significantly.

KEYWORDS: *Financial Inclusion, Urban Youth, Financial Literacy, Mobile Banking Usage, Regulatory Frameworks, Telecommunication Network Quality*

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1. INTRODUCTION

Financial inclusion, defined as fair access to and usage of inexpensive financial services, is widely seen as a fundamental driver of economic development and poverty reduction (World Bank, 2014). It is characterised as equitable access to and use of relatively inexpensive financial services. From savings to credit to insurance to payment systems, the idea covers a wide spectrum of financial services (Demirgüç-Kunt *et al*., 2018; Sahay *et al*., 2015). Even with the advancements in the world, there are still gaps in financial inclusion, especially in developing nations like Sri Lanka where differences are seen in different demographic groups and places (Central Bank of Sri Lanka, 2020). A considerable section of Sri Lanka's population is urban young (aged 18 to 35). Understanding this demography's financial requirements and behaviours is essential for fostering equitable growth as the country continues to urbanise (Department of Census and Statistics, 2019).

The financial behaviours of urban young in Sri Lanka have been the subject of limited research, despite the significance of financial inclusion. The previous research has mostly focused on financial inclusion in larger demographic segments (Atkinson & Messy, 2013; Bruhn & Love, 2014), paying minimum attention to the factors that determine young people living in urban areas. It is crucial to comprehend the factors that influence financial inclusion among this population, especially considering the growing urbanisation of areas like Galle and Colombo (Department of Census and Statistics, 2019). Examining the financial inclusion landscape is made easier by the socioeconomic variety in these districts, which reflects the potential and constraints of financial inclusion in urban environments (Central Bank of Sri Lanka, 2021).

The research concentrates on several factors; mobile banking usage, financial inclusion, including financial literacy, digital literacy, network quality, influence from family and peers and government policies and regulations that significantly determine the financial inclusion of urban youngsters. These factors have all been recognised as important drivers in previous empirical studies (Atkinson & Messy, 2013; Suri &

Jack, 2016). Higher levels of education and familiarity with digital platforms boost the possibility of obtaining and utilising financial services, which is another way in which education and digital literacy are substantially connected with financial inclusion (Suri & Jack, 2016). Particularly, it has been demonstrated that financial literacy increases financial inclusion by giving people the information and abilities they need to make wise financial decisions (Atkinson & Messy, 2013). For urban youth to interact with financial platforms successfully, a dependable and quick network is necessary where poor network quality can limit usage and have an influence on financial inclusion (Demirgüç-Kunt *et al*., 2018; Sahay *et al*., 2015). Adoption of financial innovations is also significantly influenced by family and peer pressure. According to shared experiences and suggestions, social circles may either promote or discourage the use of financial services and frequently affect attitudes towards them (Demirgüç-Kunt *et al*., 2018). Ultimately, the policy framework that financial services function within is established by governmental laws and regulations. While strict or badly conceived rules may restrict access to necessary services, further complicating the financial inclusion landscape whereas supportive policies can promote an inclusive financial ecosystem (Suri & Jack, 2016).

Several initiatives have been launched in Sri Lanka to promote financial inclusion, such as the financial literacy programmes of the Central Bank and initiatives to promote digital payments (Central Bank of Sri Lanka, 2021). These actions have the potential to significantly raise financial inclusion in the nation when combined with focused interventions for urban youth. Comprehending the root reasons are crucial in formulating efficacious policies and initiatives to foster financial inclusion. This research examines these aspects in detail to provide guidance for policy and practice aimed at advancing inclusive financial systems for Sri Lanka's youth population living in metropolitan areas.

Research Gap

Limited research exists on the financial inclusion of urban youth in Sri Lanka, despite their crucial role in driving future economic growth. The urbanised

regions of Colombo and Galle offer valuable insights into financial inclusion due to their distinct socioeconomic contexts (Central Bank of Sri Lanka, 2020). Although Colombo, as the commercial capital, boasts a well-established financial infrastructure, youth from lower-income households encounter barriers in effectively accessing available financial services (Central Bank of Sri Lanka, 2020). Galle, while smaller, is undergoing rapid urbanisation, leading to an emerging urban context where financial access is increasing but remains uneven (Department of Census and Statistics, 2019). Both districts display significant socioeconomic diversity, reflecting broader urban challenges and opportunities associated with financial inclusion. Furthermore, with the increasing prevalence of digital financial services in these areas, it is crucial to understand how urban youth engage with fintech to design effective financial inclusion policies (Central Bank of Sri Lanka, 2021). By focussing on Colombo and Galle, this study addresses a gap in the literature and provides valuable insights into extending financial services more equitably to urban youth.

Purpose of the Study

The purpose of this study is to identify and analyse the determinants of the financial inclusion among urban youth in Sri Lanka. By exploring socio-economic, educational, and technological variables, the research aims to understand the barriers and enablers affecting this demography's access to financial services. Specifically, the study investigates how factors such as financial literacy, digital literacy, network quality and regulatory frameworks encourage or hinder the financial inclusion. The findings provide valuable insights for policymakers, financial institutions, and educational organisations to develop targeted interventions that enhance financial inclusion among urban youth. Improving financial inclusion in this segment is crucial for fostering economic stability, increasing savings and investment, and promoting overall economic development in Sri Lanka. This research seeks to contribute to a comprehensive understanding of how to better integrate urban youth into the financial system, thereby supporting their economic empowerment and future growth.

Research Question

What socio-economic factors significantly determine the level of financial inclusion among urban youth in Sri Lanka?

Objectives of the Study

The objective of the research is centred upon the analysis of determinants of financial inclusion of urban youth particularly in Galle and Colombo districts. It further analyses the relationship and magnitude of each independent variable: Mobile Banking Usage, Telecommunication Network Quality, Government Policies and Regulatory Frameworks, Financial Literacy, Peer Influence and Social Networks on the dependent variable, Financial Inclusion. The results are significant in informing practical recommendations for improving financial inclusion among young urban individuals.

Significance of the Study

This study is crucial in shedding light on the determinants of financial inclusion among urban youth in Sri Lanka. By highlighting the socio-economic, educational, and regulatory factors that influence access to financial services, this research aims to offer actionable insights for policymakers, financial institutions, and educational bodies. Understanding these factors is crucial for policymakers as it can guide the development of targeted policies aimed at reducing barriers and enhancing financial access for youth, urban areas. Financial institutions stand to benefit by gaining a deeper understanding of the specific needs and challenges faced by this demographic, enabling them to tailor their services accordingly. Additionally, educational institutions can use this research to strengthen financial literacy programmes and curricula, thereby equipping youth with the necessary skills to navigate the financial landscape effectively. Ultimately, enhancing financial inclusion among urban youth not only promotes economic stability and growth but also fosters broader social benefits such as poverty alleviation and sustainable development in Sri Lanka.

Theoretical Background

Technology Acceptance Model

The Technology Acceptance Model (TAM) offers a strong theoretical framework for understanding the causes of financial inclusion, particularly via the perspective of technology adoption. The factors mentioned are greatly explained by Fred Davis technology acceptance model (TAM) that was developed in 1989. TAM assumes that perceived ease of use (PEOU) and perceived usefulness (PU) are main factors influencing the new technology acceptance and usage. Based on the Theory of Reasoned Action (TRA) advanced by Fishbein and Ajzen in 1975, TAM applies the theory's constructs to the acceptance of technology by positing that PEOU as well as PU bear a positive direct relationship with attitude towards using a particular technology, and consequently influences the technology user's perceived behavioural intention and subsequent actual usage behaviour in a projected time (Davis, 1989; Fishbein & Ajzen, 1975).

Perceived usefulness (PU) is the extent to which an individual perceives the use of a particular system, in case of DFS, to improve their financial management and financial transactions required in their occupation. Several empirical research works have corroborated the significance of PU in the use of technology. For example, Venkatesh and Davis (2000) identified that PU plays a highly significant role in shaping users' behavioural intentions towards a technology in various applications such as Internet banking and mobile commerce. Likewise, perceived ease of use (PEOU) manifests itself in the extent to which a person considers using a particular system to be trouble-free. Experiments also indicated that PEOU has influence on PU and on the attitude of the users with regards to technology. Similarly, Pikkarainen *et al*. (2004) showed that PEOU affected Internet banking acceptance leading to its categorisation as acceptance influencers.

Theory of Reasoned Action (TRA)

The basic framework for comprehending the determinants of urban youths' adoption of mobile banking is based on the Theory of Reasoned Action

(TRA). According to TRA (Fishbein & Ajzen, 1975), a person's attitudes about a behaviour and subjective norms have a major influence on their behavioural intentions. Positive views regarding mobile banking, fuelled by advantages like accessibility and convenience, are likely to increase the desire to use these services in the context of financial inclusion (Johnson *et al*., 2019). Furthermore, subjective norms that are shaped by social networks and peer behaviours have a significant influence on adolescent decisions since friend recommendations can increase confidence and familiarity with mobile banking platforms (Yang *et al*., 2017). Thus, comprehending these psychological aspects is essential to creating focused interventions that encourage urban youth to use mobile banking, which in turn enables greater financial inclusion.

Mobile Banking Usage

Mobile banking, enabled by widespread smartphone adoption, offers convenience and accessibility (Johnson *et al*., 2019). Improved telecommunication network quality enhances the reliability of digital financial transactions (Smith & Brown, 2020). Effective government policies and regulatory frameworks ensure a supportive environment for financial service innovation and consumer protection (Gupta & Sharma, 2018). Financial literacy programmes play a crucial role in equipping youth with the knowledge to manage finances effectively (Lee & Kim, 2021). Mobile banking has become a transformative force in enhancing financial inclusion among urban youth worldwide. Empirical studies underscore several critical factors influencing its adoption in this demographic. Johnson *et al*. (2019) highlights that convenience, accessibility, and technological familiarity are primary drivers. In developing countries, where traditional banking infrastructure may be lacking or inaccessible, mobile banking offers a practical solution. The ease of conducting transactions via smartphones empowers young urbanites to manage their finances conveniently and securely.

Moreover, the integration of banking apps with everyday digital activities simplifies financial interactions, making mobile banking a preferred

choice among urban youth. For instance, Johnson *et al*. (2019) found that the ubiquity of smartphones and the user-friendly interfaces of mobile banking apps significantly increase usage rates among youth. This trend not only democratises financial services but also bridges the gap between traditional banking systems and the digitally savvy younger generation. The transformative potential of mobile banking lies in its ability to empower urban youth economically by providing access to savings, credit, and payment services previously out of reach due to geographic or economic barriers. As mobile penetration continues to rise globally, especially in urban areas, mobile banking is poised to play an increasingly crucial role in fostering financial inclusion among youth.

H1: Mobile banking usage has a positive effect on financial inclusion among urban youth in Sri Lanka.

Telecommunication Network Quality

The quality and reliability of telecommunication networks are pivotal in facilitating mobile banking adoption among urban youth. Research by Smith and Brown (2020) underscores that robust network infrastructure is essential for the seamless operation of mobile financial services. In regions where telecommunication networks are inadequate or unreliable, users may face challenges in conducting transactions or accessing banking services via mobile devices. Smith and Brown (2020) argue that improvements in network coverage and technological advancements, such as the rollout of 4G and 5G technologies, are critical for enhancing the accessibility and effectiveness of mobile banking services for urban youth.

Moreover, the reliability of telecommunication networks influences user confidence and trust in mobile banking platforms. Studies indicate that urban youth are more likely to adopt mobile banking services when they can rely on consistent network connectivity to perform transactions securely and efficiently (Smith & Brown, 2020). The expansion of network coverage into underserved urban areas can significantly broaden access to financial services, thereby reducing disparities in financial inclusion among youth from different socioeconomic backgrounds. Policy initiatives aimed at improving

telecommunication infrastructure are thus crucial for fostering a conducive environment for mobile banking adoption among urban youth. Effective government policies and regulatory frameworks are pivotal in shaping the landscape of mobile banking and financial inclusion initiatives targeted at urban youth. Gupta and Sharma (2018) argue that supportive regulatory environments are essential for promoting innovation and competition among financial service providers, thereby enhancing the accessibility and affordability of mobile banking services. Clear guidelines and regulations ensure consumer protection and trust in digital financial transactions, which are crucial factors in encouraging youth to adopt mobile banking platforms.

H2: Telecommunication network quality positively influences financial inclusion among urban youth in Sri Lanka.

Government Policies and Regulatory Frameworks

Gupta and Sharma (2018) emphasise the importance of proactive policymaking to address barriers to financial inclusion, such as affordability and accessibility. Governments can play a catalytic role in facilitating partnerships between banks, telecommunications companies, and technology providers to expand the reach of mobile banking services among urban youth. By fostering an enabling regulatory environment, policymakers can stimulate investment in digital infrastructure and promote financial literacy programs tailored to the needs of young urban populations. Strategic interventions, such as targeted subsidies or incentives for mobile banking providers, can further enhance the uptake of digital financial services among urban youth. Financial literacy is a critical determinant of mobile banking adoption among urban youth, influencing their ability to navigate and utilise digital financial services effectively.

H3: Government policies and regulatory frameworks have a positive effect on financial inclusion among urban youth in Sri Lanka.

Financial Literacy

Lee and Kim (2021) highlight that higher levels of financial knowledge correlate positively with the

adoption and usage of mobile banking platforms. Educating youth about financial concepts, such as budgeting, saving, and digital transactions, enhances their confidence in managing personal finances through mobile devices. Financial literacy programmes tailored to urban youth can empower them with the necessary skills and knowledge to make informed financial decisions and leverage mobile banking for their economic well-being. Lee and Kim's (2021) research underscore the role of educational institutions and community organisations in promoting financial literacy initiatives. By integrating financial education into school curricula and community outreach programmes, stakeholders can equip urban youth with practical skills to navigate the digital economy. Enhancing financial literacy not only improves the uptake of mobile banking services but also fosters a culture of financial empowerment among young urbanites. Policy interventions that prioritise financial education as part of broader youth development strategies are essential for building a financially inclusive society where all youth can benefit from the opportunities offered by mobile banking (Lee and Kim, 2021)

H4: Financial literacy positively influences financial inclusion among urban youth in Sri Lanka.

Peer Influence and Social Networks

Peer influence and social networks significantly impact the adoption behaviours of urban youth towards mobile banking services. Yang *et al*. (2017) highlights that recommendations from peers and social media interactions play a crucial role in shaping young individuals' attitudes and perceptions towards digital financial technologies. Positive endorsements and testimonials within social circles can enhance trust and familiarity with mobile banking platforms, overcoming initial scepticism or resistance among youth. As digital natives, urban youth are often early adopters of technology-driven innovations, influenced by peer networks that validate the utility and reliability of mobile banking services.

Yang *et al*. (2017) argue that leveraging social networks effectively can amplify the reach and impact of financial inclusion initiatives targeted at urban youth. By harnessing peer influence and social media

platforms, stakeholders can promote awareness about the benefits of mobile banking and address misconceptions or concerns among young users. Collaborative efforts between financial institutions, community organisations, and youth influencers can create synergies that encourage widespread adoption of mobile banking solutions. Policy initiatives that support digital literacy and encourage peer-to-peer learning can further empower urban youth to embrace mobile banking as a tool for financial empowerment and social mobility.

H5: Peer influence and social networks positively affect financial inclusion among urban youth in Sri Lanka.

2. METHODOLOGY

In this methodology section outlines the structured quantitative approach employed to investigate determinants of financial inclusion among urban young population in Sri Lanka. The discussion covers the research design, including the conceptual framework, operationalisation of constructs, target population and sample, data collection methods, and data analysis techniques.

Conceptual Framework

The conceptual framework of this study is structured around the independent variables identified as potential determinants of financial inclusion among urban youth in Sri Lanka. These determinants include Mobile Banking Usage (Johnson *et al*., 2019), Telecommunication Network Quality (Smith & Brown, 2020), Government Policies and Regulatory Frameworks (Gupta and Sharma, 2018), Financial Literacy (Lee and Kim, 2021), and Peer Influence and Social Networks (Yang *et al*., 2017). The relevance of these determinants to urban youth in Sri Lanka is underscored by increasing adoption of mobile banking, evolving telecommunication infrastructure and the growing role of social networks among the young population in the country (Central Bank of Sri Lanka, 2021).

Table 1 – Operationalization of Conceptual Framework

Dependent Variable	Financial Inclusion	Access to and ownership of financial accounts is essential	(Demirgüç-Kunt *et al.*, 2018)
		Usage of Digital Financial Services is crucial	
		Adopting digital financial services is crucial	
Independent Variables	Mobile Banking Usage	Mobile banking offers convenient financial management.	Johnson *et al*. (2019)
		Smartphones make mobile banking easily accessible.	
		Tech-savvy youth prefer mobile banking.	
		Banking apps simplify daily financial tasks.	
		Mobile banking provides essential financial services.	
	Telecommunication Network Quality	Reliable networks ensure smooth mobile banking.	Smith and Brown (2020)
		Expanding coverage improves financial access.	
		4G/5G enhances mobile banking speed.	
		Consistent connectivity builds user trust.	
		Better infrastructure supports mobile banking adoption.	
	Government Policies and Regulatory Frameworks	Proactive policies address financial inclusion barriers.	(Gupta and Sharma, 2018).
		Partnerships expand mobile banking services.	
		Regulatory environments stimulate digital investment.	
		Subsidies/incentives boost mobile banking uptake.	
		Policies promote financial literacy programs.	
	Financial Literacy	Higher financial knowledge boosts mobile banking use.	(Lee and Kim, 2021)
		Education on budgeting and saving enhances confidence.	
		Tailored programs empower youth financially.	
		Schools and communities promote financial literacy.	
		Financial education fosters economic well-being.	
	Peer Influence and Social Networks	Peer recommendations shape mobile banking adoption.	(Yang *et al*., 2017)
		Social media enhances trust in digital finance.	
		Early adopters influence peers' technology use.	
		Social networks amplify financial inclusion efforts.	
		Peer learning encourages mobile banking use.	

Research Design

The study aims to explore the factors that determine financial inclusion among youth population in Sri Lanka. A deductive, quantitative research approach is employed, utilising a web-based, structured questionnaire to collect data. This approach facilitates the examination of predefined hypotheses concerning the relationships between independent variables (Mobile Banking Usage, Telecommunication Network

Quality, Government Policies and Regulatory Frameworks, Financial Literacy, and Peer Influence and Social Networks) and the dependent variable (Financial Inclusion). The study employs an explanatory research design to establish causal associations among these variables and test hypotheses derived from existing theories and literature.

Hypotheses

H1: Mobile banking usage has a positive effect on financial inclusion among urban youth in Sri Lanka (Johnson *et al*., 2019).

H2: Telecommunication network quality positively influences financial inclusion among urban youth in Sri Lanka (Smith & Brown, 2020).

H3: Government policies and regulatory frameworks have a positive effect on financial inclusion among urban youth in Sri Lanka (Gupta and Sharma, 2018).

H4: Financial literacy positively influences financial inclusion among urban youth in Sri Lanka (Lee and Kim, 2021).

H5: Peer influence and social networks positively affect financial inclusion among urban youth in Sri Lanka (Yang *et al*., 2017).

Population and Sample

The study's population demography is centred on population in Sri Lanka whereas the researcher has drawn a sample of young adults (Aged between 18 and 35) from the Colombo and Galle districts in Sri Lanka, which is a smaller representation of a wider community. The population size is greater than 25,000 and the sample size was 384 units according to the Krejcie & Morgan Table. The sample units were chosen using several sampling techniques including simple random, stratified, cluster, and convenient sampling techniques. Initially, 3 divisional secretariats (DS) were chosen from among the 13 DSs in the Colombo District and 2 divisional secretariats among 19 DSs in Galle using simple random sampling. The DSs chosen were Dehiwala DS, Kaduwela DS, Kollonnawa DS, Ambalangoda DS and Imaduwa DS. A reasonable number of Grama Niladri Divisions (GNDs) were selected from DSs using a proportional distribution and stratified random selection with DSs as strata. Colombo was selected as a representative

urban area with a high concentration of youth, robust financial infrastructure, and strong telecommunication networks, while Galle represents a semi-urban setting allowing for a combination of financial inclusion patterns in urban and semi-urban regions. Following that, the GNDs were classified as clusters, and the author selected sample units using the multistage cluster sampling approach. Multistage cluster sampling was employed to ensure that the sample was representative of various demographic segments with each DS division while also enhancing the logistic feasibility of data collection. Following that, data were collected from 384 young adults at the mentioned GNDs to meet the objectives of the study.

Data Collection

A standardised questionnaire, given using Google Forms, was utilised to collect primary data. The questionnaire constructed upon the five-point Likert Scale questions to get more insights into the phenomena under consideration. The questionnaire had sections for each of the independent factors and the dependent variable, with items designed to capture the intricacies of each construct. To maximise response rates, participants were solicited by email, and follow-up reminders were also sent. The Likert scale responses ranging from 1 (Strongly Disagree) to 5 (Strongly Agree) enabled to capture the participants' attitudes and behaviours towards financial inclusion. Pilot testing was conducted with a small group to ensure clarity of questions before full-scale data collection.

Data Analysis

Data analysis was performed using Partial Least Squares - Structural Equation Modelling (PLS-SEM) with the SmartPLS software. PLS-SEM was chosen for its ability to handle complex models with multiple latent variables and its suitability for exploratory research. It also allows for estimating path coefficients between variables, which are useful for testing the strength and direction of hypothesised relationships. The measurement model was evaluated using composite reliability, Cronbach's alpha and Average Variance Extracted to ensure internal consistency and convergent validity. The structural modelling was then assessed using path coefficients and R-squared values

to test the significance and the explanatory power of the hypothesised relationships.

3. RESULTS AND DISCUSSION

The results and discussion section specifies the results generated through conducting the statistical analysis.

Assessment of Reliability

	Cronbach's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	Average variance extracted (AVE)
Table 2 - Assessment of Reliability Source: Field Survey, 2022				
MBU	0.674	0.713	0.809	0.526
TNQ	0.816	0.817	0.871	0.576
GP	0.834	0.872	0.892	0.677
FL	0.919	0.926	0.94	0.758
PI	0.809	0.859	0.866	0.572
FI	0.465	0.575	0.739	0.512

The financial inclusion category has Cronbach's alpha values of 0.465 while the financial literacy category has 0.919. The composite reliability scores for all variables surpass 0.7, showing overall strong internal consistency, even though the Cronbach's alpha for Financial Inclusion (FI) is below the acceptable level. All variables can be regarded as dependable and reliable for further analysis.

Assessment of Convergent Validity

Convergent validity can be confirmed with outer loading value higher than 0.7. However, Financial

Inclusion had lower outer loadings for FI3 (0.339) than Financial Literacy (most loadings exceeding 0.7).

This implies that item revision may be required for future investigations. Convergent validity is achieved for most of constructs.

Table 3 - Outer loading of the Latent Variables
Source: Field Survey, 2022

Path	Financial Literacy	Financial Inclusion	Government Policies	Mobile Banking Usage	Peer Influence	Telecommunication Network Quality
FL1	0.635					
FL2	0.886					
FL3	0.917					
FL4	0.847					
FI1		0.845				
FI2		0.843				
FI3		0.339				
GP1			0.779			
GP2			0.730			
GP3			0.731			
GP4			0.879			
GP5			0.685			
MBU1				0.444		
MBU2				0.784		
MBU3				0.849		
MBU4				0.774		
PI1					0.771	
PI2					0.902	
PI3					0.0836	
PI4					0.918	
PI5					0.918	
TNQ1						0.819
TNQ2						0.789
TNQ3						0.916
TNQ4						0.515
TNQ5						0.774

Table 4 - Values of Square Root of AVE and Inter-Construct Correlation
Source: Field Survey, 2022

	FL	FI	GP	MBU	PI	TNQ
FL						
FI	0.708					
GP	0.789	0.982				
MBU	1.181	1.297	0.81			
PI	0.925	1.109	1.056	1.329		
TNQ	0.667	1.108	0.924	1.176	0.999	

Assessment of Discriminant Validity

The Fornell and Larcker criteria compares the square root of AVE (average variance extracted) for each concept to correlations between components. The square root of AVE values is higher than the inter-construct correlations indicating that discriminant validity is achieved. The testing means that the constructs are distinct from one another, which validates the model.
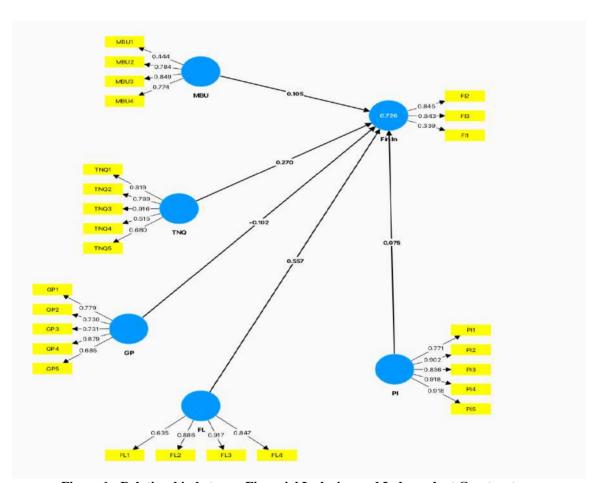

Figure 1 - Relationship between Financial Inclusion and Independent Constructs

Source: Field Survey, 2022

Table 5 - Goodness of the Fit of the Model
(Source: Field Survey, 2022)

	Saturated model	Estimated model
SUMMER	0.078	0.078
d_ULS	0.81	0.81
d_G	0.287	0.287
Chi-square	469.42	469.42
NFI	0.902	0.902

According to Table 5, the estimated and saturated models have similar fit indices. The fit indices for both models are shown below: The Normed Fit Index (NFI)is 0.902, the unweighted least squares (d_ULS) d-value is 0.78, the geodesic distance d-value is 0.287, the chi-square value is 459.424, and the SRMR is 0.078. These fit indices describe the model's goodness of fit and provides relevant information. In this situation, both models' fit indices are the same, indicating a similar degree of fit.

According to Table 6, there is a substantial positive correlation between Mobile Banking Usage and Financial Inclusion (r = 0.105, p = 0.000). Thus, it can be said that mobile banking usage has a favourable impact on all aspects of Financial Inclusion.

There is a highly significant positive correlation between Financial Inclusion and Telecommunication Network Quality (r = 0.270, p = 0.000). As a result, it can be said that the Telecommunication Network Quality has a favourable impact on all aspects of Financial Inclusion.

Because the relationship between Government Policies and Regulatory Frameworks and Financial Inclusion is statistically significant when all variables are considered at once, Table 5 also shows that Government Policies and Regulatory Frameworks have a significant positive relationship with the overall level of Financial Inclusion (r = 0.102, p = 0.000).

According to Table 6, there is a negative and significant correlation between the dependent variable and Financial Literacy (r = 0.557, p = 0.001). As a result, it can be said that Financial Literacy has a favourable impact on all aspects of Financial Inclusion.

Moreover, there is a positive and significant impact on the Financial Inclusion of Urban Youth from Peer Influence and Social Networks (r = 0.075, p = 0.000). It can be concluded that Peer Influence and Social Networks have a favourable impact on Financial Inclusion within the country.

Table 6 - The Effect of the Independent Variables on Women's Career Progression Source: Field Survey, 2022

Path	Path coefficients	P values	Decision
Financial Inclusion -> Mobile Banking Usage	0.105	0.000	Supportive
Financial Inclusion -> Telecommunication Network Quality	0.270	0.000	Supportive
Financial Inclusion -> Government Policies and Regulatory Frameworks	0.102	0.000	Supportive
Financial Inclusion -> Financial Literacy	0.557	0.001	Supportive
Financial Inclusion -> Peer Influence and Social Networks	0.075	0.000	Supportive

Limitations

The study may be constrained by its reliance on self-reported data from participants gathered using a structured questionnaire and a quantitative methodology, which could lead to response bias if individuals provided answers that are socially acceptable or do not fully reflect their experiences. To mitigate this, responses were collected anonymously,

and confidentiality was assured to encourage honesty. Additionally, the sample was limited to individuals in the Colombo and Galle Districts, Sri Lanka, which may not accurately reflect people's experiences in other regions or contexts. Future research could include a broader range of areas to address this limitation. To further enhance the overall validity of the study, triangulation techniques such as focus groups and follow-up interviews could be employed to verify and enrich the quantitative findings.

Conclusions and Future Study Directions

This study investigated the key determinants of financial inclusion of urban youth in Sri Lanka. The findings revealed that peer influence and social networks, government policies and regulatory frameworks, mobile banking usage, and the quality of telecommunication networks all positively correlated with financial inclusion. Financial literacy indicated a significantly positive impact on financial inclusion among urban youth. These results reveal the significance of mobile banking tools, reliable telecommunications infrastructure, and supportive social influences. Further, favourable government policies that foster inclusive financial environment for urban youth plays a crucial role in determining the financial inclusion. To gain a comprehensive understanding of financial inclusion across the country, future studies are requested to replicate this study nationwide, encompassing a broader range of demographics and geographic regions. Such an approach would help to evaluate how various socio-economic and regional factors shape financial inclusion across diverse population demographics.

Further research could explore which specific mobile banking features and services, such as peer-to-peer transfers and mobile wallets, are most effective in enhancing financial inclusion among urban youth. By doing so, financial institutions and policymakers can develop user-friendly mobile banking solutions tailored to distinct market segments. These solutions would promote broader adoption and increase engagement with formal financial systems. Additionally, strong regulatory frameworks that emphasise ethical conduct and consumer protection

are essential to building public trust in financial services. Social media platforms and community-based organisations could also be critical in debunking misconceptions, raising awareness about financial products and services, and encouraging greater participation in the financial system. Ultimately, a multi-faceted approach, combining mobile banking innovations, regulatory reforms, and community outreach, would contribute to the sustained advancement of financial inclusion in Sri Lanka's urban youth.

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ENHANCING PUBLIC EDUCATION AND ADDRESSING POLICY GAPS FOR RADON EXPOSURE AND LUNG CANCER RISK MITIGATION IN SRI LANKA

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ABSTRACT

Radon, a naturally occurring radioactive gas, is a significant health risk attributable to its strong association with lung cancer. In Sri Lanka, public awareness of radon exposure and its health implications remains low, and there are minimal policies addressing this risk. This systematic review aimed to analyse public awareness, policy gaps, and mitigation strategies related to radon exposure and cancer risk, particularly in Sri Lanka. Following the PRISMA 2020 guidelines, we searched three electronic databases PubMed, Google Scholar, and ScienceDirect for studies published since 2001, yielding 1,025 records. After screening, we included 51 articles, focussing on public awareness and policy frameworks in both developed and South Asian countries. The findings disclose significant gaps in both public knowledge and policy measures, highlighting the urgent necessity for targeted public education campaigns and development of comprehensive regulations for radon testing and mitigation. By addressing these issues, Sri Lanka can reduce the health risks associated with radon exposure and enhance its cancer prevention strategies.

KEYWORDS: *Radon exposure, Lung cancer prevention, Public awareness, Sri Lanka, Environmental health policy, Radon mitigation*

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1. INTRODUCTION

Background Information

A naturally occurring radioactive gas called Radon (^{86}Rn) is formed from the decay of uranium in soil and rock. It is colourless, odourless, and tasteless, which makes it strenuous to detect without specialised equipment (Degu Belete and Alemu Anteneh, 2021). Long-term exposure to radon decay products poses significant health risks, particularly lung cancer. The World Health Organisation identifies radon exposure as the second leading cause of lung cancer after smoking (*Radon*, no date). The risk is especially high in environments with elevated radon levels, such as imperfectly ventilated buildings or homes in radon-prone areas.

Context in Sri Lanka

In Sri Lanka, the public awareness of radon exposure and its correlated health risks is comparatively low. Radon levels fluctuate greatly depending on geographical location, construction implementations, and building ventilation. With proliferating urbanisation and changes in construction materials, there is a growing need to acknowledge the quantity of radon exposure and public awareness in Sri Lanka. Despite its significance, radon is not broadly discussed in public health forums, and limited studies focus on radon exposure in the Sri Lankan context.

Objectives of the Review

The primary objective of this review is to explore the existing public education efforts and identify policy gaps related to radon exposure in Sri Lanka, emphasising the need for enhanced education and understanding of the associated health risks. Additionally, the review aims to provide an overview of the research on radon risk perception, evaluating existing policy measures related to radon mitigation and cancer prevention within the selected developed countries (United States, Canada, United Kingdom, Australia, European Union) with South Asian countries (India, Pakistan, Bangladesh, Nepal, Bhutan, Sri Lanka, Maldives, Afghanistan). By comparing these policies to international best practices, the review seeks to identify gaps and areas for improvement. Ultimately, the review aspires to offer actionable recommendations for improving public education and policy development on radon exposure, ensuring that the population is better informed and protected from the potential health hazards associated with this radioactive gas.

2. METHODOLOGY

This systematic review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guideline.

Search Strategy

This review systematically searched three electronic databases PubMed, Google Scholar, and ScienceDirect for studies on radon exposure, public awareness, policy gaps, and cancer prevention. The search used the query: "radon exposure" AND "public awareness" OR "policy gaps" OR "cancer prevention" OR "cancer risk" OR "Sri Lanka." Only English-language studies were included, with no time restrictions, ensuring comprehensive topic coverage as of December 3, 2023.

Study selection

Two researchers (W.V.A.S.L and S.N.H) independently evaluated titles and abstracts based on eligibility criteria, covering publications from 2001 onward. A total of 1025 records were identified from three databases, as shown in Figure 3 following PRISMA guidelines.

A total of 842 records were identified under the category of public awareness of radon exposure in developed countries (Figure 1). The selection process prioritised studies from nations with robust public health systems and radon mitigation strategies, offering valuable insights for Sri Lanka. United States: From 429 records, 10 were selected for their in-depth analysis of public awareness campaigns, policy frameworks, and successful mitigation efforts. Canada: Out of 211 records, 3 were chosen for their focus on public health initiatives, educational outreach, and radon awareness programmes relevant to Sri Lanka's context.

United Kingdom: Of 122 records, 2 were selected for their emphasis on government-led efforts and policy adaptations, offering practical insights for bridging awareness gaps. Australia: From 34 records, 1 study was chosen for its discussion on risk communication and public engagement strategies, adaptable to countries with low radon awareness. European Union: Of 46 records, 16 were selected due to the diverse policy measures across member states and the region's comprehensive approach to radon exposure management.
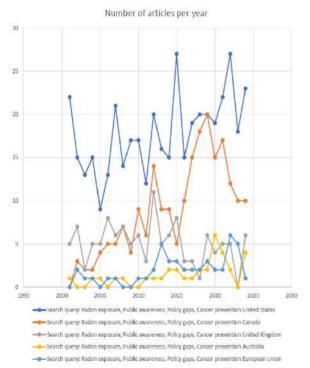

Figure 1. Timeline distribution of the articles included in the systematic review in developed countries

Under the category of public awareness of radon exposure in South Asian countries resulted in 184 records (Figure 2), which provided context for comparing radon awareness and policy frameworks in countries with similar socio-economic and public health challenges faced by Sri Lanka.

India: Out of 137 identified records, only 4 were selected for their analysis of radon risk, all of which centred on measurement rather than awareness campaigns or public education efforts. Pakistan:

Among 37 reviewed records, 6 studies were chosen for their focus on radon concentration levels, but, again, none addressed public knowledge or mitigation strategies.

Bangladesh: All 4 available records were included due to the limited literature on radon exposure, but none explored public awareness initiatives. Nepal: Both available records were included, although there is a lack of focus on public health education and policy challenges related to radon exposure. Bhutan: The only record on radon and helium monitoring, with no emphasis on public awareness. Sri Lanka: Just 1 record was found, which was included due to its direct relevance to the study's focus on radon exposure in the country. Like in the other countries, this record did not delve into public awareness or policy issues. Maldives: No records were available, indicating a significant research gap in both radon measurement and awareness. Afghanistan: The single record identified was selected for its relevance to radon exposure in Aisa-pacific areas, offering insights for awareness strategies in similarly high-risk regions.

In summary, while radon measurement studies are available in several South Asian countries, there is a notable deficiency in research focused on public awareness and education.

Criteria for Eligibility and Inclusion

The eligibility criteria for study selection were as follows: Inclusion criteria included original research articles or government reports focussing on radon risk knowledge, public awareness, or policy gaps related to cancer prevention. Only research published after 2001, covering both empirical data and policy analysis, was considered. Additionally, articles had to provide an analysis of risk perception, public knowledge, and policy frameworks. Exclusion criteria included letters to editors, conference abstracts, as well as studies that did not address radon exposure in the context of public health or policy.

The data analysis focused on two main areas: public awareness and policy measures. For public awareness, academic journals, policy documents, and government reports were analysed to evaluate the level of knowledge about radon exposure and its health risks.
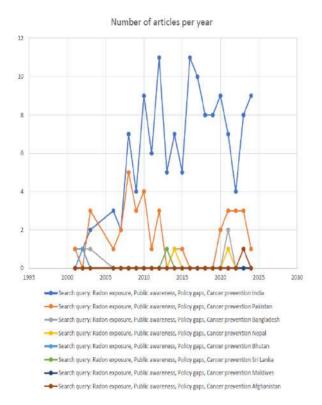
Figure 2. Timeline distribution of the articles included in the systematic review in South Asian Countries
Data Extraction

This analysis included comparing awareness levels with international standards. For policy analysis, existing policies in Sri Lanka were reviewed and evaluated against global best practices. Gaps and areas needing improvement were identified based on this comparison.

3. RESULTS

Search Results and Study Characteristics

Figure 3 shows the article selection process for this review. Initially, 1025 articles (702 + 144 + 179) were identified from the databases. After removing 502 records due to duplication, ineligibility, or other reasons such as language barriers, geographical irrelevance, 523 articles were screened. Of these, 340 were not directly related to the objectives, and 85 could not be retrieved. During the full-text evaluation, 47 more articles were excluded for lack of new data or being too specific or generic. Ultimately, 51 articles were included to compare radon awareness in
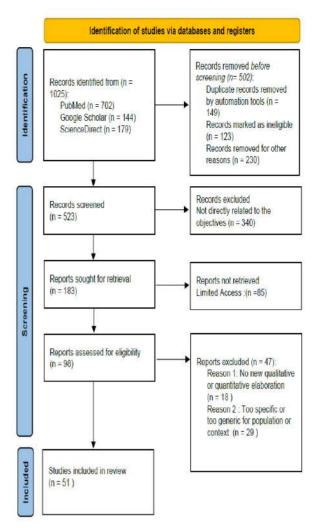
Figure 3. PRISMA 2020 flow diagram

developed countries and South Asian regions, including Sri Lanka.

Overview of Radon Exposure and Health Risks

A radioactive gas called Radon emanates from the ground and can accumulate in constructions, especially in regions with high levels of uranium content in the soil. Academic journals provided insights into global and regional research on radon exposure and public awareness (IAEA, 2013; 'NOTICE : this is the author 's version of a work that was accepted for publication in Journal of Environmental Radioactivity. Changes resulting from the publishing process, such as peer review, editing, corrections, structural formatting, and

ot', 2018; Martin, Ryan, Delaney, David A Kaminsky, *et al.*, 2020; Martin, Ryan, Delaney, David A. Kaminsky, *et al.*, 2020; Khan, Gomes and Chreim, 2021; Celen *et al.*, 2023; Dessemon *et al.*, 2024; Khan *et al.*, 2024). It can drain into buildings through cracks in walls, floors, and foundations, pre-eminent to its inflation in indoor air (Abed *et al.*, 2024). The primary health risk correlated with radon exposure is lung cancer, which occurs due to the inhalation of radon decay particles that irradiate lung tissues. and significantly increase the risk of developing lung cancer. These particles persevere to emit radiation, which can lead to mutations in lung cells and ultimately result in cancer. Driver molecular alterations have been recently identified in non-small lung cancer (NSCLC), such as somatic mutations (*BRAF, HER2, EGFR, MET*) or chromosomal rearrangements (*ALK, NTRK, ROS1, RET*), mainly in the non-smoking population, where no risk factor has been identified yet (Riudavets *et al.*, 2022). The latency period for radon-instigated lung cancer is typically long, often taking many years or even decades to manifest (Draft, no date). Nevertheless, the severity of the health risk is contingent on the concentration of radon, the continuation of exposure, and individual factors such as smoking habits (Lantz, Mendez and Philbert, 2013).

Epidemiological studies have consistently illustrated a clear correlation between radon exposure and lung cancer risk. According to the World Health Organisation (WHO), approximately 3% to 14% of lung cancers are allocated to radon exposure, depending on the average radon concentration in a given geographical area and the prevalence of smoking (WHO, 2007). Even at low levels of radon exposure, there is no safe threshold, and any proportion of radon inhalation conveys a risk of lung cancer.

While lung cancer is the most well-documented health risk of radon exposure, emerging research suggests that radon may also be associated with other respiratory conditions. Some studies have designated a potential association between radon exposure and chronic obstructive pulmonary disease (COPD), though the evidence is less robust compared to lung cancer (Figure 4) (Turner *et al.*, 2012). The inhalation of radon progeny may contribute to the development or exacerbation of respiratory illnesses by causing

oxidative stress and inflammation in lung tissues (Chen *et al.*, 2020). However, further research is needed to fully understand these syndicates and the mechanisms behind them.
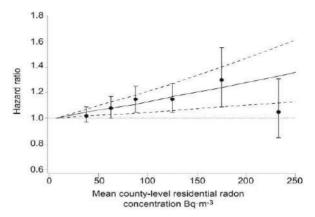

Figure 4: Adjusted hazard ratios with 95% confidence intervals for COPD mortality were analysed in relation to categorical and continuous indicators of mean residential radon concentrations (Lawrence Berkeley National Laboratory, Berkeley, CA, USA) from 1982–2006 in the American Cancer Society Cancer Prevention Study-II. Reference category: <25 Bq·m⁻³ (Turner *et al.*, 2012).

In addition to respiratory diseases, there is expanding concern about the potential for radon exposure to cause other types of cancers, such as leukaemia and other hematologic malignancies. While the evidence remains indeterminate, some studies have indicated a possible link between radon exposure and an increased risk of leukaemia, especially in children (Ngoc, Park and Lee, 2022). The hypothesised mechanism necessitates the damage to bone marrow cells by radon decay products, leading to mutations that could result in leukaemia (Bräuner *et al.*, 2010). However, these findings are still under investigation, and more conscientious studies are needed to authenticate any causal relationships.

Public Awareness of Radon Exposure

Globally, public awareness of radon exposure fluctuates significantly. In countries such as the United States and Canada, radon awareness programmes and mitigation strategies have been implemented extensively. These programmes often incorporate public education campaigns, radon testing

resourcefulness, and construction regulations to minimize radon levels. Furthermore, in many developing countries, including Sri Lanka, awareness is limited. Factors influencing public awareness include insufficiency of information, inadequate testing facilities, and limited media coverage. Studies have shown that strengthened public awareness about radon can guide to higher rates of testing and mitigation, thus lowering health risks (Neri *et al.*, 2018).

Policy Measures for Radon and Cancer Prevention

Effective policies for radon and cancer prevention often necessitate a coalescence of public awareness initiatives, and regulatory measures, and contribute to research. Countries with strong radon policies consistently have guidelines for radon testing in homes and workplaces, standards for radon levels, and requirements for radon mitigation in new and existing buildings (World Health Organisation, no date). In addition, policies may include reinforcement for radon research and funding for public health campaigns. Identifying and communicating policy gaps is decisive for developing comprehensive strategies to anticipate radon-induced lung cancer.

Public Awareness of Radon Exposure in Developed Countries

In developed countries, public awareness of radon exposure differs, but there has been a significant prominence on education and prevention due to the acknowledged health risks corresponding with radon. This section provides a recapitulation of how different developed countries address radon awareness and its influence:

1. United States

In the United States, social awareness of radon is proportionately high due to considerable public education campaigns and safety legislation. The American Lung Association (ALA) and the Environmental Protection Agency (EPA) have led initiatives to educate the public about radon risks (Howlader N, Noone AM, Krapcho M, Miller D, Brest A, Yu M, Ruhl J, Tatalovich Z, Mariotto A, Lewis DR, Chen HS, Feuer EJ, 2010; Program, Ground and Unlimited, 2012).The EPA provides guidelines for radon testing and mitigation and has advanced

educational materials that are broadly distributed (United States Enviomental Protection Agency, no date). Additionally, many states have radon programmes that offer free or low-cost radon testing kits, conduct public transcend, and provide information on how to mitigate radon levels in homes (Department of Health, no date; Health, no date; Montana.gov, no date; Official Pennsylvania Government Website, no date; State and Health, no date; United States Enviomental Protection Agency, no date; EPA, 2016). The National Radon Action Plan aims to decrease radon-related lung cancer by expanding testing, mitigation, and public education (The Authors Team, 2022).

2. Canada

Canada has also made considerable intentions to elevate awareness about radon. Health Canada and provincial agencies encourage radon testing and mitigation through public education campaigns, which include informational brochures, websites, and media outreach. The Canadian government has established radon guidelines and encourages homeowners to test for radon, particularly in areas known to have elevated radon levels. The Canadian Home Builders' Association and other organisations collaborate to integrate radon-resistant construction practices in new homes. Public awareness is further reinforced by research on radon levels and health risks, which aids inform and updating safety recommendations (Control, no date; Government of Canada, no date; Manitoba Health, no date).

3. United Kingdom

In the United Kingdom, the awareness of radon exposure has been accompanied by initiatives from Public Health England (PHE) and the Health Protection Agency (HPA). PHE anticipates information on radon risks, testing, and mitigation through its website and public health campaigns. The UK Radon Association and other organisations provide resources and guidance for homeowners and builders. The government has established radon action levels and dispenses support for testing and remediation in homes and workplaces. Awareness is elevated by localised radon maps that help recognise areas with higher radon potential,

promoting targeted testing and preventive measures (Authors Team, 2018; UK Data Service, 2021).

4. Australia

In Australia, radon awareness is less conspicuous compared to some other developed countries, but attempts are increasing. The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) furnishes information on radon and its health risks, though public education is not as extensive as in the U.S. or Canada. The focus has been on research and monitoring radon levels in areas where geological conditions are known to produce higher radon concentrations (Figure 5) (Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), no date). Public awareness is primarily raised through specified studies and occasional outreach campaigns, with a slighter emphasis on widespread testing and mitigation programmes.

Figure 5: Hierarchy of Controls Pyramid in Response to Natural Radon Exposure (Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), no date).

5. European Union

Across the European Union, awareness of radon fluctuates by country. The European Commission reinforces radon awareness through its Radiation Protection programme, which contributes guidelines and recommendations for member states. Countries such as Sweden, Switzerland, and Germany have strong radon awareness programmes, with comprehensive public education campaigns, testing initiatives, and regulatory frameworks (Rivki *et al.*, no date;

Strahlenschutz, no date; Piller and Johner (INVITED), 1998; Akerblom *et al.*, 2000; Roserens, 2000; Wichmann *et al.*, 2006; Khan *et al.*, 2021; Petermann and Bossew, 2021; Vienneau *et al.*, 2021). In contrast, awareness is slighter developed in some Southern and Eastern European countries, where radon risks may be higher but public knowledge and testing rates are lower (Sarrou and Pashalidis, 2003; Vukotic *et al.*, 2008; Clouvas, Xanthos and Takoudis, 2011; Celebi *et al.*, 2014; Tushe *et al.*, 2019; Savković *et al.*, 2020; Coretchi, Ene and Ababii, 2021).

Overall Impact

In developed countries with high levels of public awareness, radon testing and mitigation efforts have led to a convalescent understanding of radon risks and refined public health outcomes. Education campaigns, government regulations, and community transcends play significant roles in amplifying awareness and decreasing radon-related health risks. Additionally, the extent of public awareness and the effectiveness of radon mitigation impacts can still differ, emphasising the requirements for continued education and policy reinforcement to address radon exposure effectively.

Public Awareness of Radon Exposure in South Asian Countries

Radon awareness across South Asian countries is generally low, with significant discrepancies in public education, government initiatives, and research efforts. This region, consisting of Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, and Sri Lanka, faces unique challenges related to radon awareness due to diverging levels of economic development, public health infrastructure, and environmental priorities. This section provides an overview of radon awareness in the selected countries:

1. India

In India, public awareness of radon exposure is deficient, although some progression has been made through research and localised studies. The Bhabha Atomic Research Centre and other scientific institutions have supervised studies to map radon levels in distinct regions of the country, especially in areas with high uranium content in the soil (Ramachandran *et al.*, 2003; Raghavendra *et al.*, 2014; Singh *et al.*, 2015a,

2015b). However, these studies are substantially constricted to academic circles and have not translated into general public awareness. Government efforts to educate the public about radon are minimal, and there are no national campaigns or policies specifically targeting radon testing or mitigation. Awareness is predominantly confined to professionals in the fields of radiation protection and environmental science.

2. Pakistan

In Pakistan, radon awareness is similarly low. Research on radon exposure has been conducted by institutions such as the Pakistan Atomic Energy Commission (PAEC), but public dissemination of information is limited. The general public is substantially unaware of the health risks related with radon exposure, and there are no significant government-led initiatives to encourage radon awareness (Matiullah *et al.*, 2003; Rahman, Anwar and Matiullah, 2008; Matiullah and Muhammad, 2016; Matiullh and Muhammad, 2016; Ahmad *et al.*, 2018; Shah *et al.*, 2024). Public health campaigns in Pakistan have traditionally focussed on more immediate health concerns, such as infectious diseases, rather than long-term environmental risks like radon exposure.

3. Bangladesh

In Bangladesh, the awareness of radon exposure is minimal, with insufficient public education or government intervention in this area. Research on radon levels has been accompanied by universities and research institutions, but these studies are not broadly known outside academic circles (Srivastava *et al.*, 2001; Srivastava, 2005b, 2005a; Hasan *et al.*, 2021, 2023). The deficiency of public awareness campaigns and governmental focus on radon mitigation contributes to the general unawareness of radon risks among the population. Comparable to other South Asian countries, Bangladesh's public health priorities have largely been concentrated on communicable diseases and disaster management, with radon exposure receiving little attention.

4. Nepal

Nepal faces indistinguishable challenges in terms of radon awareness. The country's mountainous territory and geological conditions make it susceptible to diverse

radon levels, but public knowledge about radon risks remains low. Several studies have been conducted to assess radon concentrations in different regions, but there has been a miniature effort to translate these findings into public awareness or policy measures (Thapa and Shah, 2014; Rijal *et al.*, 2021). The government and public health agencies have not prioritised radon assessing or mitigation, leaving the population predominantly uninformed about the potential precariousness of radon exposure.

5. Bhutan

In Bhutan, there is constrained awareness of radon exposure among the general population. The country has not conducted extensive research on radon levels, and there is an insufficiency of public education initiatives or government policies conveying radon risks. Bhutan's centralisation on environmental conservation and sustainable development does not currently include radom awareness, and the issue remains largely unexplored in public discourse (Virk, Sharma and Sharma, 2002).
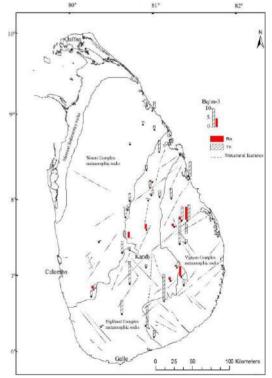

Figure 6: Radon (^{222}Rn) and thoron (^{220}Rn) distribution in the geographical locations in Sri Lanka (Nalaka *et al.*, 2013)

. 6. Sri Lanka

In Sri Lanka, public awareness of radon exposure is also quite low, as highlighted by limited research and a lack of government-led awareness campaigns. While several academic studies have been conducted to measure radon levels in various divisions of the country, these findings have not been widely distributed to the public (Nalaka *et al.*, 2013). Most people in Sri Lanka are unaware of the health risks associated with radon, and there are no national policies or guidelines particularly addressing radon testing or mitigation (Figure 6).

7. Maldives

The Maldives has almost no public awareness of radon exposure. Given the country's unique geography, with shallow islands and minimal mineral content in the soil, radon is not seen as a significant public health concern. As a result, there is no research, public education, or policy efforts associated with radon in the Maldives.

8. Afghanistan

Afghanistan, like other South Asian countries, has low public awareness of radon exposure. The country's occurring political and economic challenges have led to a focus on more immediate health and security issues, abrogation of radon exposure and its associated risks largely unaddressed. There has been minimal research on radon levels, and public health campaigns do not include radon awareness as a priority (Janik *et al.*, 2023).

Overall Impact

In South Asian countries, public awareness of radon exposure is generally low, with limited research and minimal government intermediation. The insufficiency of widespread public education and the inadequacy of national guidelines or policies on radon testing and mitigation contribute to the region's vulnerability to radon-related health risks. Broadening public awareness, encouraging research, and advancement of regulatory frameworks are essential steps to mitigate these risks and protect public health in South Asian region.

4. DISCUSSION

Implications of Findings

The review reveals that public awareness of radon exposure in Sri Lanka is alarmingly low. There is a noticeable lack of enriched information sources available online and offline that cater to the Sri Lankan population. Most existing resources are either technical, aimed at professionals, or are not tailored to the local context, making them less accessible to the general public. While developed nations such as the United States, Canada, and the United Kingdom have established regulations mandating radon testing in homes, schools, and workplaces, Sri Lanka lags significantly in this area.

The absence of large-scale public health campaigns specifically aimed at raising awareness about radon exposure is another factor contributing to the knowledge gap in Sri Lanka. In developed countries, public health agencies actively promote educational campaigns through television, radio, and digital platforms, informing the public about the potential health risks of radon exposure. In Sri Lanka, however, there have been no substantial efforts to inform the general public through similar outreach initiatives. Additionally, outreach to rural and high-risk communities where radon exposure might be more prevalent due to geological factors is almost non-existent. In contrast, developed countries target these areas with tailored campaigns to ensure that even the most vulnerable populations are informed about testing options and mitigation strategies.

Another key factor hindering public understanding of radon exposure in Sri Lanka is the lack of substantial academic research and local data. In contrast to developed nations where universities and research institutions actively study radon exposure, Sri Lankan academic bodies have not contributed significantly to this area of public health. The scarcity of local research makes it difficult for policymakers to create evidence-based interventions, further widening the gap between academic insight and public policy.

Cultural perceptions and the focus on more immediate health threats such as dengue fever, tuberculosis, and chronic diseases have also contributed to the limited

awareness about radon exposure in Sri Lanka. Radon exposure may be seen as a distant or insignificant threat compared to more visible or pressing health concerns. This contrasts with the situation in many developed countries, where radon exposure is perceived as a serious public health issue due to extensive awareness campaigns and media coverage.

Mainstream media in Sri Lanka rarely covers the topic of radon exposure, further contributing to the lack of public knowledge. In contrast, many developed countries regularly highlight radon risks through news reports, public service announcements, and even social media campaigns. The digital presence of radon-related information is also lacking in Sri Lanka.

Finally, economic factors play a role in limiting public awareness and testing. While radon exposure may be seen as a serious health issue in developed countries, where economies can support extensive public health measures, Sri Lanka's economic priorities may differ. Addressing immediate public health concerns such as communicable diseases and poverty alleviation may take precedence over longer-term, less visible risks like radon exposure. Additionally, even if awareness were to increase, the costs associated with radon testing and mitigation could prove prohibitive for many families, especially in rural areas with lower economic means.

Policy Measures

In Sri Lanka, the Sri Lanka Atomic Energy Board offers a specialised Radiation Monitoring Service to institutions and individuals for measuring radioactivity, radiation levels, contamination, dose rates, or radon concentration. This service is available through both laboratory measurements and in-field/in-situ assessments. It is particularly beneficial for irregular objects such as mineral samples (including semi-precious gems), unspecified minerals, and other suspicious materials. The techniques engaged are non-destructive, acknowledging a precise approximation of radioactivity levels and radioisotope configuration without damaging the samples (SRI LANKA ATOMIC ENERGY BOARD, no date). Despite the availability of this advanced monitoring service, Sri Lanka still faces significant challenges in addressing radon exposure at a policy level.

Relationship between This Review and Previous Studies

Public awareness of radon exposure varies significantly worldwide. Developed countries like the United States and Canada have implemented extensive radon awareness programs, including educational campaigns and testing regulations, leading to reduced health risks associated with radon. For example, the American Lung Association and the Environmental Protection Agency (EPA) in the U.S. have successfully raised awareness, resulting in increased testing and mitigation efforts. In contrast, many developing countries, including Sri Lanka, face challenges that hinder awareness, such as insufficient information, limited testing facilities, and minimal media coverage. Consequently, the general population remains largely uninformed about radon risks and mitigation strategies.

Theory, Practice, and Policy Formulation

The absence of effective public health campaigns in Sri Lanka further exacerbates this issue. Unlike developed nations that utilise various platforms to disseminate information, Sri Lanka lacks substantial outreach efforts, especially in rural and high-risk communities. Cultural perceptions prioritise immediate health threats, such as infectious diseases, over long-term risks like radon exposure. Additionally, a scarcity of local research and data on radon limits policymakers' ability to create evidence-based interventions, widening the gap between academic findings and public policy.

Economic factors also play a role in limiting awareness and testing. Public health initiatives in Sri Lanka often focus on pressing health issues, leaving radon exposure as a low priority. Even if awareness were to improve, the costs associated with radon testing and mitigation could be prohibitive for many families, particularly in economically disadvantaged areas.

Overall, addressing these gaps in public awareness and policy is crucial for improving health outcomes in Sri Lanka. Initiatives must prioritise education, research, and resource allocation to effectively tackle the risks associated with radon exposure and enhance public health awareness.

5. CONCLUSION

This review highlights the critical gaps in public awareness and policy regarding radon exposure, particularly in Sri Lanka compared to developed countries. While extensive awareness initiatives in nations like the United States and Canada have successfully reduced radon-related health risks, similar efforts in Sri Lanka are virtually non-existent. The lack of public education campaigns, inadequate testing facilities, and minimal research contribute to a widespread unawareness of the dangers posed by radon. Increasing public awareness through targeted outreach, especially in high-risk communities, and establishing regulatory measures for radon testing and mitigation are vital steps toward enhancing public health. Addressing these issues will not only protect the population from radon-related health risks but also foster a more informed society capable of making safer choices regarding their environmental health.

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PLANKTON ASSEMBLAGE AND POTENTIAL INDICATOR SPECIES FOR WATER QUALITY ASSESSMENT IN SELECTED WETLANDS IN COLOMBO

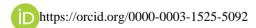HDCS Perera , BDIM Batugedara, MTV Kolambage and SAMAIK Senanayake

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ABSTRACT

Wetlands are considered one of the most productive ecosystems on Earth. Plankton is an essential part of wetland biodiversity and vital to wetland functioning. Plankton is an ideal bioindicator for assessing wetlands' water quality and environmental status. This study was carried out to determine plankton assemblage and to identify potential indicator species for water quality assessment in selected wetlands in Colombo Ramsar Wetland City, including Nawala Wetland Park, Diyatha Uyana, Diayasaru Park, and Beddagana Wetland Park. Water and plankton samples were collected for four months (October 2022- February 2023). Both phytoplankton and zooplankton were studied. During the study period, 39 phytoplankton and 24 zooplankton species were reported. The identified phytoplankton species were categorised into three prominent families: Bacillariophyceae, Chlorophyceae, and Cyanophyceae. Genus Melosira was recorded as the Most abundant species *in all wetlands (more than 50%). Identified zooplankton were categorized into three main groups: Rotifera, Copepoda, and Ichthyoplankton. Rotifers were the dominant zooplankton group, and Keratella spp.; Brachionus spp. were dominant in all wetlands. Pediastrum spp., Chlorella sp., Closterium sp., Phacus sp., Euglena sp., Melosira spp., Microcystis spp., Navicula sp., Oscillatoria sp., Scenedesmus sp., and Synedra sp., Keratella spp., Brachionus spp., and Lecane spp. were identified as potential bioindicators for pollution. According to the Shannon-Wiener diversity index, phytoplankton diversity is higher than zooplankton diversity. Fourteen indicator species were observed, exhibiting varying levels of abundance. Most of them are indicators of pollution. Hence, it may be inferred that the population density of these species was relatively high, and the degree of contamination in the wetland was also found to be high.*

KEYWORDS: *Wetlands, Water quality, Plankton, Bioindicators*

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1. INTRODUCTION

Wetlands are crucial for safeguarding global biodiversity as they serve as hotspots for different species (Alikhani *et al.*, 2021). Wetland ecosystem services are estimated to have the highest value per hectare of any ecosystem. Moreover, 47% of all global ecosystem values come from the services provided by wetlands. (Xu *et al.*, 2019). Therefore, wetlands are considered one of the planet's most essential and productive ecosystems.

However, wetlands are among the most threatened habitats globally (Davidson, 2014; Assefa *et al.*, 2022). Worldwide inland wetland loss is 69–75% in the twentieth century and has increased in the twenty-first century (Davidson, 2014). Over one-third of the wetlands have disappeared in the first two decades of the twenty-first century around the world (Assefa *et al.*, 2022). Nevertheless, in the past 100 years, almost 50% of the world's wetlands have degraded and are lost due to human interference, and the degradation of wetlands is continuing (Wu and Chen, 2020).

Physio-chemical characteristics of the water in wetlands can be used to evaluate the status of wetlands (Wijeyaratne and Nanayakkara, 2020). Bioindicators are living organisms that can be utilized to monitor the health of natural ecosystems (Parmar, Rawtani, and Agrawal, 2016). Aquatic organisms such as plankton are used as biological indicators to determine water quality, such as collecting, counting, and identifying species (Soetignya et al., 2021).

Plankton are aquatic organisms that inhabit the water column. They comprise phytoplankton (unicellular plants) and zooplankton (millimeters or less small animals) that drift on the currents (Harris and Vinobaba, 2012). Due to their short life cycle, plankton respond rapidly to anthropogenic environmental changes and disturbances, which can be considered early-warning signs that indicate the overall condition of an aquatic system (Singh *et al.*, 2013). Therefore, planktons are very useful for identifying the condition of the water body and have been widely used in assessing the quality of the water (Parmar, Rawtani, and Agrawal, 2016; Hemraj *et al.*, 2017). Furthermore, plankton are ideal bioindicators

that assess water status and quality in wetlands (Wijeyaratne and Nanayakkara, 2020; Kahsay *et al.*, 2022).

Globally, wetland ecosystems are under pressure from rapidly increasing urban populations (Ehrenfeld, 2000). Hydrological conditions in wetlands induce habitat heterogeneity (Chaparro *et al.*, 2018). Frequent water quality and pollution assessment is necessary to minimise further wetland damage. Sri Lanka is a rapidly urbanising country in South Asia. In Colombo, the commercial capital of Sri Lanka, wetlands are alarmingly reducing because of the area's high urbanisation and development projects (Munaweera and Bandara, 2021). Colombo was declared a Ramsar wetland city in 2018 by Ramsar, and it is the first capital to become a Ramsar wetland city in the world (Wijeyaratne and Nanayakkara 2020). Over the past 30 years, 40% of Colombo's wetlands have been lost because of direct and indirect influences. Therefore, determining the status of Colombo wetlands is crucial. However, fewer previous studies have been reported in plankton-based studies conducted in Colombo wetlands (Wijeyaratne and Nanayakkara, 2020; Wickramasinghe *et al.*, 2012). Most of the previous studies were focussed on the assessments of biological and physicochemical parameters from the whole wetland area of Diyawanna Oya. They lack detailed, site-specific studies that examine water quality conditions in each wetland. This approach will allow to identify more targeted conservation strategies and management practices, which are essential for protecting the unique ecological roles that different wetlands play. Therefore, the current study was conducted to determine the water quality status of some selected wetlands in Colombo, with particular emphasis on plankton communities as indicators.

2. MATERIALS AND METHODS

A. *Study area*

The present study was conducted in four selected wetlands in Colombo, Sri Lanka, which are connected to Diyawanna Oya (Figure 1), including Nawala Wetland Park, Diyatha Uyana Wetland Park, Diyasaru Wetland Park, and Beddagana Wetland Park.
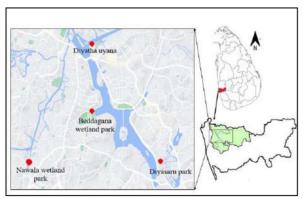
Figure 1. Map of the study area

B. Sampling
i) Plankton sampling

Plankton samples were collected every month from October 2022 to February 2023 using a 55 µm mesh-sized plankton net. Three samples were collected from each wetland each month. Lugol's solution and 4% formalin were used immediately to preserve the plankton samples, which were then transported to the laboratory for further analysis.

ii) Water sampling

The sampling locations within wetlands were chosen from four directions, namely site 1 (West), site 2 (North), site 3 (East), and site 4 (South) in each wetland within the same distance. Water samples were collected during the same period. Water samples were collected into high-density polythene screw-capped bottles (500mL) for laboratory analysis of water quality parameters. Glass bottles (250mL) were used to collect water samples to determine Dissolved Oxygen (DO) and Biological Oxygen Demand (BOD). Collected water samples were labelled and placed in an insulated box before transportation to the laboratory.

C. Sample analysis
i) Plankton analysis

Plankton were identified to the lowest possible taxonomic level and counted using a light microscope at 10×10 magnification. Their abundance was calculated using a Sedgwick rafter counting chamber (SRC) for quantitative investigations.

ii) Water sample analysis

Physical parameters, including temperature, total dissolved solids, pH, salinity, and electrical conductivity, were measured at the site. DO, BOD_5, total phosphate, and nitrate concentrations were measured in the laboratory using standard methods (APHA, 2017) (Table 1).

Table 1. Water sample analysis methods

Parameter	Test method
1. Temperature	Thermometric (Thermometer)
2. pH	Electrometric (pH meter - pH400S)
3. Electrical conductivity (EC)	Electrometric (Conductivity meter - HQ14d)
4. Total Dissolved Solids (TDS)	
5. Salinity	
6. Dissolved Oxygen (DO)	Titrimetric (Winkler's method)
7. Biological Oxygen Demand (BOD_5)	
8. Nitrate	Spectrometric (Sodium salicylate method)
9. Total Phosphate	Spectrometric (Phospho-vanado-molybdate method)

D. Data analysis
i) Calculation of plankton abundance

Zooplankton and phytoplankton were counted using a Sedgwick rafter counting cell. The following equation was used to calculate the abundance of plankton cells/m^3 units (Soetignya et al., 2021).

$$N = n \times V_t / V_{src} \times A_{src} / A_a \times 1 / V_d$$

Where,

N = Plankton abundance (cells/m^3)
n = number of observed plankton
V_t = volume of water in the sample bottle (mL)
V_{src} = volume of water in the SRC (mL)
A_{src} = SRC's area of view (1000 mm^2)
A_a = area of view (mm^2)
V_d = volume of filtered water sample (m^3)

ii) Calculation of Shannon-Wiener diversity index (H') and Pielou's evenness index (J)

The Shannon-Wiener diversity index was used to calculate species diversity in the samples. The Shannon-wiener diversity index was used to determine the pollution level and condition of the plankton. H′ values of 0–1, 1– 2, 2–3, and > 3 represent heavy, moderate, light, and no pollution, respectively. If H′<, the biota community is unstable and 1<H′ 3, the biota community is stable.

The following formula was used for the calculations (Soetignya et al., 2021)

$$H' = - \sum p_i \ln p_i$$

Where,

n_i = number of individual species [th]
N = total number of individuals
$P_i = n_i/N$

Pielou's evenness index (J) was calculated using the following equation,

$$J = H'/\ln S$$

Where,

S = Number of species encountered

Evenness measures the relative abundance of various species in a given area. If evenness is 1, all species were perfectly even in site. J values of 0-0.3, 0.3-0.5 and >0.5 represent heavy, moderate, and light or no pollution, respectively (Zhu et al., 2021).

iii) Calculation of Simpson's Dominance Index (C)

The Simpson Dominance Index was used to identify the dominance of species in the wetlands. The Simpson index was calculated using the following equation.

$$C = \sum (p_i)^2 = (n_i / N)^2$$

Where,

N = total number of individuals
n_i = number of individual species
The index values are in the 0 to 1 range. If the value is close to 0, the community has no dominating genus; if it is close to 1, there is a dominant genus (Soetignya et al., 2021).

iv) Similarity index / Sorenson's coefficient (CC)

Sorenson's coefficient (CC) was calculated to determine the similarity between the different communities. The range of Sorenson's coefficient is 0 to 1. The closer the value is to 1, the more communities share similarities (Khatri et al., 2022).

Sorenson's coefficient was calculated using the following equation,

$$CC = 2C/ (S1+S2)$$

Where,

C = number of species the two communities have in common
S1 = total number of species found in community 1
S2 = total number of species found in community 2

v) Statistical analysis

Pearson correlation analysis was used to determine the relationship between water quality parameters. A one-way ANOVA test was employed to find significant differences between parameters. Microsoft Office Excel 2013 and Minitab 18.1 software were used for calculations and statistical analysis.

3. RESULTS AND DISCUSSION

A. Plankton identification
i) Plankton distribution and diversity

During the study period, 39 phytoplankton species belonging to three main groups (Bacilariophycea, Cynophycea, and Chlorophycea) were recorded from the four wetlands (Table 2, Figure 3). In addition, 24 zooplankton species belonging to three groups (Copepods, Rotifers, and Ichthyoplankton) were identified (Table 2, Figure 4). Figure 2 displays some of the observed plankton species during the study.

Table 2. Identified plankton species and their occurrence during the study period in wetlands

Plankton Group	Species	Number of species	Nawala	Diyatha	Diyasaru	Beddagana
Phytoplankton						
Bacillariophyceae (Diatom)	*Asterionella* sp.	1			+	+
	Attheya sp.	1	+			
	Cymbella sp.	1	+			

Plankton Group	Species	Number of species	Nawala	Diyatha	Diyasaru	Beddagana
	Melosira spp.	3	+	+	+	+
	Navicula sp.	1		+	+	+
	Nitzchia sp.	1		+	+	
	Synedra sp.	1			+	
Chlorophyceae (Green Algae)	*Actinastrum* sp.	1			+	
	Chlorella sp.	1		+	+	+
	Coelastrum sp.	1	+	+		
	Gonium sp.	1	+			
	Monactinus spp.	2		+	+	
	Pandorina sp.	1	+			+
	Pediastrum duplex	1		+	+	
	Pediastrum simplex	1	+	+	+	+
	Pediastrum spp.	2	+	+	+	
	Scenedesmus spp.	2		+	+	
	Staurastrum spp.	2	+	+	+	
	Tetraselmis sp.	1		+	+	
	Tetraedron sp.	1			+	
Cyanophyceae (Blue Green Algae)	*Anabena* sp.	1				+
	Lyngbya sp.	1			+	
	Microcystis spp.	3	+	+	+	+
	Ocillatoria sp.	1		+	+	+
	Nostoc spp.	2				+
	Spirulina sp.	1	+	+		
Euglenophycea	*Euglena* sp.	1		+		
	Phacus spp.	2		+		
	Unidentified sp.3	1	+	+		
	Unidentified sp.4	1	+	+		
Zooplankton						
Copepods	*Cyclops* spp.	3	+	+	+	+
	Nauplius	3	+	+	+	+
Rotifers	*Brachionus angularis*	1			+	
	Brachionus falcatus	1		+	+	
	Brachionus spp.	2	+	+	+	+
	Filinia sp.	1	+			
	Karetella	1	+		+	

Plankton Group	Species	Number of species	Nawala	Diyatha	Diyasaru	Beddagana
	cochlearis					
	Karetella spp.	3	+	+	+	+
	Lecane spp.	2	+	+	+	
	Lecane luna	1	+	+	+	
	Polyathra sp.	1	+	+	+	
	Polyathra vulgaris	1	+	+		
Ichthyoplankton		2	+	+	+	+
	Unidentified sp.1	1	+	+	+	+
	Unidentified sp.2	1	+			
+ indicate the presence of the species						
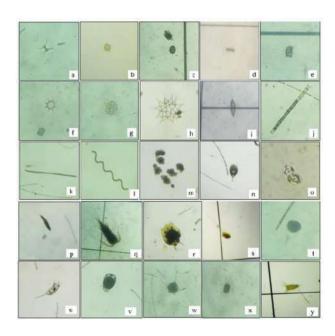
Figure 2. Some recorded plankton species (a) *Staurodesmus* **sp. (b)** *Gonium* **sp. (c)** *Coelastrum* **sp. (d)** *Scenedesmus* **sp. (e)** *Pandorina* **sp. (f)** *Pediastrum simplex* **(g)** *Pediastrum duplex* **(h)** *Pediastrum* **sp. (k)** *Ocillatoria* **sp.(l)** *Spirulina* **sp. (m)** *Microcystis* **spp.** *(n)* *Phacus* **sp. (o) unidentified sp. 3 (p)** *Euglena* **sp. (q) Copepod (r)** *Brachionus* **sp. (s) unidentified sp. 1 (t)**

unidentified sp. 2 (u) *Keratella* **sp. (v)** *Lecane* **sp. (w)** *Filinia* **sp. (x)** *Polyathra* **sp. (y) Nauplii**
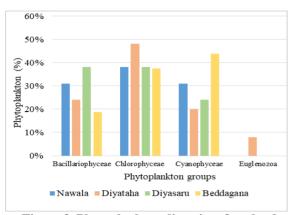

Figure 3. Phytoplankton diversity of wetlands

Chlorophycea was the most diverse phytoplankton group in wetlands. Besides the three main groups (Chlorophycea, bacilariophycea, and cyanophycea), two plankton species from class Euglenoidea were recorded in Diyatha. The highest number of phytoplankton species was found in Diyatha wetland. The lowest diverse phytoplankton community was found in the Nawala wetland. Previously, the presence of phytoplankton species such as *Pediastrum* spp., *Melosira* sp., *Synedra* sp., *Cymbella* sp., *Navicula* sp., *Spirulina* sp., *Microcystis* spp., and *Scenedesmus* sp. have been reported from the selected sites in the Diyawanna Wetland System (Wijeyaratne and Nanayakkara, 2020).

Melosira spp. was recorded as the dominant species in all wetlands. The other major phytoplankton in study sites were *Pediastrum spp, and Microcystis spp.*. Some of the recorded phytoplankton species were identified as potential bioindicators of pollution in the studied wetlands. The occurrence of such species as *Pediastrum* spp*., Melosira* spp., and *Microcystis* spp. is a terrific indicator of pollution (Harris and Vinobaba, 2013; Wijeyaratne and Nanayakkara, 2020; Heramza et al., 2021). *Microcystis* spp. requires a relatively low phosphorus amount and can utilise sulfur instead of phosphorus in its metabolism. It indicates that *Microcystis* spp. can be adapted to tolerate changes in water chemistry. *Melosira* spp. is opportunistic and well-adapted to environmental fluctuations (Heramza *et al*., 2021). *Pediastrum*

simplex and *Pediastrum duplex* were identified as potential eutrophication indicators because these two species are increasing their number in response to increased nutrient concentrations (Wijeyaratne and Nanayakkara, 2020).

Pediastrum spp. *Chlorella* sp., *Closterium* sp*., Euglena sp., phacus* sp., *Melosira* spp., *Microcystis* spp*., Navicula sp., Oscillatoria* sp*., Scenedesmus* sp*.,* and *Synedra* sp., *Cymbella* sp. were identified as indicator phytoplankton in eutrophic water bodies (Abubacker *et al*.,1996; Harris and Vinobaba, 2013; Wijeyaratne and Nanayakkara, 2020; Heramza *et al*., 2021). Furthermore, phytoplankton genera such as Melosira, Navicula, Pandorina, Phacus, Chlorella, Synedra, Pediastrum, Actinastrum, Coelastrum, and Nitzschia were identified as organic pollution indicators (Palmer,1969).
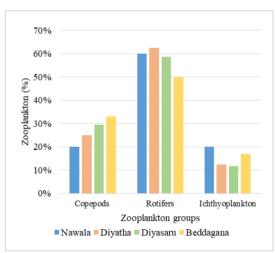

Figure 4. Zooplankton diversity of wetland

In four wetlands, copepods, rotifers, and ichthyoplankton were recorded as zooplankton (Figure 4). The group rotifers were the most diverse zooplankton group in wetlands. Among rotifers, *Brachionus* spp. and *Keratella* spp. were most dominant in all wetlands. However, zooplankton's diversity was generally lower in wetlands than phytoplankton.

Like the present study, Rotifers have been recorded as the most diverse zooplankton group in the Kotte Kolonnawa wetland, Sri Lanka (Wickramasinghe *et al*., 2012). Rotifers belonging to the Brachionidae family are known to be strongly associated with water

eutrophication (Houssou *et al*., 2018). *Keratella* spp., *Brachionus* spp., and *Lecane* spp. were identified as indicator zooplankton in eutrophic water bodies (Houssou *et al*., 2018). Due to the aforementioned zooplankton species, the four wetlands are more likely to be eutrophic. Industrial runoff, urbanised catchment areas, and anthropogenic activities mostly cause the eutrophication in these wetlands. According to Goel and Chavan (1991), *Brachionus* sp. and *Keratella* sp. are organic pollution indicators. Therefore, Brachionus spp. and Keratella spp were present. indicates organic pollution in these wetlands. However, zooplankton's diversity was generally lower in wetlands than phytoplankton.

ii) Plankton abundance

The average plankton densities of the wetlands were 176 cell/L, 166 cell/L, 172 cell/L, and 68 cell/L in Nawala, Diyatha, Diyasaru, and Beddagana wetlands, respectively (Figure 5). According to one-way ANOVA test results (Table 5), plankton abundances calculated during the study period were not significantly different from each wetland (*p* >0.05). However, the Beddagana wetland had the lowest abundance of plankton compared to other wetlands.
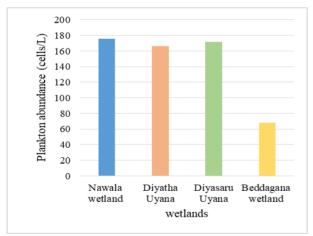

Figure 5. Plankton abundance in wetlands

iii) Development of biotic indices

The calculated Shannon-Wiener diversity index (H '), evenness (J), and Simpson's dominance index (C) values for wetlands are indicated in the table 3.

Shannon-Wiener index (H') was the most popular diversity index among researchers for plankton-based studies (Wu *et al*., 2014). According to the calculated

H' values for zooplankton (0-1) and phytoplankton (1-2), there was a very low level of zooplankton diversity and a low level of phytoplankton diversity, respectively. Although the calculated H' values for phytoplankton are significantly different among wetlands (ANOVA, p=0.03), there was no significant difference (p=0.22) in H' values for zooplankton. High values of H' represent more diverse communities. A community with a single species would have a value of 0 for H', while if the species were distributed evenly H' value would be at a maximum (Wu et al., 2014). Hence, all wetlands have low H' values close to 1 for zooplankton and phytoplankton, which indicates that the studied wetlands did not indicate diverse plankton communities.

H′ values of 0-1, 1-2, 2-3, and >3, respectively, represented as heavy, moderate, light, and no pollution (Zhu *et al*., 2021). Clean water is indicated by Shannon Wiener index values over 3, while polluted water is indicated by values below 3. For all wetlands, H' for zooplankton communities were classified as heavily polluted, while phytoplankton communities at all wetlands were classified as moderately polluted. Previous studies have assessed the Diyawnna Oya wetland area as polluted (Wijeyaratne and Nanayakkara, 2020). H' value decreases with the deterioration of water quality. The Lowest H' value for phytoplankton was recorded in Diyatha wetland. Therefore, Diyatha wetland might have a higher level of pollution. .

Simpson's dominance index (C) values were 0.5 or less than 0.5 for zooplankton and phytoplankton in Diyatha, Diyasaru, and Beddagana wetlands. Nawala wetland has the highest C value for phytoplankton (Table 3).

These diversity indices have been constructed considering species number and relative abundances. This means that if the values of these diversity indices are high, the water body will be in good condition (Thakur *et al*., 2013). The study area is located within a highly urbanised city in Sri Lanka. Waste disposal by households, industrial runoff and other point and non-point pollution sources may influence nutrient enrichment of the area (Hettiarachchi *et al*., 2013). Throughout the study period, all wetlands exhibited

abundant floating aquatic weeds in large quantities. Therefore, the abundance of weeds indicates a eutrophic condition of water bodies.

Simpson dominance index was used to quantify habitat biodiversity and give more weight to common or dominant species (Sharma *et al*., 2015). In the Simpson index, values range between 0 and 1, where values near 0 indicate that species are evenly distributed in communities and there is no single dominant species. Values close to 1 indicate that species are unevenly distributed, which makes dominance of one species. Results of the study showed that the highest C value was recorded for phytoplankton in the Nawala wetland, indicating a dominant phytoplankton species in Nawala. In Nawala wetland, *Melosira* sp. was the most abundant and at 80% of the total phytoplankton density.

Table 3. Shannon-Wiener diversity index (H '), evenness (J), and Simpson's dominance index (C) values for wetlands

Wetland		H '	C	J
Nawala	Phytoplankton	1.6	0.7	0.7
	Zooplankton	1.0	0.4	0.8
Diyatha	Phytoplankton	1.2	0.5	0.4
	Zooplankton	0.8	0.5	0.7
Diyasaru	Phytoplankton	1.6	0.3	0.6
	Zooplankton	1.0	0.4	0.9
Beddagana	Phytoplankton	1.7	0.3	0.7
	Zooplankton	1.0	0.3	1.0

According to Sorenson's Coefficient values presented in Table 4, there was not much similarity between the Nawala and Beddagana wetlands and Diyasaru and Beddagana wetlands. Other wetlands have more similarities. Diyasaru and Diyatha have the highest similar species composition.

Table 4. Sorenson's Coefficient values between wetlands

Wetland	Nawala wetland	Diyatha wetland	Diyasaru wetland
Diyatha wetland	0.6		
Diyasaru wetland	0.5	0.9	
Beddagana wetland	0.3	0.5	0.3

iv) Water Quality Results
Table 5 shows the reported mean values for each wetland's selected water quality parameters during the research period.

Table 5. Water quality parameters

Parameter	Standard value	Mean ±SD				*P* value
		Nawala	Diyatha	Diyasaru	Beddagana	
pH	6-8.5	6.88± 0.04	7.07 ±0.32	6.88± 0.14	6.32± 0.09	**0.001**
Conductivity (µS/cm)	-	346.6 ±29.4	168± 58.9	212.2 ±7.3	131.0 ±21.9	**0.000**
TDS (ppm)	-	170.3 ±32.4	80.3 ±27.3	102.0 ±5.1	68.75 ±5.5	**0.000**
Nitrates (mg/L)	≤ 5 mg/L	1.55± 0.2	0.9± 0.08	0.9±0.08	1.05± 0.52	**0.022**
Total Phosphate (mg/L)	≤ 0.4 mg/L	0.09± 0.009	0.24 ±0.04	0.07± 0.01	0.095 ±1.02	**0.000**
DO (mg/L)	≥ 3 mg/L	7.35± 1.35	7.49 ±2.2	6.52± 1.2	5.93± 1.64	0.548
BOD (mg/L)	≥ 5 mg/L	2.97± 0.78	3.0± 0.98	3.7±0.4	2.7±1.02	0.391
Plankton abundance (cells/L)	-	176±44.5	166± 52.3	147± 35.9	68±78.3	**0.008**

According to the Central Environmental Authority's water quality standards for maintaining healthy aquatic life in Sri Lankan inland waters, the results of the water quality analysis indicate that all the studied wetlands comply with the ambient water quality standards established by CEA (National Environmental (Ambient Water Quality) Regulations, No. 01 of 2019).

Physiochemical paramters indicate that water bodies of these wetlands are safe for aquatic life but not suitable for human consumption according to Sri Lankan standards. Eventhough, biological parameters indicate pollution in each wetland, water quality parameters show wetlands provide basic enviornmental conditions that allow life to thrive. Biological indicators suggest that some organisms are being affected, but the water quality has not reached the point where life cannot persist. Despite the pollution, water body supports the growth of life though the ecosystem may not be in its healthiest state.

In Nawala wetland, EC and temperature (0.983), BOD and DO (0.949) nitrate and TDS (0.888), Total phosphate and EC (0.967) showed strong positive correlations. In Diyatha wetland, pH and EC (0.914), TDS and EC (1.0), TDS and pH (0.912), and DO and BOD (0.933) showed strong positive correlations. Nitrate and total phosphate (-0.860) showed a strong negative correlation. It indicates that if one variable increases the other variable tend to decrease. In Diyasaru wetland, EC and TDS (0.894), DO and BOD (0.907), DO and nitrate (0.750), pH and nitrate (0.912) showed strong positive correlations while EC and nitrate (-0.831) showed a strong negative correlation. In Beddagana wetland, EC and TDS (0.963), BOD and DO (0.930), phosphate and nitrate (0.979) showed strong positive correlations.

Among wetlands, there was no significant difference in DO and BOD concentrations ($P>0.05$). According to person correlation analysis values in wetlands, there is a robust positive correction between DO and BOD. If the concentration of organic matter in a water body is high, the degradation of those nutrients by microorganisms in water will be high, which causes an increase in BOD (Singh *et al.*, 2021). An increase in BOD in water can indicate higher levels of organic water pollution.

In this study, the concentration of total phosphate and nitrate shows significant variation among wetlands. The highest mean concentration of total phosphate (0.24±0.04 mg/L) was observed in Diyatha wetland, while the lowest mean concentration was at Diaysaru wetland (0.07±0.01 mg/L). Untreated sewage surface runoff, decomposing rocks, and industrial effluent are the primary sources of phosphate in water bodies (Singh *et al.*, 2021). The highest phosphate level was recorded at the Diyatha wetland, possibly due to its more stagnant water, as observed during the study period, compared to the other wetlands. The highest value of nitrates was recorded in the Nawala wetland (1.55±0.2 mg/L), and the minimum (0.9 ±0.08 mg/L) values were observed in Diyatha and Diyasaru wetlands.

Eutrophication is caused by a water body with high nitrate and phosphate levels (Singh *et al.*, 2021). Studies show mesotrophic streams' total phosphates range from 0.70–1.50, and total nitrate ranges from 0.025–0.075 (Gurung *et al.*, 2013). Therefore, all wetlands can be categorised as mesotrophic according to the phosphate and nitrate concentrations of the present study.

Previous studies show the water quality of the Diyawanna Oya area was not good during the 2004 – 2014 time period (Metro Colombo Urban Development Project, Environmental Screening Report, 2016). However, water quality seems to have improved after 2014. The water quality in Diyawanna Oya can be improved due to better wetland management strategies. It was found that the vegetation cover of the Colombo wetland area is increasing with time, and wastelands are converting into wetlands (Hettiarachchi *et al.*, 2014). Therefore, these factors may contribute to enhancing water quality in the region.

4. CONCLUSION

According to the diversity indices, there is a low level of plankton diversity in Nawala Wetland Park, Diyatha Uyana Wetland Park, Diyasaru Wetland Park, and Beddagana Wetland Park with a considerable

level of water pollution, but they are still suitable for growth and survival of aquatic life. *Pediastrum* spp. *Closterium* sp., *Chlorella* sp., *Euglena sp., phacus* sp., *Melosira* spp., *Microcystis* spp., *Navicula* sp., *Oscillatoria* sp., *Scenedesmus* sp., and *Synedra* sp., *Keratella* spp., *Brachionus* spp., and *Lecane* spp. were identified as potential pollution indicator species.

In this case, the presence of pollution-indicator species might not be directly linked to nutrient pollution. Other factors, such as localised pollution sources and historical contaminations, can influence plankton diversity. Further investigations into potential pollutants (heavy metals, organic contaminants) might be necessary to understand the ecosystem's health fully.

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EXPLORING ER-UMA TYPE DWARF NOVAE USING PHOTOMETRY DATA OF TRANSITING EXOPLANET SURVEY SATELLITE (TESS)

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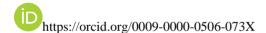
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ABSTRACT

An investigation was conducted into eleven ER Ursae Majoris (ER-UMa) star systems using photometric light curve data obtained from the Transiting Exoplanet Survey Satellite (TESS), with a focus on exploring their mass ratios, superoutburst characteristics, and superhump dynamics. This research marks the first instance where all ER Ursae Majoris-type dwarf novae observed by TESS were investigated simultaneously. In this study, we determined the A, B, and C stages of the superhumps in the superoutbursts of each ER-UMa system using the O-C method, and we derived the mean superhump periods as well as the superhump periods in each of the A, B, and C stages. Employing the stage A superhump periods, we estimated the mass ratios (M2/M1) between the white dwarf primary (M1) and the red dwarf secondary (M2) in each system. In addition to the TESS data, we utilised photometric light curve data from the American Association of Variable Star Observers (AAVSO), Zwicky Transient Facility (ZTF), and the All-Sky Automated Survey for Supernovae (ASAS-SN) project to determine variations in supercycle periods and the recurrence periods of normal outbursts for each ER-UMa system.

KEYWORDS: *ER-Ursae Majoris (ER-UMa), Superoutburst, Superhumps, TESS (Transiting Exoplanet Survey Satellite)*

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1. INTRODUCTION

Nonmagnetic cataclysmic variable stars (CVs) are semi-contact binary systems with a white dwarf primary and a red dwarf secondary. The secondary fills its Roche lobe and transfers mass onto the white dwarf through the inner Lagrange point, forming an accretion disk around it. Among nonmagnetic CVs, Dwarf Novae (DNe) are the most common subtype, with SU Ursae Majoris (SU-UMa) type DNe being one subgroup, alongside U Geminorum (U-Gem) and Z Camelopardalis (Z-Cam) (Warner, 1995).

As explained by (Osaki, 1989), SU-UMa dwarf novae with orbital periods below the period gap (2-3 hours) show two types of outbursts: normal outbursts and superoutbursts. Superoutbursts occur less frequently and last longer than normal outbursts. During superoutbursts, a periodic brightness variation feature known as superhumps can be seen due to the interaction between the orbital period of the system and the precessional period of the disk. The precession is generated by tidal distortion of the elliptical disk caused by a resonance between the orbiting disk particles and the secondary orbit with a 3:1 period ratio (Lasota, 1995).

ER-UMa type dwarf novae, a subset within the SU-UMa type dwarf nova category, distinguish themselves through notably high mass transfer rates and heightened outburst frequencies compared to SU-UMa type members (Kato & Kunjaya, 1995; Kato, *et al.*, 1999). Compared to SU-UMa systems, the Supercycle length (the interval between superoutbursts) of ER-UMa systems is narrowed down to 19-48 days (Kato, *et al.*, 2013). In other words, short-Supercycle systems (more frequent superoutbursts) within the SU-UMa subgroup are known as ER-UMa DNe (long-Supercycle systems are called WZ Sge stars). The origin of high mass-transfer rate characteristic in the ER-UMa systems with compared to the SU-UMa systems cannot be explained by the canonical view where mass transfer is governed solely by gravitational wave radiation for systems below the period gap (<2h) (Hellier, 2001). Although several possibilities have been suggested for the increased mass transfer in ER-UMa systems other than gravitational wave radiation, the exact reason behind the higher mass transfer rates in ER-UMa systems are

yet to be confirmed. In contrast to the usual SU-UMa systems, all ER-UMa systems exhibit large amplitude early superhumps with steady period compared to the normal superhumps (Kato, *et al.*, 2013).

A small number of the ER-UMa stars show standstills in their light curves, which are a prominent characteristic in Z Cam type dwarf novae. As described in the disk instability theory, the presence of the standstill may be a result of variable mass transfer (Osaki, 1996), providing some understanding about how the radius and angular moment within the disk vary (Kato & Kojiguchi, 2023). AM CVn stars are known to be Helium rich CVs with compared to the usual CVs which rich in hydrogen. Kato *et al.* (2000) found that CR Boo and V803 in AM CVn category show ER-UMa characteristics in terms of their supercycle period which is 46.3 and ~60 days respectively.

In this context, it is noticeable that various ER-UMa systems show unique characteristics of SU-UMa, Z Cam, and AM CVn dwarf novae categories. This convergence of features across different subclasses of cataclysmic variables points to a more detailed interaction of physical mechanisms than previously understood. These systems might be crucial in bridging the gap between our current models of outbursts mechanisms, disk instability etc. which influence the evolutionary pathways of cataclysmic variables systems. Understanding these unique features could potentially lead to revisions in the theoretical framework that describes the behaviour of such systems.

In this paper, our main focus is to determine whether the observed period changes in superhumps during a superoutburst as described by Kato *et al* (2009) are applicable to determine the mass ratio (q) in the ER-UMa systems, DI UMa, ER-UMa, IX Dra, RZ LMi, V1159 Ori, CM Mic, DDE 48, NY Ser, BK Lyn, BK Lyn, MN Dra and V4140 Sgr obtained via TESS archives. In Section 2, we discuss the acquisition of data for this research, and in Section 3, we present our data analysis and results. Finally, in Sections 4 and 5, we summarise our results and provide a discussion, respectively.

2. METHODOLOGY

Data Acquisition

The main data source used in this research is the archived data of the NASA's Transiting Exoplanet Survey Satellite (TESS). Although the TESS was primarily designed to search transiting exoplanets it produces all-sky survey by using a set of 4 wide-field, red-sensitive cameras (each camera has 4 CCDs) which all together cover with 24 degrees by 96-degree strip of the sky. The TESS exposes these cameras for 2 minutes in each observation and stacks these images for every 30 minutes (Ricker *et al* 2015). TESS observed sky by 26 sectors, mapping the southern half first and the northern half next. TESS data is better than ground-based observational data because it eliminates atmospheric distortions and provides continuous monitoring, enabling the capture of detailed light variations in the targeted systems like dwarf novae. This continuous coverage ensures a more accurate and thorough analysis for this research. TESS data are distributed to the Mikulsky Archive for Space Telescopes (MAST) by the TESS Science Operating Center (SOC). The TESS data comes with two types of light curves which are (1) Simple Aperture Photometry (SAP) flux light curves and (2) Pre-search Data Conditioning SAP (PDCSAP) flux light curves.

For this analysis, only the SAP flux light curve data obtained via MAST were utilized. In the study of Cataclysmic Variables (CVs), the long-term variability captured by SAP flux light curves is crucial for revealing the evolutionary aspects of CVs, making them more suitable for this research compared to PDCSAP light curves.

The analysis in this research included all eleven ER-UMa systems observed by TESS to date, with seven of them demonstrating superoutbursts. For the mass-ratio calculations, these seven systems exhibiting superoutbursts were utilised. Table 01 provides details of the TESS-observed ER-UMa systems.

In addition to utilizing data from TESS, we have obtained photometry light curve data from three supplementary sources: the American Association of Variable Star Observers (AAVSO) (Burbeck, 1917), the Zwicky Transient Facility (ZTF) (Smith *et al*.,

2014), and the All-Sky Automated Survey for Supernovae (ASAS), an astronomical survey project (Kochanek *et al*., 2017). These additional datasets are essential for improving the accuracy of determining the supercycle length of ER-UMa systems. While TESS provides high-quality data, it is limited by its relatively short observation period, 27 days, which are insufficient for a comprehensive analysis of objects with longer supercycles, such as ER-UMa systems.

The AAVSO, ZTF, and ASAS datasets extend our observational timeline significantly for 1 year to several decades, allowing us to capture the full range of variability in these systems over much longer periods. By integrating data from these sources, we not only fill in the temporal gaps left by TESS but also increase the robustness of our analysis. This combination of datasets enables us to determine the supercycle lengths with greater precision, enhancing our understanding of the long-term behaviour of ER-UMa systems.

Furthermore, the inclusion of data from multiple independent sources allows for cross-validation of our findings. This redundancy is particularly valuable in astrophysical research, where the ability to confirm results across different datasets strengthens the reliability of the conclusions. The diverse observational techniques and instruments used by AAVSO, ZTF, and ASAS provide different perspectives on the same phenomena, offering a more comprehensive view of the ER-UMa systems' dynamics.

TESS Data Analysis

As mentioned in the section 1, our main objective of this research is to find the applicability of the method introduced by Kato & Osaki (2013) to determine mass-ratio (q) for all ER-UMa systems which were considered. With this purpose we transformed all original SAP flux data into their corresponding magnitudes as follows described in Liu, *et al*., 2024,

$$\Delta mag = -2.5 \log_{10}(SAP_{flux}) + 6 \text{ ---(1)}$$

The Magnitudes of quiescence part of the light curves were set to 0 to identify the amplitudes of the superoutbursts much easier. (Left panels of Figure 1a & 1b). The trends in superoutbursts of TESS light curves were removed (detrending) by fitting a curve using

Table 01: Details of ER-UMa Stars

Star	TIC ID	Sector	Duration of Observation (Barycentric Julian Date/ BJD 2,457,000+)
DI UMa	279823992	21	1870.44 -1897.79
		47	2579.82-2606.95
ER-UMa	453428902	21	1870.44-1897.79
		48	2607.94-2635.99
		74,75	3312.87-3367.49
IX Dra	236763903	14,15,16	1683.35-1763.32
		18,19	1790.66-1841.15
		21,22	1870.44-1926.49
		24,25,26	1955.79-2035.14
		40,41	2390.65-2446.58
		48,49	2607.93-2664.32
		51,52,53	2692.96-2768.98
		55,56,57	2797.10-2882.11
		60	2936.90-2962.58
		74,75	3312.86-3367.48
RZ LMi	4896794	21	1870.45-1897.79
		48	2607.94-2635.99
V1159 Ori	50620873	32	2174.23-2200.23
CM Mic	91046109	27	2036.28- 2060.65
		67	3126.65- 3154.40
DDE 48	1951569775	41	2419.99-2446.58
		55	2797.10-2824.27
NY Ser	1101183649	24	1955.80-1982.29
		51	2692.96-2717.54
BK Lyn	8765832	21	1870.44-1897.79
MN Dra	236999760	75	3339.78-3367.48
V4140 Sgr	300664897	67	3126.65-3154.40

Locally Weighted Scatterplot Smoothing (LOWESS) method (Cleveland, 1979) to get highlighted the superhump periodic signals in the light curves (Right panels of Figure 1a & 1b). The generalised Lomb–Scargle periodogram (LSP) method (Lomb, 1986; Scargle, 1982; Press & Rybicki, 1989; VanderPlas, 2018) was used to determine the mean superhump periods of each light curves of our sample.

In order to determine q, O-C (Observed minus Calculated) diagrams were constructed for each light

curve for our sample using following standard equation,

$$C = t_0 + nP \text{ ---- (2)}$$

Where, t_0 is initial epoch time, n is the cycle number, P is the mean superhump period and C is the calculated time of nth cycle.

The observed values (O) for O-C diagram were obtained using the maximum peak time of each superhump in detrended light curve. The O-C values were then calculated by subtracting the calculated values (C) from the observed (O) values. An O-C graph
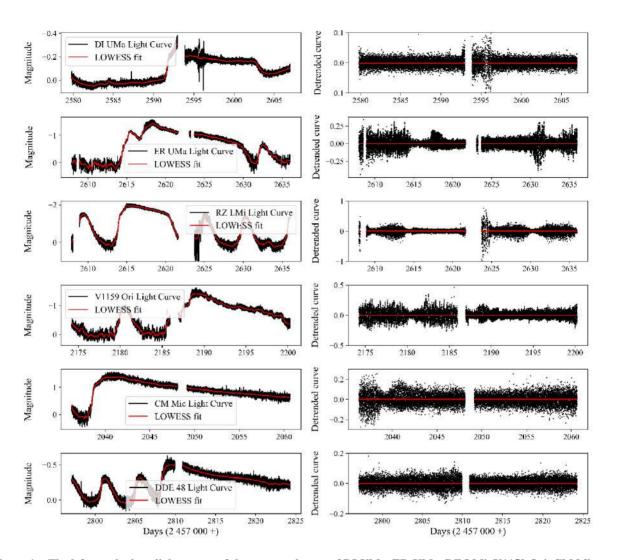
Figure 1a: The left panels show light curves of the superoutbursts of DI UMa, ER-UMa, RZ LMi, V1159 Ori, CM Mic and DDE48. The right panels show detrended light curves of those stars respectively.

was subsequently plotted, displaying the O-C values against the observed peak times. This graph is used to identify any variations that exist in the mean superhump-period within a single superoutburst. Such variations in mean superhump-periods for each superoutbursts are classified by Kato (2009) as three stages: A, B and C.

The Stage A represents the earliest phase of the superhump period variation. The superhumps are growing during this stage and the superhump period is longer than the other stages. During stage A, the superhump amplitude is also reaching its maximum. In

the O-C diagram, Stage A is marked by a positive slope, indicating that the observed superhump period is longer than expected. The period derivative $\dot{P}$ (the rate of period change) is positive, which means the period is increasing during this stage. After stage A, the stage B occurs which represents the phase where the superhump period is affected by the unknown disk pressure (Kato & Osaki, 2013). In the O-C diagram, Stage B shows a downward parabolic curve, meaning the O-C values first decrease, reach a minimum, and then increase. However, Stage B has a shorter superhump period than Stage A. The final phase, Stage
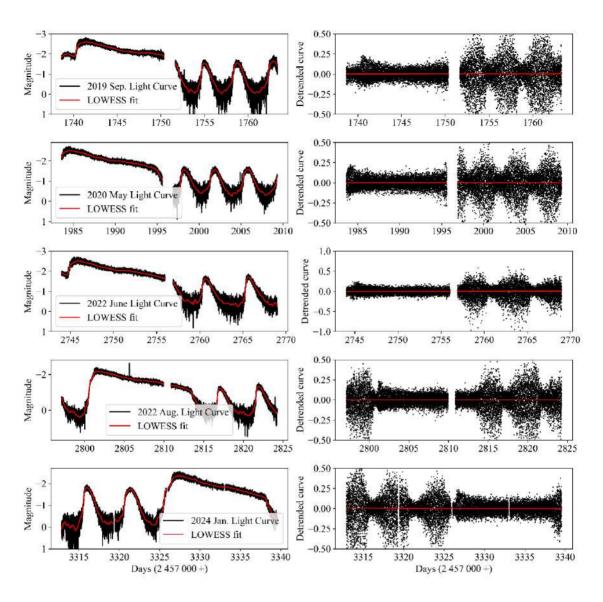
Figure 1b: The left panel shows light curves of the superoutbursts of IX Dra during 2019 September 2020 May 2022 June, 2022 August and 2024 January. The right panel shows detrended light curves of those outbursts respectively.

C superhump period is shorter than in Stage B and typically closer to the orbital period. In the O-C diagram, Stage C is marked by a negative slope, indicating that the observed superhump period is shorter than the expected mean superhump period. The period derivative $\dot{P}$ is negative, meaning the period is decreasing.

After analysing these characteristics, Osaki and Kato (2013) highlighted that, unlike stages B and C, stage A superhumps are unaffected by external forces other than the precession of the disk. As a result, the

superhump period in stage A can be utilised more accurately for mass-ratio estimation, expressed as:

$$q = -0.0016 + 2.60\epsilon^* + 3.33(\epsilon^*)^2 + 79.0(\epsilon^*)^3 \quad \text{--(3)}$$

Where ϵ^* is the fractional superhumps excess in frequency, can be calculated from system's orbital period, P_{orb} and the stage A superhump period, P_{shA} using,

$$\epsilon^* = 1 - P_{orb}/P_{shA}$$

Table 02: Mean Superhump periods and reference orbital periods

Star	Sector	Mean superhump period/days	Error/ days	Orbital period/days
DI UMa	47	0.05532	0.00007	0.054579(6) (Rutkowski, *et al.*, 2009)
ER-UMa	48	0.06568	0.00008	0.06366(3) (Thorstensen, *et al.*, 1997)
IX Dra	16	0.06706	0.00009	0.06482(3) (Otulakowska-Hypka, *et al.*, 2013)
	25	0.06708	0.00008	
	53	0.06697	0.00008	
	55	0.06696	0.00008	
	74	0.06698	0.00008	
RZ LMi	48	0.05949	0.00009	0.05792 (Kato, et al., 2016)
V1159 Ori	32	0.06071	0.00007	0.06217801(13) (Thorstensen, *et al.*, 1997)
CM Mic	27	0.08028	0.00010	0.07696(10)

AAVSO, ZTF and ASAS data Analysis

As mentioned, one of the significances that ER-UMa type dwarf novae distinguish themselves is their heightened outburst frequencies (Kato & Kunjaya, 1995; Kato, *et al.*, 1999) which fall between 19 days to 48 days, and the normal outbursts on the other hand are packed in a rapid succession between these superoutbursts (Hellier, 2001).

In order to obtain the continuous observation of superoutbursts to determine their supercycle lengths, it is required to obtain older and long-term observational data. For this purpose, AAVSO, ZTF and ASAS photometry archives were used to obtain such data for our ER-UMa sample. The supercycle lengths of each ER-UMa system and the variations in their supercycle periods were determined using those data. The required orbital periods for these calculations were sourced from previously published studies, as the orbital periods of low-inclination (less than 65 degrees) ER-UMa systems cannot be accurately derived from photometric data, such as TESS SAP flux light curves.

3. RESULTS

Results of TESS data analysis

The analysis conducted in this research using TESS photometry data aimed to investigate the mass ratios of ER-UMa systems by analysing the variations in superhump periods. Using the O-C diagrams and mean superhump periods, we identified distinct stages of superhumps and calculated mass ratios. The findings presented below provide the applicability of the method introduced by Kato & Osaki (2013) for ER-UMa systems.

1. Construction of O-C Diagrams:

O-C diagrams (described in Section 2) were constructed for each system to examine any variations in the mean superhump periods. The mean superhump periods were calculated using the generalised Lomb-Scargle (LS) periodogram method, with the required orbital periods obtained from previously published studies (Table 2).

2. Observation of Superhump Stages:

Variations in the mean superhump periods within a single superoutburst were identified as Stage A, B, and C in all O-C diagrams constructed for the sample systems and the Stage demarcations were placed as described in section 2 (see Figure 2). The stages were clearly observed and categorised as per the methodology detailed in Section 2.

Table 03- Superhumps stage A, B, and C period

Star	Sector	Stage	Time period BJD (2 457 000+)	n/ the cycle number	Period/ days	Error/ days
DI UMa	47	A	2592.524-2594.619	0-39	0.05530	0.00015
		B	2594.619-2597.339	40-88	0.05536	0.00010
		C	2597.339-2599.656	89-130	0.05522	0.00011
ER-UMa	48	A	2619.100-2620.047	0-14	0.06614	0.00026
		B	2620.047-2623.140	15-62	0.06592	0.00019
		C	2623.140-2629.222	63-155	0.06547	0.00009
IX Dra	16	A	1740.361-1741.439	0-16	0.06764	0.00024
		B	1741.439-1746.532	17-92	0.06708	0.00011
		C	1746.532-1748.066	93-115	0.06702	0.00019
	25	A	1983.656-1985.204	0-11	0.06707	0.00029
		B	1985.204-1990.847	12-107	0.06706	0.00010
		C	1990.847-1992.706	108-136	0.06656	0.00018
	53	A	2744.789-2746.134	0-20	0.06749	0.00022
		B	2746.134-2751.094	21-94	0.06710	0.00011
		C	2751.094-2754.495	95-145	0.06680	0.00013
	55	A	2800.984-2802.327	0-20	0.06749	0.00022
		B	2802.327-2807.817	21-102	0.06700	0.00011
		C	2807.817-2809.884	103-133	0.06684	0.00017
	74	A	3326.413-3327.756	0-19	0.06746	0.00022
		B	3327.756-3332.450	20-89	0.06714	0.00012
		C	3332.450-3336.120	90-145	0.06681	0.00013
RZ LMi	48	A	2615.038-2615.628	0-10	0.06009	0.00037
		B	2615.628-2619.141	11-69	0.05933	0.00010
		C	2619.141-2620.328	70-89	0.05908	0.00018
V1159 Ori	32	A	2190.927-2191.872	0-15	0.06255	0.00023
		B	2191.872-2194.732	16-62	0.06069	0.00012
		C	2194.732-2199.155	63-135	0.06064	0.00010
CM Mic	27	A	2039.613-2042.759	0-39	0.08084	0.00021
		B	2042.759-2046.292	40-83	0.08049	0.00019
		C	2046.292-2053.028	84-168	0.08008	0.00015

3. Determination of Mean Superhump Periods:

The mean superhump periods for Stage A, B, and C were determined using the LS periodogram method (see Table 3). These stages correspond to different phases within a superoutburst, and the data obtained were critical for subsequent mass-ratio calculations.

4. Mass-Ratio Calculations:

The superhump period in Stage A was specifically used for mass-ratio (q) calculations, as described in Equation (3). The calculated mass-ratio values are provided in Table 4, showing a detailed comparison of the results obtained from this method.
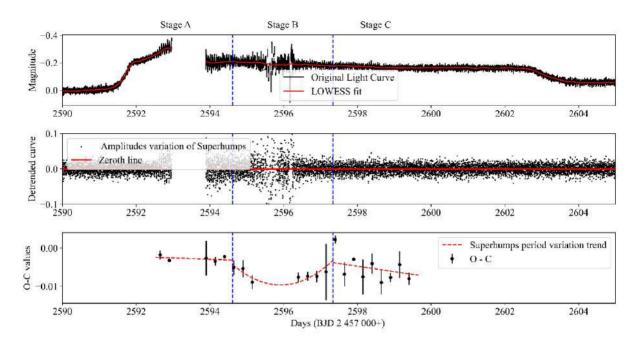
Figure 2a: Top panel shows the light curve of superoutburst of DI UMa. Middle panel shows the detrended light curve. Bottom panel shows the O-C diagram of the superhumps.
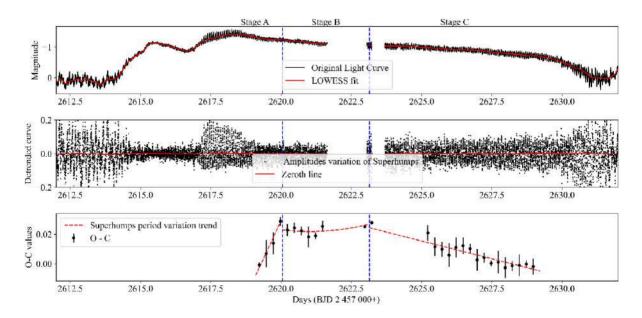

Figure 2b: Top panel shows the light curve of superoutburst of ER-UMa. Middle panel shows the detrended light curve. Bottom panel shows the O-C diagram of the superhumps.
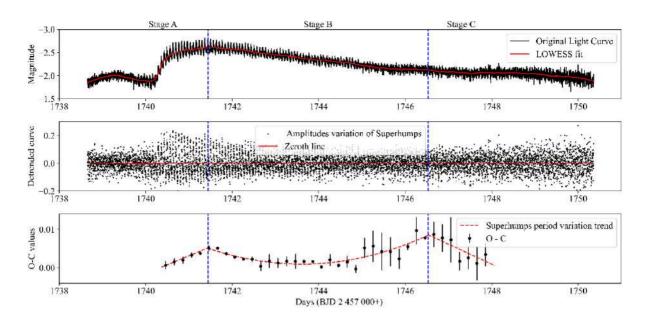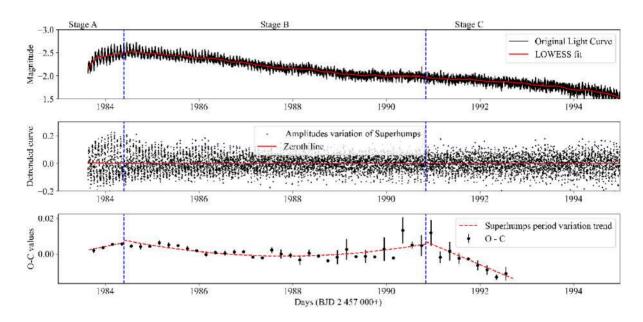
Figure 2c: Top panel shows the light curve of superoutburst of IX Dra (Sector 16). Middle panel shows the detrended light curve. Bottom panel shows the O-C diagram of the superhumps.

Figure 2d: Top panel shows the light curve of superoutburst of IX Dra (Sector 25). Middle panel shows the detrended light curve. Bottom panel shows the O-C diagram of the superhumps.
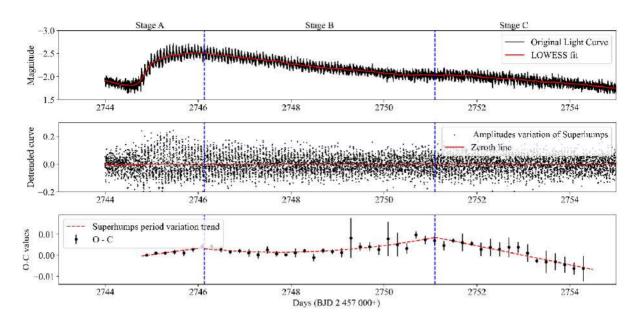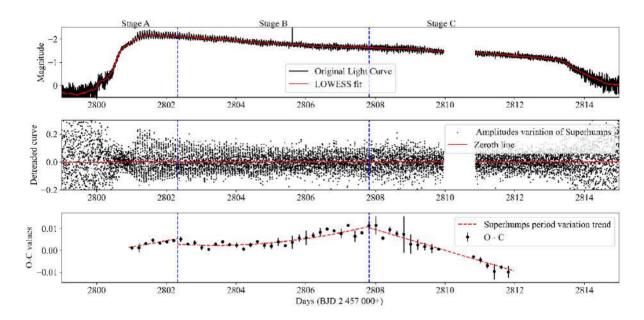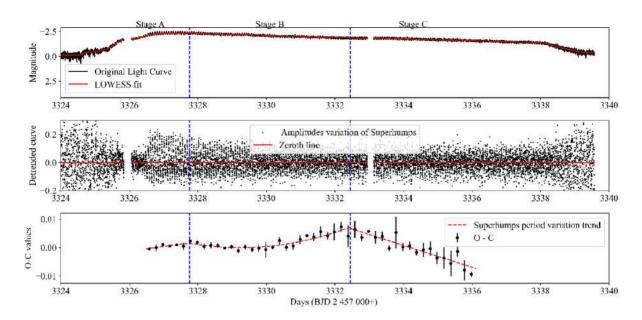
Figure 2e: Top panel shows the light curve of superoutburst of IX Dra (Sector 53). Middle panel shows the detrended light curve. Bottom panel shows the O-C diagram of the superhumps.

Figure 2f: Top panel shows the light curve of superoutburst of IX Dra (Sector 55). Middle panel shows the detrended light curve. Bottom panel shows the O-C diagram of the superhumps.

Figure 2g: Top panel shows the light curve of superoutburst of IX Dra (Sector 74). Middle panel shows the detrended light curve. Bottom panel shows the O-C diagram of the superhumps.
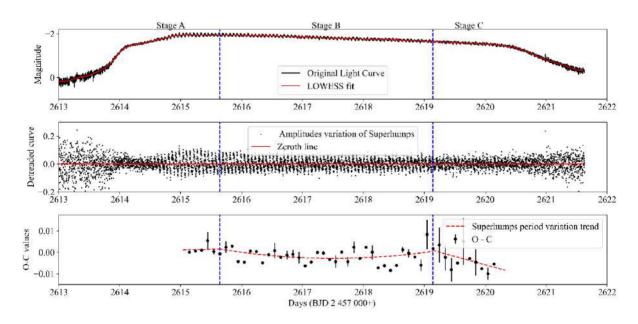

Figure 2h: Top panel shows the light curve of superoutburst of RZ LMi. Middle panel shows the detrended light curve. Bottom panel shows the O-C diagram of the superhumps
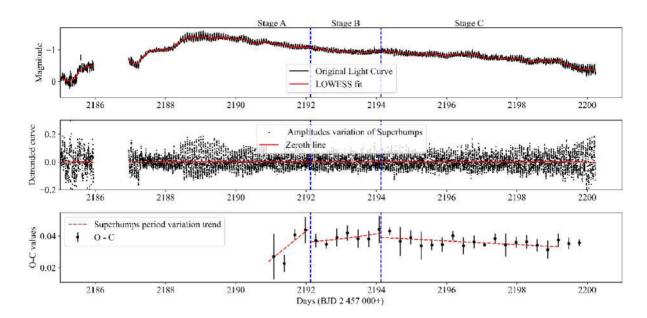
Figure 2i: Top panel shows the light curve of superoutburst of V1159 Ori. Middle panel shows the detrended light curve. Bottom panel shows the O-C diagram of the superhumps.
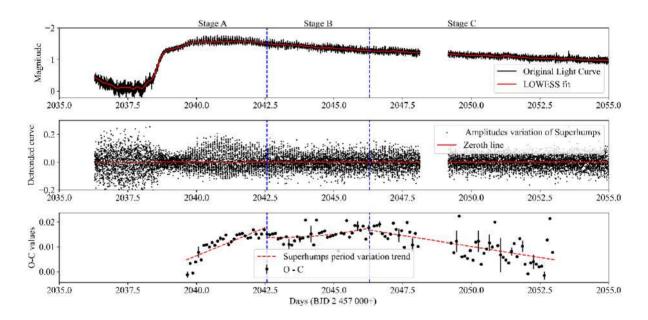

Figure 2j: Top panel shows the light curve of superoutburst of CM Mic. Middle panel shows the detrended light curve. Bottom panel shows the O-C diagram of the superhumps.
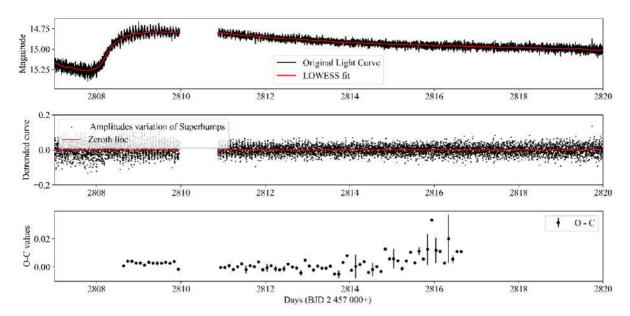
Figure 2i: Top panel shows the light curve of superoutburst of DDE 48. Middle panel shows the detrended light curve. Bottom panel shows the O-C diagram of the superhumps.

Table 4- Mass-Ratio (q) values of stars with and without early large amplitude humps

Star	Mass-Ratio calculated using Stage A superhump period	large amplitude Superhump (LAS) period / days	Mass-Ratio calculated using LAS period	Mass-Ratio calculated from other methods	Percentage deviation (%)
DI UMa	0.033 ± 0.005	No LAS	-	0.06 (Fried, et al., 1999)	45
ER-UMa	0.105 ± 0.010	0.06598	0.097 ± 0.010	0.1 (Ohshima, et al., 2014)	5
IX Dra	0.101 ± 0.015	No LAS	-	0.101 ± 0.009 (Liu & Qian, 2023))	0
RZ LMi	0.100 ± 0.016	No LAS	-	0.105 (Kato, et al., 2016)	4.8
V1159 Ori	0.014 ± 0.009	0.06255	0.014 ± 0.008	No literature data	
CM Mic	0.139 ± 0.030	No LAS	-	No literature data	

5. Comparison with Previous Studies:

Among the ER-UMa systems used for mass-ratio calculations, only ER-UMa and V1159 Ori had mass-ratio values previously determined by other methods. The mass-ratio values obtained in this study are compared with those previously published (see Table 4).

6. Superhump Behaviour in ER-UMa Systems

In certain SU-UMa systems (e.g., RX Vol, SS UMi, V485 Cen), superhumps emerge with a delay after the
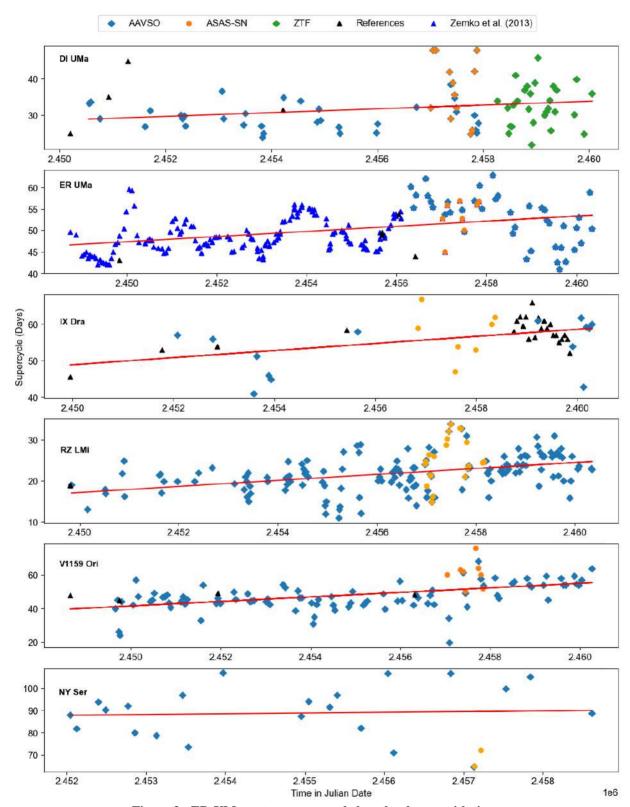
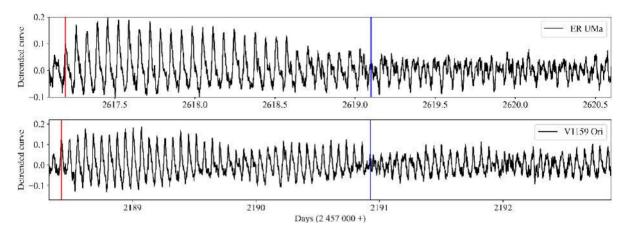**Figure 3: ER-UMa systems supercycle lengths change with time**

Figure 4: Superhump profiles during the superoutbursts of ER-UMa (top panel) and V 1159Ori (bottom panel). High-amplitude early superhumps are indicated to the left of the blue lines, while normal superhumps are shown to the right of the blue lines.

superoutburst onset, while others (e.g., AK Cnc, GX Cas) show superhumps during the decline phase. In contrast, in the ER-UMa and V1159 Ori systems, superhumps developed during the rise of the superoutburst, with larger amplitudes than in SU-UMa systems (see Figure 4). These high-amplitude superhumps decayed over several days, transitioning to normal-amplitude superhumps. Despite using normal-amplitude superhump periods for mass-ratio calculations, no significant changes in the q values were observed (see Table 4).

Results of AAVSO, ZTF and ASAS data analysis

The supercycle lengths for each ER-UMa system were calculated, and any variations in the supercycle period were tracked over time by plotting the supercycle length against time for each system (see Figure 3).

Our findings suggest that the supercycle period in ER-UMa systems is not static but evolves over time. Table 05 shows the calculated supercycle lengths for each system, along with any detected changes in the supercycle period.

4. DISCUSSION

The ER-UMa systems in our sample exhibit distinctive superhump behaviours that set them apart from SU-UMa type systems, particularly in stars like ER-UMa and V1159 Ori, which display high-amplitude

superhumps early in the superoutburst phase. These pronounced superhumps, which gradually transition into the normal-amplitude superhumps typically seen in SU-UMa systems, are likely due to the higher mass-transfer rates in ER-UMa systems (Kato et al., 2013). A high mass-transfer rate causes the accretion disk to expand rapidly, reaching the 3:1 resonance, a critical condition where the orbital period of the disk material matches three times that of the binary system. This resonance induces tidal instabilities within the disk, leading to the precession that generates the characteristic superhump light variations (Warner, 1995). However, not all ER-UMa systems in our sample exhibit these high-amplitude superhumps, even though they also possess higher mass-transfer rates than their SU-UMa counterparts. This indicates that while a higher mass-transfer rate is necessary for the formation of high-amplitude superhumps, it may not be the sole factor. We hypothesise that a threshold range or critical value of mass-transfer rate must be exceeded for these superhumps to manifest with such high amplitude. In systems where this threshold is not met, the superhumps may exhibit lower amplitude. This suggests that superhump formation in ER-UMa systems is governed by a complex interplay of factors, with the mass-transfer rate being a significant, but not exclusive, determinant.

Our analysis underscores the critical role of Stage A superhumps in SU-UMa type systems, particularly in ER-UMa. These superhumps arise when the accretion

Table 05 – Supercycle change rates

System	Observed time duration in JD	Calculated new Supercycle (days)	Calculated Supercycle Change Rate (d d⁻¹)	Past Literature Results (d d⁻¹)
DI UMa	2450553.7 - 2460057.7	33.78 ± 0.06	5.2×10^{-4}	4.3×10^{-4} (Otulakowska-Hypka & Olech, 2014)
ER-UMa	2456313.0- 2460347.4	50.93 ± 0.05	6.0×10^{-4}	1.3×10^{-3} (Otulakowska-Hypka & Olech, 2014) 6.7×10^{-4} (Zemko, et al., 2013) 3.3×10^{-4} (Bean, 2021)
IX Dra	2452085.4- 2460296.5	60.78 ± 0.02	9.7×10^{-4}	1.8×10^{-3} (Otulakowska-Hypka & Olech, 2014)
RZ LMi	2449830.5- 2460346.8	25.07 ± 0.04	7.3×10^{-4}	5.0×10^{-4} (Otulakowska-Hypka & Olech, 2014) 5.5×10^{-4} (Bean, 2022)
V1159 Ori	2449656.5- 2460269.1	55.35 ± 0.02	1.3×10^{-3}	1.1×10^{-3} (Otulakowska-Hypka & Olech, 2014) 3×10^{-3} (Bean, 2022)
NY Ser	2452039.5- 2458621.6	-	3.3×10^{-4}	

disk is minimally influenced by external factors, allowing the precession of the disk to be purely dynamical, as noted by Kato & Osaki (2013). This absence of external perturbations makes Stage A superhumps a reliable benchmark for precise mass-ratio calculations. Importantly, our study reveals that the mass-ratio values obtained from Stage A superhumps in ER-UMa and V1159 are in close agreement with those derived from high-amplitude early superhumps. These early superhumps, which occur before Stage A, are similarly devoid of external influences such as pressure effects of the disk, further reinforcing their dynamical nature. The consistency between the mass-ratio values derived from both Stage A and early superhumps supports the reliability of purely dynamical superhumps in mass-ratio determinations, as suggested by Kato & Osaki (2013). To solidify this finding, further investigation is recommended, particularly focusing on higher-amplitude early superhumps in ER-UMa systems, to ensure the robustness of this correlation across a broader range of observations.

Our findings also suggest that the supercycle period in ER-UMa systems is not static but evolves over time.

The increase in supercycle length observed in some systems could be indicative of changes in the accretion disk's structure or the mass-transfer rate from the secondary star. According to Osaki's 1995 model, this phenomenon is directly linked to a secular decline in the mass transfer rate between the binary components. The observed lengthening of the supercycle, denoted as Ts, is a direct consequence of this decreasing mass transfer. This trend is indicative of the gradual evolution of the system, potentially leading to a future state where mass transfer is significantly reduced or evolved to another type of binary systems.

However, the variability observed in systems like DDE 48, where the A, B, and C stages of superhumps were not clearly discernible, underscores the complexity of these systems. This could be due to data scattering or other observational challenges, emphasising the need for further research.

5. CONCLUSION

This study investigated the mass ratios and superhump behaviours of ER-UMa systems using TESS photometry data, alongside additional analysis of supercycle periods from AAVSO, ZTF, and ASAS data.

The period of superhumps in Stage A was utilised for mass-ratio calculations. With the exception of the DI UMa system, all calculated mass-ratio values are in good agreement (within 5%) with those obtained through alternative methods, as shown in Table 4. The higher scattering of TESS data for DI UMa, illustrated in Figure 2a, likely explains its deviation (~45%). This finding supports the primary objective of our research: that the method proposed by Osaki & Kato (2013) for determining mass-ratios (q) in binary systems is applicable to ER-UMa type dwarf novae.

Our study also highlighted distinctive superhump behaviours in ER-UMa systems, such as high-amplitude superhumps during the rise of superoutbursts in ER-UMa and V1159 Ori systems. These superhumps transitioned into normal-amplitude superhumps as the superoutburst progressed. Despite this, mass-ratio calculations using both types of superhumps showed no significant changes, further validating the reliability of the Osaki & Kato method.

Additionally, we analysed supercycle periods using data from AAVSO, ZTF, and ASAS, showing that the supercycle length evolves over time. This evolution likely reflects changes in the accretion disk's structure or the mass-transfer rate, consistent with Osaki's (1995) model. The lengthening of the supercycle observed in some systems suggests a gradual decline in mass-transfer rates, indicating an ongoing evolution of these binary systems.

The findings from this study contribute to a more nuanced understanding of the interplay between mass transfer, disk precession, and resonance in dwarf novae. Future work should focus on exploring the mechanisms driving the evolution of supercycle periods and the implications of early high-amplitude superhumps on mass-ratio determination. Additionally, addressing data irregularities and expanding the sample size could help clarify the unique characteristics of ER-UMa type systems.

6. ACKNOWLEDGEMENTS

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